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COSPAR 2018

42ND ASSEMBLY | 60TH ANNIVERSARY

Scientific Assembly Abstracts

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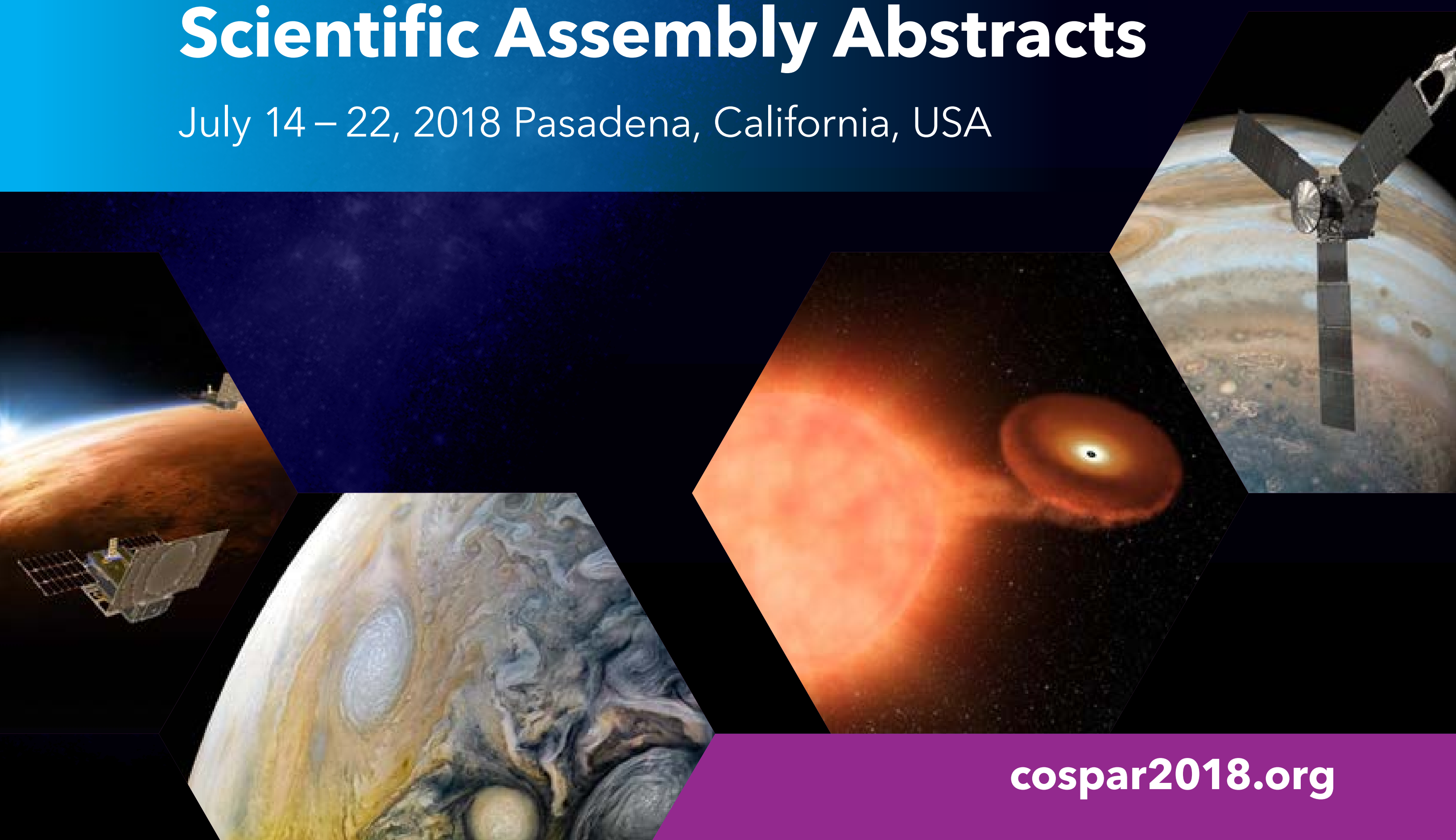

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COSPAR COMMITTEE ON SPACE RESEARCH

Space Studies of the Earth's Surface, Meteorology and Climate (A)

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A0.1-0001-18 RESEARCH ON REMOTE SENSING IMAGE ON-BOARD TARGET RECOGNITION BASED ON LOCAL INVARIANT FEATURE

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With the development of satellite remote sensing technology, the resolution of satellite image is increasing. And the high resolution satellite image can apply to the civil and military fields. Especially in military field, satellite image recognition is an important way to obtain military information. As the remote sensing satellite has the poor on-board process ability, traditional recognition and processing work of satellite image is carried out mainly in the ground. By the reason of satellite data transmission ability and the influence of ground station distribution, image acquisition process is very complex. The data from acquisition to the ground station is about in one day, because of the different satellite orbit. However, on-board target recognition can process the satellite image on orbit, and transmit the processed data to the ground command center through relay satellite or telemetry system. By this way, the access time of the information is shortened greatly, which ensure the timeliness of the remote sensing information. In this paper, we proposed a satellite image on-board target recognition method. According to the characteristics of remote sensing images and the problems exist in the onboard processing, this method is proposed combined with the development trend of the target recognition technology. We also make a deep research with the step of target recognition, such as feature detection, feature description and match recognition. In addition, we design an onboard fast target recognition system based on the characteristic of proposed method. We expect the system will provide theoretical basis and suggestions for practical engineering application. Aiming at ensure the rapidity and accuracy of the target recognize, we proposed a fast feature point detection algorithm based on the scale space theory. The algorithm builds the scale space by down sampling the image, and detects the feature points with AGAST algorithm in every scale space. However, the scale space will lead the feature point translation. Considering this problem, we proposed a method based on the feature point local relocation to location of feature points. Experiment results show that the algorithm is robust to scale, viewpoint and illumination transform. What's more, the algorithm takes a shorter time, and higher precision of feature points detect. In view of the complex and changeable characteristics of remote sensing images, especially the problem of illumination changes, we proposed a FREAK description algorithm based on feature point intensity normalization. First, we adjust the FREAK sample model to make the sampling points pay more attention to the edge and contour feature. And then, we estimate the dominant orientation of the descriptor by sampling point's gradient. At last, we normalized the pixel intensity by the neighborhood of feature point. Experiment results show that

the performance of proposed algorithm is better than others in scale, rotation and illumination transform. And the performance of viewpoint transform can satisfy the onboard process. In addition, the algorithm takes a relatively short time and is suitable for fast processing of remote sensing image. Take consider with the large amount of satellite image data and the low processing ability on the satellite, we proposed a hybrid spill tree data search method for satellite image on-board target recognition. The algorithm redundant segments the data in feature data preprocessing stage. By give up the edge of the sparse data points, the algorithm can adopt segmentation method based on center point. In feature matching stage, the algorithm measure the distance between feature vectors using XOR operation. We also improve SIFT feature matching strategy by using K nearest neighbor distance instead the second nearest neighbor distance. Finally, we use RANSAC algorithm to eliminate false matching points. Experiment results show that using the proposed search algorithm to recognize the target in remote sensing image, which has higher efficiency, shorter processing time and higher matching accuracy. When the high angle of the sun is low, the satellite image will appear many shadow areas. And these shadow areas will lead to a low target recognition rate. Taking consider with this problem, we proposed a target matching recognition method based on super pixel segmentation and reconstruction. First, we need to estimate the orientation of aircraft by using histograms of oriented gradients. And then, an improved SLIC super pixel segmentation algorithm is provided. By comparing texture feature instead of color feature space, we cluster the pixels that with the same features. Last, through target template images and orientation we reconstruct the super pixels. And the lowest error matching ratio is the recognized target. The test results show that the algorithm is more accuracy with target segmentation and wipe off the shadow areas efficiency. Compared with the situation of before superpixel segmentation, our method is more exactly. In engineering application, we develop an on-board rapid target recognition system based on FPGA+DSP combination form. We adopt the ideas of OpenVPX bus design and dual DSP parallel pipelining to ensure versatility and scalability of the system. By this way, we can improve the processing efficiency of the algorithm and lay the foundation for the on-board rapid target recognition. In addition, high speed interface provides a strong guarantee to the transmission of large amount of remote sensing image data on satellite. At last, we show the result of target recognition based on original satellite image data, which verification the feasibility of on-board target recognition.

A0.1-0002-18 OCEAN OBSERVATION FROM SPACE USING MARINE TRAFFIC DATA

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Our presentation focus on the description of a transformative technique allowing omni-situ ocean surface currents measurements relying on environmental data sets and ship motions data analytics. The technology makes it possible to retrieve real time and historical ocean surface currents information at a global scale. First the technique is introduced, how machine learning on environmental data sets and ship motions can produce omni-situ ocean surface currents. Performances are assessed showing results in different ocean dynamic conditions, comparing HF radar measurement, drfters and geostrophic currents derived from altimetry with eOdyn products. Technology' fields of application, as well as its limitations and development status are introduced. A one year omni-situ ocean surface currents climatology is compared to the bottom topography. At last, new possibilities allowed by this technique are highlighted.

A0.1-0003-18 JAGUAR MONITORING STORE-AND-FORWARD SATELLITE: JAGUARSAT

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JaguarSAT is a hypothetical 1U CubeSat proposed as a part of 5th Pre-Mission Idea Contest held in August 2017 in Japan to realize a store-and-forward approach in jaguar tracking in America's forests with trap cameras. Lowering number of the jaguars indicate the signs of the ecosystems in these forests are getting worse; hence the studies of these areas for jaguar tracking is not only for jaguar population but all the ecosystem in these locations. JaguarSAT is proposed in this paper to accelerate the scientific studies by providing availability data from these remote areas to the ground stations of the institutes or governments ready to collaborate. Ground and space segment of the project are detailed as well as the whole project budget and space system implementation plan.

A0.1-0004-18 THE ABERRATION EFFECT IN ORBITAL EARTH OBSERVATION

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When the satellite images from the Earth orbit, light will take an interval of time to travel between the source (the terrestrial surface) and the sensor. The higher the sensor flies, the longer the interval lasts. Thus, an obvious geolocation problem for orbital imaging emerges that the observation geometry is changing from the time when the light leaves the source to the time when the light arrives at the sensor. This phenomenon, called light aberration in astronomy, is resulted from the relative motion between the source and the sensor. In earth observation, the aberration effect can be divided into two parts. One comes of the motion of the sensor, and the other is caused by the earth's rotation. The aberration effect has seldom been taken into consideration in geometry modeling until the high resolution earth observation system is developed. Recently, some aberration compensation algorithms have been constructed for better understanding of the errors in high-precision geolocation. In this paper, we use a two-step method to describe the error caused by the aberration effect in the geocentric celestial reference system (GCRS) for earth observation. Based on the simulation, a comparison between different orbits, including low earth orbit, geostationary orbit, and lunar orbit, will be presented. The result shows how the orbit altitude impacts on the magnitude of aberration error.

A0.1-0005-18 DESIGNING A SPACECRAFT TO EXPLOIT SIGNALS-OF-OPPORTUNITY FOR EARTH SYSTEM SCIENCE

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RF Signals of Opportunity (SoOp) are signals generated by communication or navigation satellites in Earth orbit, whose interaction with the Earth's surface can be exploited to address a wide range of Earth system science measurements. The most commonly known SoOp signals are L-Band GPS reflections, which were measured systematically by NASA's CyGNSS mission to reveal ocean surface wind speeds beneath cloud cover generated by cyclones. SoOp are spread across the RF spectrum, from VHF to Ka-band, with more and more sources available every year. This is significant, because Earth scientists use microwave signals reflected off the Earth's surface to characterize a wide range of geophysical variables, including water vapor and ice column densities in the atmosphere, sea surface heights, currents, wind speeds and wave direction, ocean salinity, snow water equivalence, soil moisture, biomass and moisture content of vegetation canopies, freeze/thaw in arctic soils, sea ice extent, and surface deformation. Different wavelengths are better suited to each of these measurements.

The advent of low-cost, yet capable spacecraft platforms in cubesat form factors present an opportunity to develop LEO constellations of SoOp missions that can dramatically increase the temporal frequency of the above-mentioned Earth System Science measurements. To truly be cost-effective, such a constellation must be capable of receiving signals in multiple bands, adapting to the available sources from above. This will involve a considerable degree of autonomous operation. Depending on the underlying terrain (e.g. ocean, ice, desert, forest, agriculture), different algorithms may be used in onboard processing to retrieve surface properties of interest. This paper will describe the challenges involved in designing a spacecraft targeting multiple SoOp and multiple science measurements.

The research described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

A0.1-0006-18 MATCHING SCIENCE QUESTIONS AND TECHNOLOGY CAPABILITIES FOR FUTURE INFRARED SOUNDING MEASUREMENTS

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Current operational infrared (IR) atmospheric sounders including the Atmospheric Infrared Sounder (AIRS) on Aqua, the Crosstrack Infrared Sounder (CrIS) on JPSS, and the Infrared Atmospheric Sounding Interferometer (IASI) on MetOp measure the upwelling spectrum in the IR from about 3.8 to 15.4µm with very high spectral resolution (Λ/ΔΛ 1000) with spatial resolution of about 14 km and wide swath (>1500 km). AIRS, IASI and CrIS all have had high impact on operational forecasts, despite clouds limiting the forecast use of IR information to mostly clear areas and to the upper troposphere. Current sounders have also demonstrated skill in observing weather-related metrics appropriate for decision making applications, including drought and vector-borne disease indicators. However, as global and regional weather forecast models move to spatial resolution finer than about 10 km, information about processes at the smallest scales necessitates finer spatial resolution observations. This paper will discuss the operational, applications, and science research requirements of future IR sounders, how they fit into the 2017 NRC Decadal Survey, and the instrument requirements that result from the other requirements. We will also show instrument concepts developed at JPL that address these requirements. Finally. we will identify challenges in technology, measurement approach, and retrievals as we move ahead.

A0.1-0007-18 GRACE FOLLOW-ON: THE NEXT CHAPTER OF TIME-VARIABLE GRAVITY OBSERVATIONS FROM SPACE

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The GRACE Follow-On mission is set to continue the successful data record from the original GRACE mission, which ended in mid-2017 after 15 years of successful operations and science discoveries. GRACE has provided a unique data record of subannual to decadal temporal variations in the Earth's gravity field that has become indispensable for climate-related studies and critical measurements of Earth's time varying mass distribution. These measurements enable key and revolutionary observations of the global water cycle, including ocean dynamics, polar ice mass changes, and global ground water changes.

In 2010, NASA (US) and GFZ (Germany) agreed to jointly develop and support the GRACE Follow-On mission to ensure data continuity, as well as to demonstrate a new Laser-Ranging Technology to further improve the spacecraft-to-spacecraft ranging measurements for nextgeneration gravity missions.

In the lead-up to launch, the GRACE Follow-On project has performed extensive simulations of the expected GRACE Follow-On performance on-orbit, including intersatellite ranging (both microwave and laser interferometer), accelerometer, thermal variability and deformation, and other instrument errors. The simulated data have been used for fully integrated end-to-end Science Data System testing, and to improve ground analysis software.

In this presentation, we will provide a review of the GRACE Follow-On project integration and tests before launch, the expected science performance, and a first status update of the postlaunch checkout and early operations phases and science payloads. We will also discuss science data continuity from GRACE to GRACE Follow-On, as well as to future potential successor missions.

A0.1-0008-18 SMALL SATELLITES FOR SPACE SCIENCE (4S) COSPAR ROADMAP

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In 2016 COSPAR commissioned an international scientific roadmap on Small Satellites for Space Science (4S), focusing particularly on CubeSats and CubeSat-technology enabled small satellites. The report is motivated by recent progress and results summarized in a published paper (Zurbuchen, von Steiger et al., Performing High-Quality Science on CubeSats, Space Research Today, Vol. 196, pp. 10-30, August 2016) and a study by the US National Academies (Zurbuchen, Lal, et al., Achieving Science with CubeSats: Thinking Inside the Box, The National Academies Press, Washington, DC, 2016).

The roadmap has been developed by a study team that covers a broad range of scientific disciplines, from Earth to planetary science and from solar system science to astronomy. The team is composed of scientists and engineers working in universities, public research institutions and industry.

The report is structured into three main parts: I. Our Neighborhood: current status and scientific potential of small satellites and CubeSats II. Visions for the Future: potential ideas for what small satellites could be in the future III. Challenges to Further Development and Progress, and Ways to Overcome Them: roles of agencies, industry, policies, international collaboration and exchange

In this presentation, members of the study team will give an overview of the roadmap and summarize the findings of the study team with emphasis on the parts relating to Earth observation in particular. The final report is intended to be of value to space agencies, key actors, industries, and governments involved in Small Satellites

A0.1-0009-18 AUTONOMOUS SCHEDULING REQUIREMENTS FOR AGILE CUBESAT CONSTELLATIONS IN EARTH OBSERVATION

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Distributed Space Missions such as formation flight and constellations, are being recognized as important Earth Observation solutions to increase measurement samples over space and time. Cubesats are increasing in size (27U, 40 kg) with increasing capabilities to host imager payloads. Given the precise attitude control systems emerging commercially, Cubesats now have the ability to slew and capture images within short notice. Prior literature has demonstrated a modular framework that combines orbital mechanics, attitude control and scheduling optimization to plan the time-varying orientation of agile Cubesats in a constellation such that they maximize the number of observed images, within the constraints of hardware specs. Schedule optimization is performed on the ground autonomously, using dynamic programming with two levels of heuristics, verified and improved upon using mixed integer linear programming. Our algorithm-in-the-loop simulation applied to Landsat's use case, captured up to 161% more Landsat images than nadir-pointing sensors with the same field of view, on a 2-satellite constellation over a 12-hour simulation.

In this paper, we will derive the requirements for the above algorithm to run onboard small satellites such that the constellation can make time-sensitive decisions to slew and capture images autonomously, without ground support. We will apply the above autonomous algorithm to a time critical use case - monitoring of precipitation and subsequent effects on floods, landslides and soil moisture, as quantified by the NASA Unified Weather Research and Forecasting Model. Since the latency between these event occurrences is quite low, they make a strong case for autonomous decisions among satellites in a constellation. The algorithm can be implemented in the Plan Execution Interchange Language - NASA's open source technology for automation, used to operate the International Space Station and LADEE's in flight software

- enabling a controller-in-the-loop demonstration. The autonomy software can then be integrated with NASA's open source Core Flight Software, ported onto a Raspberry Pi 3.0 for a software-in-the-loop demonstration. Future use cases can be time critical events such as cloud movement, storms or other disasters, and in conjunction with other platforms in a Sensor Web.

A0.1-0010-18 CUBESATS FOR ASTROPHYSICS: THE STAR-PLANET ACTIVITY RESEARCH CUBESAT (SPARCS)

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The observational problems in Astrophysics are fundamentally different from those in Earth Science. Interesting Astrophysics generally takes place at the limit of detectability, requiring long exposures, sensitive instruments, and very stable platforms.

Here we describe the landscape of scientifically competitive Astrophysics missions using CubeSats and compare it with the Earth Science one. We identify potential science opportunities, discuss technological bottlenecks, and identify ways to overcome the unique challenges imposed by Astrophysics. As case studies, we review the four funded Astrophysics missions, with a special emphasis on the Star-Planet Activity Research CubeSat (SPARCS).

SPARCS' mission is to study the ultraviolet (UV) environment of exoplanets around low-mass stars. Low-mass stars are the most common type of stars in the Universe and host the most exoplanets. UV radiation from the star modifies the atmospheres of exoplanets, impacts their habitability, and limits our ability to determine their composition. However, little is known about the UV behavior of the stars over time: SPARCS seeks to fill this gap.

SPARCS will be a 6U CubeSat hosting a 9 cm telescope and an ultrasensitive 2-band UV camera (160 nm and 280nm). The spacecraft will fly on a sun-synchronous 6 pm orbit and stare continuously at 12 targets over a period of one year. The telescope has been designed to minimize the impact of the expected pointing jitter (7″-10″ over 10 minutes). The camera will carry a JPL-developed delta-doped detector, which offers high efficiency (5-10x GALEX), high stability and durability (no flooding required unlike HST-WFC), and tailorable response in the entire UV spectral range. Autonomous on-board software will track the development of flares in the target stars, and produce postage stamps for downlink.

Slated to fly in late 2021, SPARCS is led by Arizona State University (ASU). ASU will perform payload integration and testing and manage the project. JPL will fabricate and test the camera. Funding for SPARCS is provided by NASA's Astrophysics Research and Analysis program, NNH16ZDA001N.

A0.1-0011-18 VISTA+ INSTRUMENT: A NEW MICRO-THERMOGRAVIMETER DEVICE FOR IN-SITU MEASUREMENTS IN PLANETARY ENVIRONMENTS AND IN-SPACE OUTGASSING MONITORING

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The proposed instrument, VISTA+, is a follow-up of the VISTA (Volatile In-Situ Thermogravimetry Analyzer) instrument [1] that was studied for Phase A of different Cosmic Vision Space missions, such as the M2 Marco Polo and the M3 MarcoPolo-R [2] and during Contamination Assessment Microbalance Project (CAM-ESA) which aimed to develop a Quartz Crystal Microbalance-device able to monitor the contamination due to materials outgassing in space environment [3]. VISTA: is a micro-thermogravimeter able to measure dust and water ice and to search for volatiles (such as hydrated and organic compound) possibly present in the collected dust. The core of the instrument is a Piezoelectric Crystal Microbalance (PCM) in which the temperature can be changed by a built-in heater and performing Thermogravimetric cycles (TGAs). An improvement of VISTA would be 1) the identification of grain size distribution, especially for the particles <20 µm that are more affected to clinging and charging and can be more dangerous in the perspective of the future human exploration and 2) the capability to perform TGA at temperatures up to 773 K (500°C), allowing the desorption of organics. Besides, knowing the grain size distribution would be also useful to detect and monitor the contaminants that are going to deposit on critical spacecraft surfaces, such as optical systems, solar panels, thermal radiators and thermal management systems [4]. Thanks to VISTA heritage, VISTA+ will include the following units: 1) Sensor Head 1 (SH1), consisting in an array of three quartz crystal microbalances, devoted to grain size measurements and water ice detection; 2) Sensor Head 2 (SH2), based on a GaPO4 crystal, devoted to TGA at high temperatures to measure water and organic amount in the dust; 3) Proximity electronic, 4) Main Electronic Unit (MEU) to acquire data, to control the temperature for TGA measurements and to supply the power to the two sensor heads; 5) User interface. The SH1 mass should not exceed 100g, whereas 40g is the expected mass of SH2. These characteristics makes it a competitive instrument for landers or rovers as well as for an orbiters/spacecrafts to detect and characterize the contaminants produced in space and their outgassing rates [5] by means of TGA.

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[5] Dirri F. et al., Atmos. Meas. Tech., 9, 655-668, 2016.

A0.1-0012-18 CARBON NANOTUBES: APPLICATIONS IN SATELLITES

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Space Exploration is one of the industries where the advancement of technology is at its peak, It helps us gain insights to the universe, explore new frontiers and also the technology that are developed leads to the invention of modern products and gadgets which are used in everyday life. One of the major objectives of space missions is to deliver payloads. The payloads are Satellites which is an artificial object that is placed in an orbit to do a certain job, this covers a wide range of activities including weather monitoring, natural calamities prediction, ocean surveillance, voice communication, navigation systems and others. The technology that is used in these satellites is updated with the latest in technology. Therefore, presenting a massive opportunity for consumer-focused space technology is Nanotechnology. Carbon Nanotubes are an advanced Nanotech material that is ideal for space usage. It exhibits high strength, conductivity, radiation resistance and unique properties such as ballistic electron conduction and low-voltage field emission. Carbon Nanotubes have been studied thoroughly for 25 years. Several laboratory breakthroughs and prototypes particularly for use in space have been demonstrated. This review intends to detail about the applications of SWCNTs in various components of satellites, the change in efficiency of each subsystem. The article explains how each property of nanotubes is being used in different applications. The electrical conducting property of the nanotubes is being used in antennas which increases the performance 20 times compared to those of the conventional ones, The same property is being utilized for Electromagnetic Radiation shielding. Batteries that use nanotubes as their electrode increases the energy density by 10 times as well as withstanding the extreme temperature. CNTs are used as an additive material along with a variety of materials to make space ready structures. Because of their high thermal conducting property, the nanotubes are being used as a black hole forming material which absorbs the light 99.965% which are further used to prevent stray light, the same coating is being used on solar panels to increase the light absorbing capacity. The critical element in the satellites is considered to be the thruster that propels the satellite. The nanotubes offer a great solution for their field emitting property. The current density is found to be as high as 4 A/cm^2 which also produces the electric field as low as 2 V/µm. By improving the performance of each subsystem, It increases the efficiency of the satellite as a whole.The special nanotube properties and applications have been thoroughly reviewed in this work.

A0.1-0013-18 OBSERVATIONS OF MULTI-DIRECTIONAL PARTICLE DETECTOR FROM HXMT

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Hard X-ray Modulation Telescope(HXMT) was Chinese first space astronomy satellite, which launched into 550km with inclination of 43 °on June 2017. The Multi-directional Particle Detector on HXMT was designed to provide measurements of energetic protons and electrons. The detector is an all solid-state system that can make 16-directional flux measurements of electrons with energy 200KeV and protons with energy 1.5MeV, and can also measure the differential energy spectra of electrons from 0.4>1.5MeV and protons from 3300MeV with 7 channels separately from single direction. The detector can characterize particles distribution for detail especially in SAA which is important for low earth orbit missions. Here, we give brief induction of the instrument and show the primary observation results from the Multi-directional Particle Detector and evaluate the effect of anisotropy on flux measurements.

A0.1-0014-18 POSTER AUTHORS TO ADVERTISE THEIR POSTER (EG 1 SLIDE AND 1 MN MAX) + DISCUSSION

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This will give an opportunity for poster authors who wish to advertise their poster to present 1 slide and speak for 1 minute, max.

A0.1-0015-18 SERB, A FIRST INNOVATIVE PROOF-OF-CONCEPT NANO-SATELLITE OF A CONSTELLATION TO MEASURE THE EARTH RADIATION BUDGET

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The only way to measure the imbalance with sufficient accuracy is to measure both the incoming solar radiations (total solar irradiance) and the outgoing terrestrial radiations (top of atmosphere outgoing longwave radiations and shortwave radiations) onboard the same satellite, and ideally, with the same instrument. The incoming solar radiations and the outgoing terrestrial radiations are of nearly equal magnitude of the order of 340.5 W/m????2. The objective is to measure these quantities over time by using differential Sun-Earth measurements (to counter calibration errors) with an accuracy better than 0.05 W/m2. It is necessary to observe during a decade and to measure the global diurnal cycle with a dozen satellites. Solar irradiance and Earth Radiation Budget (SERB) is a potential first in orbit demonstration satellite. The SERB nano-satellite aims to measure on the same platform the different components of the Earth radiation budget and the total solar irradiance. Instrumental payloads (solar radiometer and Earth radiometers) can acquire the technical maturity for the future large missions (constellation that insure global measurement cover) by flying in a CubeSat. This presentation is intended to demonstrate the ability to build a lowcost satellite with a high accuracy measurement in order to have constant flow of data from space.

A0.1-0016-18 15 YEARS OF SORCE SOLAR IRRADIANCE MEASUREMENTS AND THE NEW TSIS OBSERVATIONS

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The Spectral Irradiance Monitor (SIM), the SOLar STellar Irradiance Comparison Experiment (SOLSTICE), and the XUV Photometer System (XPS) instruments on board the Solar Radiation and Climate Experiment (SORCE) mission have been taking daily Solar Spectral Irradiance (SSI) measurements since April 2003.

We present the latest data releases from these instruments, describing the improvements in the new datasets and the trends measured during Solar cycles 23 and 24. An inter-comparison of the SSI over the overlapping wavelengths for SIM and SOLSTICE is presented as well as a comparison with the results of the first few months of Total and Spectral Solar Irradiance Sensor operations.

A0.1-0017-18 THE FY-3 GNOS II INSTRUMENT CONFIGURATION AND PERFORMANCE

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Introduction Global Navigation Satellite System (GNSS) Radio Occultation measurements can remote sensing Earth's neutral atmosphere and ionosphere. Meanwhile, another GNSS remote sensing technique named GNSS Reflectometry (GNSS-R) has been developed rapidly, which can retrieve sea surface wind speed. The GNSS Occultation Sounder (GNOS) instruments were designed for FY-3 series of meteorological satellites for sounding the Earth's atmosphere and ionosphere since the 2nd batch FY-3 satellites. After the launch of the European TDS-1 satellite and the American CYGNSS constellation, to measure the sea wind field using GNSSR technique is proved to be effective. The Chinese researchers propose to integrate these two GNSS remote sensing techniques in one sounder, a new instrument named GNOS II is designed, which will be a payload for the third batch FY-3 satellite.

GNOS II Configuration The GNOS II instrument includes six antennas, four RF front-end units and one signal processing unit (SPU). One antenna used for precise orbit determination (POD) is installed on zenith side. Two front viewing and two back viewing occultation antennas are configured for occultation tracking, which are used for atmosphere sounding and ionosphere sounding respectively. Four RF front-end units are installed close to the antennas, in order to reduce the loss of the cable between antenna and RF front-end unit.

The SPU is the major unit of the GNOS II which accomplished the GNSS signal down-convertor and baseband processing. There are three function modules inside the SPU. The navigation module receives GNSS direct signals by a POD antenna, and then calculates the real-time position and velocity information of the FY-3 satellite, also outputs the carrier phase data for the precise orbit determination in post processing. Based on the GNSS and FY-3 satellites' geometry information, the occultation module predicts and tracks the ionospheric and neutral atmospheric occultation signals using ionospheric and neutral atmospheric occultation antennas, respectively. Similarly, the reflection module generates Delay Doppler Maps (DDMs) of GNSS signals scattered from the ocean surface, which is used for wind speed retrieval.

Measurement accuracy and ability The precision of code and carrier phase and real-time navigation were analyzed in the lab, using a Spirent GSS9000 GNSS signal simulator. The simulator allows for a realistic modeling of FY-3 satellite trajectory. By using the double difference method, the satellite and receiver clock errors can be eliminated, and the accuracy of the receiver observations can be determined. The results showed that the carrier phase precisions were less than 1.0 mm (C/N0=48dB•Hz) for both GPS L1 and L2. We also estimated the precision of the pseudorange, the precisions were less than 10cm for both BeiDou Navigation Satellite System (BDS) and GPS.

The first GNOS II instrument has 8 occultation channels for GPS, 8 occultation channels for BDS and 4 occultation channels for Galileo. More occultation channels and wide coverage atmosphere occultation antenna will help increase the number and quality of occultation tracking. The distribution of GPS system radio occultation events received by GNOS II in one day, rising and setting occultation number is 590 times for only GPS system by simulation, up to 1700 times taking into account BDS and Galileo system.

The GNOS can receive GPS L1, BDS B1 and Galileo E1 sea surface reflected signals simultaneously and real time onboard process them into Delay Doppler Maps for sea surface remote sensing. The reflected signals in orbit respond to ocean surface roughness, from which wind speed is retrieved. There are 8 DDMs channels in total, 4 channels for GPS L1, 3 channels for BD B1 and 1 Channel for Galileo E1. The coherent integration time and incoherent times of each DDM are 1ms and 1000. So, one DDM channel can output 1 DDM per second. DDM's Delay and Doppler pixels are 122 and 20 with the resolution of 0.25 chips and 500Hz respectively.

Summary The GNOS II instrument is a payload on the third batch of FY-3 series satellites. The GNOS II can generate Delay Doppler Maps (DDMs) of GNSS signals scattered from the ocean surface, which is an important improvement compared with the first generation GNOS. The test results show that the GNOS II instrument has excellent performance in precision of code, carrier phase and real-time navigation.

A0.1-0018-18 SPACE-BASED RADIO IMAGING ISSUES FOR SYNTHESIS ARRAY DESIGN, EVALUATION, AND OPTIMIZATION

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Amrita Vishwa Vidyapeetham University, TN, India Radio interferometry site configuration

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Configuration study for large arrays involves several aspects pertinent to synthesis imaging, that in turn identify an optimization to the topology. These include identification of the most appropriate locations (in terms of hostile interference signals), picking an appropriate subset among them for locating a reasonable performance array, and the setting up of basic characteristics of the configuration with the establishment of terrain specific masks. The resultant array layout has the potential to create several artefactual morphologies in the synthesised radio map. Application of potent deep learning algorithms provides the much needed insight on the nature of such morphologies. Optimization of the array layout can then be pursued, considering parameters such as dynamic range, fidelity index, radio map dimensions, spatial resolution, distributed radio source location vis-a-vis the phase center of the array, and a few other operational and image reconstruction techniques, towards a reconfigured array that minimizes the occurrence of these artefacts, which shall otherwise contribute erroneous information regarding various physical phenomenon in space-based radio wavelength imaging and surveys.

A0.1-0019-18 THE GRACE FOLLOW-ON LASER RANGING INTERFEROMETER

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GRACE Follow-On will replace the Gravity Recovery and Climate Experiment (GRACE) mission, which has been measuring Earth's gravity field since 2002; with launch planned for spring 2018. Like GRACE, GRACE Follow-On will use a microwave link as its primary instrument to measure micron-level changes in the 200km separation of a pair of satellites in a following polar orbit. GRACE Follow-On will also include a 2-way laser-link, the Laser Ranging Interferometer (LRI), as a technology demonstrator package. The LRI is an NASA/German partnership and will demonstrate inter-spacecraft laser interferometry with a goal of 10 times better precision than the microwave instrument, or about 90 nm/rtHz between 10 and 100 mHz. This talk will present first results of the interferometer link.

A0.1-0020-18 NOVEL POLARIZATION IMAGING SPECTROSCOPY

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A novel principle and scheme of static Imaging Polarization Spectroscopy which can obtain the image, spectrum and polarization information of the target simultaneously based on Savart polariscope is presented. It can not only acquire the image of the target, but also get the spectrum and full Stokes parameters of each pixel. The experiment device of Interference Imaging Spectropolarimeter was developed and simulated spaceborne detection experiments was carried out, acquiring the long-range target image, spectrum and polarization information, realizing the static, same time, real-time acquisition of image, spectrum and polarization information. Novel Static Imaging Polarization Spectroscopy has the advantages of small size and light weight, wide field of view, high spatial and spectral resolution, high detection sensitivity, no moving parts, and the ability of acquiring image, spectrum and polarization information simultaneously. Its features go beyond any single camera (imager), spectrometer, or other devices which can obtain image and spectrum. It has important scientific significance and broad application prospects in space exploration, earth observation, aerospace, and detection of land surface, atmosphere and ocean remote sensing.

Key words: Novel Imaging Polarization Spectroscopy; Image, spectrum and polarization 4-D integration information acquisition technology; Novel principle, technology and equipment of hyperspectral remote sensing.

A0.1-0021-18 RESEARCH ON NEW HYPERSPECTRAL IMAGING TECHNIQUES FOR DEEP SPACE SCIENCE DETECTION

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The depth and breadth of space science research depends on the breakthrough and support of a series of key technologies. Space probes can boldly go where no human has gone before, and obtain the space target information, such as the shape, size, surface form, mineral content, element and so on. The new scientific payload technology is one of the key technologies of space probes to obtain the above information. Based on the analysis of the characteristics of hyperspectral imager, this paper proposes a new system concept of hyperspectral imaging technology, with a large field of view of ±10º, high spectrum of 5nm-10nm, and spatial resolution which is better than 30m@500km. If needed, the field of view could increase to ±20º. Such new hyperspectral imaging techniques will be used to lay the technical foundation of deep space science detection.

A0.1-0022-18 A NEW GERMAN HYPERSPECTRAL MISSION ENMAP: IMAGE PRODUCTS

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The upcoming Environmental Mapping and Analysis Program (EnMAP) - German imaging spectroscopy mission - is a joint response of German Earth observation research institutions, value-added resellers and space industry to the increasing demand for accurate, quantitative information about the status and evolution of terrestrial ecosystems. EnMAP is currently in the construction phase with a launch planned in 2020. The project management is led by the Space Agency of DLR. The space segment consisting of instrument and bus will be established by OHB System AG.

The EnMAP satellite will be operated on a sun-synchronous orbit at 643 km altitude with a local time of descending node 11:00 to observe any location on the globe under defined illumination conditions featuring a global revisit capability of 21 days under a quasi-nadir observation. The satellite has an across-track tilt capability of ± 30° enabling a revisit time of four days. The hyperspectral instrument will be realized as a pushbroom imaging spectrometer. Its data acquisition over the broad spectral range from 420 nm to 2450 nm will be performed by a CMOS (Complementary Metal Oxide Semiconductor) detector array for VNIR (visible and near infrared) with 95 spectral channels, i.e. 6.5 nm spectral resolution, and by a MCT (Mercury Cadmium Telluride) detector array for SWIR (shortwave infrared) with 135 spectral channels, i.e. 10 nm spectral resolution. The ground pixel size is 30 m × 30 m at nadir at 48° northern latitude. In this context a pointing accuracy of better than 500 m is expected. The pointing knowledge and therefore the accuracy of image products will be better than 100 m and can be improved by ground processing, if a reference image is available, to approximately 30 m (i.e. 1 pixel) w.r.t. the used reference image. The sensors' 1000 pixels in spatial direction result in a swath width of 30 km. Regular on-board calibration measurements are performed to update the calibration tables for the processors.

EnMAP level 0 (L0) image products (raw data) will be long-term archived while L1B products (systematically and radiometrically corrected data), L1C products (geometrically corrected data) and L2A products (atmospherically corrected data) will be processed on demand. The L1B processor corrects the hyperspectral image cube for systematic effects of the focal plane detector array, e.g. radiometric non-uniformities, and converts the system corrected data to physical at-sensor radiance values based on the currently valid calibration tables. The L1C processor creates ortho-images based on direct geo-referencing techniques implementing a lineof-sight model, which uses on-board measurements for orbit and attitude determinations as well as the sensor look direction vectors based on the currently valid calibration values. Furthermore, it is foreseen to automatically extract ground control points from existing reference data sets by image matching techniques to improve the geometric accuracy better than one pixel size. The L2A processor performs atmospheric correction and haze detection of the images by estimating the aerosol optical thickness and the columnar water vapor. Output products will be the ground reflectance cube and masks of land, water, cloud, cloud shadow, haze, cirrus and snow.

A0.1-0023-18 RESEARCH ON TRACKING METHOD OF SPACE-BASED INFRARED SYSTEM FOR THE HIGT DYNAMICS TARGET IN ATMOSPHERE

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The characteristics of high speed and ultra maneuver for high dynamics target vehicles in atmosphere have brought great difficulties for maneuvering target localization and tracking. Traditional filtering algorithms obviously cannot give accurate target state estimation and the tracking performance has declined. In this paper, a tracking method to the high dynamic target in atmosphere is derived for spaced-based infrared system. By analyzing the radiation principle of a high dynamic target in atmosphere, the line of ray (LOR) algorithm for the infrared characteristics of the target affected by high temperature gas is given. And then its infrared intensity is calculated via the LOR algorithm. The coverage of space-based infrared system to the typical high dynamic and high altitude target in atmosphere is obtained by the formulas of the signal to clutter ratio (SCR) and detection range. Considering about large-scale maneuverability of high dynamics target in atmosphere, the algorithm of combining interacting multiple model (IMM) and multi-satellites passive location method are built for tracking for the target, the purpose of high precision tracking for high dynamic target in atmosphere is achieved. And then a novel single-satellite tracking algorithm is further proposed based on the multi-satellites passive location algorithm above. The superior accuracy on tracking for the high dynamic target in atmosphere of these two tracking algorithms are verified by simulation results, hence both multi-satellites and single-satellite passive location can obtain high precision target tracking data.

A0.1-0024-18 THE COHERENCE CHARACTERISTIC ANALYSIS FOR HIGH-RESOLUTION TERRASAR-X DATA - MAN-MADE OBJECTS AND NATURAL OBJECTS

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We can gather different kinds of information due to the specific wavelength of SAR. The TerraSAR-X series (TerraSAR-X and TanDEM-X) are one of the high specification commercial X-band SAR satellites, and play significant roles especially for acquiring high spatial-resolution images of 1 m up to 25 cm at the highest. One of the promising application fields of SAR data is disaster monitoring, and many researchers have studied the estimation of the damaged area caused by the earthquake, flood, landslide eruption of the volcano, etc., by utilizing the change detection methodology. However, the difficulty of the method for most of the studies has several factors (land cover, acquisition times, orientation of the building, water vapor) except the damage related issue affect the image quality and the value of the threshold and the detection accuracy vary depending on the situation. One of the reasons is the insufficient understanding of the feature of the sensors, and the applicability for the methodology. The purpose of this study was to acquire the knowledge of the coherence value for TerraSAR-X due to the baseline, acquisition duration, and land cover. The study site was the central of Tsukuba in Ibaraki Prefecture. Tsukuba station built in 2005 was the center of the images. First, we classified the land cover into man-made objects and natural objects using the reference “High-Resolution Land Use and Land Cover map” produced by AVNIR-2 on ALOS satellite operated from 2006 to 2011. It is noted that the classification errors is occurred due to the errors of the products and the difference of the times of the acquisition. Both StripMap mode and High-resolution SpotLight mode data were acquired in 2008, and the orbit direction of these data was also different. We conducted the interferometric analysis and acquired the coherence maps of the 25 pairs of dataset. Finally, we evaluated the coherence value of man-made objects and natural objects for each pair of image. The result showed that the coherence value of man-made objects was higher from 0.12 to 0.26 than natural objects for all pairs (the deviation of the coherence in the same pair was about 0.15, and it did not depend on the land cover). The difference was neither related to the baseline nor the acquisition duration, however the difference of the coherence was highly related to the coherence value themselves (man-made, natural objects). This study showed that the coherence of the natural objects showed highly negative correlation with acquisition duration. On the contrary, that of the man-made objects was not related to the acquisition duration comparing with natural objects. However, as a result of the multiple regression analysis, the value was expressed using both baseline and acquisition duration. We also revealed that this tendency was not affected by the acquisition mode and orbit direction.

A0.1-0025-18 INTER-ANNUAL VARIABILITY OF THE MONSOON INVERSION OVER THE ARABIAN SEA AS INFERRED FROM SATELLITE MEASUREMENTS AND WRFARW MODEL SIMULATIONS

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A high resolution dynamical downscaling data for 38 years starting from 1980 to 2017 is used in this present study to identify the variability of the Monsoon Inversions (MI) that forms over Arabian Sea (AS) before the onset of Asian Summer Monsoon (ASM) season and persists through-out the ASM. As the MIs are mainly formed due to cross-equatorial winds and we have analysed the parameters that controls the formation and seasonal persistence of the MI. Weather Research and Forecast (WRF) model is used to generate long-term high-resolution data by adopting continues re-initialization method. This high-resolution data enables us to explore the long-term trends and intermittent atmospheric phenomena over the Arabian Sea for the extended period containing the entire solar cycle, many cycles of ENSO and Quasi - periodic phenomena. Along with the WRF data, we have also used the radiosonde data for five stations to explain the MI characteristics and frequency of occurrence. Further we have also used 10 years of MetOp onboard IASI sounder observations to study the MI characteristics.

The statistical analysis between WRF and observations at the coastal stations indicates a drift in temperature, humidity and winds in the altitude region of 1 - 2 km, which is the height of MI's. The statistical significance of MI analysis from WRF data is at 95 % confidence level as per Mann-Kendall and Sen's slope estimator over the study area. A long-term trend analysis is also carried out to identify the effect of winds and inter-annual variability of MI. The MI has been forming during the monsoon season over Salalah at an average altitude of 0.5 - 2 km. The core of the low-level jet (LLJ) is at the height of around 1.5 km. The climatological WAS winds at 950 and 850 hPa shows a decreasing trend in the winds, MI strength, frequency of occurrence and also the height of the MI. The trends computed from the spatial data clearly revealed that the negative trends over the central (high), western and eastern Arabian Sea (moderate values). The decreasing wind speed across the Arabian Sea is responsible for the decrease of the MI intensity, height and the frequency of occurrences. The variability of the MI for two epochs of 1980 - 1998 and 1998 - 2017 indicates that in the first epoch trend is constant and in the later epoch it is significantly decreasing.

A0.1-0027-18 PERFORMANCE EVALUATION OF A REGIONAL NWP MODEL COSMO DURING THE PASSAGE OF A VERY SEVERE CYCLONIC STORM

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In the first week of December 2017, a Very Severe Cyclonic Storm, namely - "OCKHI" made its landfall near the coast of south Gujarat and adjoining Maharashtra of the Indian sub-conenent. During its entire course of movement, this cyclonic storm caused severe damage to the structure and affected human lives as well in the Indian coastal regions. Here, we present a case study on the performance evaluation of a regional numerical weather prediction (NWP) model, COSMO (Conosrtium for Small-scale Modelling) during the passage of OCKHI cyclonic storm over the Arabian Sea. The COSMO model simulations are evaluated with a special emphasis on the predictability of three distinct aspects, namely: (i) lead-time required for prediction of such severe cyclonic storm; (ii) intensity of the cyclonic storm; and (iii) locations of the landfall. Results obtained from this case study indicate that the model is able to capture such severe weather events almost 18 hours ahead of its occurrence. The intensity of cyclonic storm and its track simulated by the model are compared with the observations. An attempt is also done to improve the leadtime in predictability of such severe weather events by introducing a new scheme of initialization in the COSMO model by providing a 24 hrs spin-up from the global model analyses fields.

A0.1-0029-18 INDUS RIVER MONITORING USING SATELLITE ALTIMETRY

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The optimal management of water resources, or any other resource, requires, as a prerequisite, the availability of data. To bring into sustainable equilibrium the supply and demand for water, it is necessary, therefore, to have access to accurate and near real time data quantifying the supply and the consequent demand. The quantification of the supply of water in the Indus river basin has been a serious challenge for Pakistan to overcome. This has manifested itself as a grave problem in various sectors. First and foremost is the issue of efficient allocation of water to its users, mainly agriculture which utilizes almost 97% of the water. In addition, relations among the riparian provinces, principally Punjab and Sindh, and also among the riparian states in the Indus river basin have been adversely affected. Furthermore, given that there exists extreme variability in the flows of the Indus River, mainly due to majority of its water coming from the himalayan glaciers, the creation of a river management plan necessitates the availability of accurate and precise water level data. Therefore, combatting this critical issue requisites efficient monitoring of the available water level, and hence the total surface water supply. Targeting the supply side of this challenge,therefore, this research aims to explore the feasibility and the potential of Satellite Radar Altimetry (SAR) in monitoring the water level of the Indus river basin.

A0.1-0030-18 HIGH-SENSITIVITY SOLID STATE MAGNETOMETRY LEVERAGING SILICON CARBIDE QUANTUM CENTERS

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Magnetometry has a lot of tradition in space and planetary science. Among the first launched satellites altogether in history, Sputnik 3 and Pioneer 1 and 2 ferried magnetometers into orbit in 1958, as did most scientific exploration missions following them. The telltale magnetometer boom is one of the prominent recognizable features of an exploration spacecraft, nowadays carrying the spaceflight state-of-the-art fluxgate and vector helium√ magnetometers. These well-tried systems have excellent sensitivities in the range of 100 pT / Hz, but are intrinsically complex, requiring non-miniaturizable parts and electronics (fluxgate), or cryogenics and lasers (optically pumped atomic gas). We propose a new approach for a self-calibrating solid-state vector magnetometer, relying on spin-carrying quantum centers in silicon carbide semiconductor devices. We show a proof-of-concept miniature magnetom√eter using an off-the-shelf silicon carbide device, reaching a sensitivity on the order of 100 nT / Hz. We also discuss the potential increase of sensitivity by defect-engineering in both commercially available and homegrown devices. Additionally, we consider the notion of increasing sensitivity while reducing weight and volume footprint by placing multiple magnetometers on the spacecraft; to offset and negate the influence of the spacecraft's own field in relation of the desired background field.

A0.1-0031-18 RESEARCH OF MICRO-DEFORMATION MEASUREMENT FOR HIGH-RESOLUTION SPACE CAMERA COMPLEX STRUCTURED

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The requirement for ever-increasing-resolution space cameras drives focal length and diameter of optical lenses be increasing. High-frequency vibration in the process of launching and complex environmental conditions of the outer space generate micro deformation in components of space cameras. As a result, images from the space cameras are blurred. Therefore, it is necessary to measure the micro deformations in components of space cameras in various experiment conditions. This paper presents a high-accuracy micro deformation measurement method. The method is implemented as follows: (1) fix Invar balls onto a space camera being measured and measure the coordinate for each ball under the standard condition; (2) simulate high-frequency vibrations and environmental conditions like the outer space to measure coordinates for each ball under each combination of test conditions; and (3) compute the deviation of a coordinate of a ball under a test condition combination from the coordinate of the ball under the standard condition and the deviation is the micro deformation of the space camera component associated with the ball. This method was applied to micro deformation measurement for space cameras of different models. Measurement data for these space cameras validated the proposed method.

A0.1-0032-18 ADVANCED RETARDING POTENTIAL ANALYSER FOR MARTIAN IONOSPHERIC STUDIES

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ARIS (Advanced Retarding potential analyser for martial Ionospheric Studies), an ionospheric plasma and electrostatic instrument used for the structural and compositional studies of Martial Ionosphere, is a payload in the upcoming MOM (Mars Orbital Mission)-2 of ISRO. ARIS uses a Dual-Retarding Potential Analyser (RPA) configuration which consist of two RPAs in its architecture, Ion mode-RPA(I-RPA) and Electron mode-RPA(E-RPA). RPA is a plasma diagnostic tool that measures ion/electron energy distribution, which consists of a collector shielded from the plasma by a series of biased grids. It acts as a high pass filter which allows particles with energy to charge ratios greater than the retarding potential to pass and reach the collector. The instrument is designed in such a way that it is capable of handling ion/electron concentration of 10 - 106 cm−3, ion/electron temperature 100 -25000 K, ion drift velocity of 0.01 - 2.0 km/s, solar wind electron temperature of 25000 - 5x105 K and solar wind electron concentration of 0.5 - 100 cm−3. A five-ion retarding grid configuration is used for obtaining a high energy resolution of 1 amu and to minimize retarding potential homogeneities. Other grids are used for reducing aperture fringe fields and eliminating focusing and defocusing effects. The I-V (Particle Current-Retarding voltage) curve that results from measuring current as a function of the retarding potential is related to the flux distribution of the incoming particles and can be used to infer the particle density, particle temperature, ion composition and the component of the velocity vector in the direction of motion normal to the instrument aperture plane.

A0.1-0033-18 ATTITUDE ESTIMATION OF SMALL SATELLITES IN CONSIDERATION OF GEOMAGNETIC FIELD ANOMALIES

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Low Earth orbiting small satellites commonly use magnetometers as an attitude determination instrument. The difference in the components of the magnetic field vectors or the angle between them (model and measurement data) affects the estimation accuracy of the satellite's attitude. For attitude determination system, IGRF model is used in most of the cases but the difference between the sensor and model increases when the geomagnetic activity occurs. On the other hand, geomagnetic field anomalies are treated like noises on the magnetometer measurements and estimated using one of the stochastic processes. However, the differences are not supposedly caused by the magnetometer noises but might be caused by the external magnetic field especially in magnetically disturbed days which is sensed by the magnetometer but not by an internal magnetic field model.

In this study, geomagnetic field model, T89 including the external variations in the Earth's geomagnetic field resulting from the solar wind and interplanetary magnetic field aside from the internal field is also considered. Those two models can be evaluated to see a noticeable difference on extraterrestrial field effects on satellite's attitude determination system changing with its height. The comparisons are made between the models and observations and between the models under various magnetospheric activities. Extended Kalman filter is implemented in order to estimate the satellite's attitude using different sensor configurations including one or more of the sensors, a combination of the magnetometer, sun sensor, and gyroscope for the nanosatellite's attitude determination system with IGRF and T89 on magnetically quiet and active times. It is concluded that magnetic field anomaly affects the satellite's attitude more or less depending on both the sensor configuration and the magnetic activity times.

A0.1-0034-18 PFL: A MODERN APPROACH TO SMALLSAT FLIGHT SOFTWARE

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SmallSat flight software is usually proprietary, mission specific, and difficult to write for those unfamiliar with computing concepts. Projects like NASA's Core Flight Software and Kubos are headed in the right direction, but the methodology for flight software is still stuck in the 1970s. As processor power increases and component and launch costs decrease, scientist and engineer time becomes the most important resource. PFL's purpose is to drastically decrease development time and staff requirements for SmallSats by providing support for high-level languages, greatly increasing readability, and providing methods for code reuse between different missions and different bus configurations. We present an open-source, cross-platform, crosslanguage flight software platform named Python Flight Layer (PFL). Based on a microkernel architecture, PFL consists of subsystem servers that can be written in any language with socket support. By providing readable and accessible infrastructure, we enable those without flight software skills to easily and quickly write reliable code.

A0.1-0035-18 LIFE TESTING AND PERFORMANCE EVALUATIONOF 1.0 N THRUSTER FOR SATELLITE APPLICATIONS BASED ON GREEN PROPELLANT

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Satellite propulsion and instrumentation is designed to provide capability to perform certain operations such as attitude control, orbit transfer, orbit maneuver and deorbiting at the end of life. Use of green propellants such as hydrogen peroxide (H2O2) in satellite propulsion is not new. Hydrogen peroxide was first used in the reaction control systems of US X-1 and X-15 space planes, also in SYNCOM series and early bird satellites. A significant amount of work was carried out in the 1960s at NASA laboratories on hydrogen peroxide decomposition and its applications but this effort was subsequently abandoned due to availability of effective hydrazine catalysts. Recently, hydrazine has been banned by European Union because of its toxic and carcinogenic nature. It is neither easy to handle nor its preservation is simple. In February 2008, US government showed its concerns over US navy launch of spy satellite towards its own satellite which could release hydrazine vapors at breathing level. Therefore, efforts are being carried out to search an alternate who could meet the propulsive performance of hydrazine along with environment friendly nature. One such alternative is highly concentrated hydrogen peroxide (high test peroxide, HTP), often referred as a 'Green' or low toxic propellant. H2O2 is an economically viable and simple solution to health and safety problems. The purpose of this research is to design an environment friendly, green propellant based thruster, which could work over a longer period of time without deterioration so that the thrusters could be mounted in future satellite as a reaction control system. To decompose HTP into high temperature and environment friendly product gases (i.e. oxygen and steam), a silver catalyst bed is developed as per experimental results already available. The testing has been conducted using highly pure 88% -90% HTP in conformance with the American MIL-P-16005E standards. The work presented in this paper is not only about brief discussion of design methodology to develop HTP based thruster but also focuses, in details, on performance and life testing of thruster for over 9000s in steady state mode. Extensive testing of the thruster has been performed and the performance and life of the thruster is evaluated. The results obtained i.e. the chamber pressure in particular, are presented and the thruster chamber roughness and chamber pressure degradation over time have been studied. Thruster has also been tested on thrust measurement bench and results are shown. Through this work, successful life testing of the thruster has been performed and the research work established and proved H2O2 a potential candidate to constitute green propellant thruster configuration along with other instruementation for use in reaction control system of future satellites.

A0.1-0036-18 A MULTI-PROPELLANT RADIO FREQUENCY PLASMA THRUSTER

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Applied Plasma Technologies, Corp. (APT) and International Plasma Technology Center, Corp. (IPTC), both US corporations, offer for discussion the results of preliminary modeling and tests of a Multi-Propellant 25 kW radio-frequency (RF) plasma thruster for deep space exploration. A list of plasma gases or propellants includes Ar, water steam, CO2, and could be extended by other gases and their blends. APT and IPTC have a line of commercial high power and high pressure RF plasma systems for a wide range of applications. Operation pressure - from 1 bar to 10 bar. A Multi-Propellant Thruster Concept is a result of significant progress in the RF plasma development and could be considered as a platform for other space needs, as space waste processing, CO2 decomposition, minerals processing, etc.

A0.1-0037-18 SPACE STUDIES OF THE EARTH'S SURFACE, METEOROLOGY AND CLIMATE

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ETIOPIAN SPACE SCIENCE AND TECHNOLOGY INSTITUTE, Addis Ababa, Ethiopia 1/15/ 2018 zolomlkt@gmail.com +251-918-312-314 ADDIS ABABA, ETHIOPIA ZELALEM WUDU TO: COSPAR ZARM

Dear Sir/Madam Recently I completed the requirements for the Bachelor of degree in Mechanical Engineering at Bahir-Dar Institute of Technology and working on Entoto Observatory and Research Center as a junior researcher. I am exploring potential opportunities with a well established firm that will lead me to become a great researcher on this field of study. I would like to participate in this program to develop my knowledge for further study and research work. I have an excellent communication skill and a strong background in Mechanical Engineering. I have good analytical, practical and sound knowledge in all major subject of my discipline. My personal characteristics such as poise, confidence, dependability patience, creativity etc are highly admirable. I am motivated to learn and perform best capacities. I spent most of my time in studying and trying to learn new techniques in the area of study. I have several strengths but my main strength is the motivation of further studying and research area. I work well with my colleagues and administration during my final year thesis project and I learn many things from them. Thank you for your consideration and the opportunity.

With Best Regards Yours Sincerely, ZELALEM WUDU

A0.1-0038-18 MICROCHANNEL THERMALIZATION INLET TO ELIMINATE MOLECULAR FRAGMENTATION IN ORBITAL CLOSED-SOURCE MASS SPECTROMETERS

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Mass spectrometers for flybys and orbiters have been used to analyze neutrals which are sampled as they enter the instrument inlet at relatively high velocity. Two types of inlet designs used in the past are "open source" and "closed source". However, these inlet designs present some limitations. Open source inlets are not as sensitive as closed sources. On the other hand, molecular species can be altered in closed source inlets due to the high kinetic energy of impact. Sampled molecules are vibrationally excited upon impact, and subsequently can fragment. These fragments are, of themselves, not stable compounds and will only make it to the ionizer of the mass spectrometer after they combine with some other fragments. Radical-radical recombination on the surface of the closed source walls is a likely mechanism. Thus the altered original composition of the samples leads to incorrect interpretation of measurements. Calculations show that dissociation lifetimes after impact, for compounds and velocities relevant to some mission scenarios, occur at the order of microseconds-shorter than the time needed for thermalization due to multiple impacts inside the source. We are developing a source that overcomes the above problem by thermalizing or cooling the sampled molecules much more quickly than in a conventional source. Molecules are cooled faster than their dissociation lifetime. These quenched molecules remain intact during the sampling process and during introduction to the mass spectrometer. This source employs a microchannel array. Channels with diameter of tens of microns reduce the time between thermalizing impacts from tens of microseconds to tens of nanoseconds. Initial efforts focus on stainless steel channels, but in theory other materials will also work, such as ceramic. The channels allow ram pressure enhancement and the accompanying increase in sensitivity of an open source, without the fragmentation present in a closed source. This source would be beneficial to any flyby or orbiter mass spectrometer, including such instruments sampling plumes on ocean satellites in the outer solar system.

A0.2-0001-18 INTRODUCTION TO SCIENTIFIC EVENT A0.2

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COSPAR became a Group on Earth Observations (GEO) Participating Organization in 2007 and, since then, has focused its contributions towards advancement of understanding of the global integrated Earth system. GEO is building a Global Earth Observation System of Systems (GEOSS). In 2016, COSPAR prepared a 2016-2025 Roadmap on observations and modeling for global integrated Earth system science (Advances in Space Research, 57, 2037-2103) to contribute to the GEO 2016-2025 Strategic Plan for building GEOSS. GEO accomplishes its work through a variety of mechanisms that span thematic, as well as geographic domains. We shall hear about scientific and technological foundations of several of these efforts. The intent of this scientific event is to encourage broader participation of COSPAR Associates in GEO's global efforts to build a truly integrated global observing system.

A0.2-0002-18 GEOGLAM: EARTH OBSERVATION IN SUPPORT OF TIMELY, ACCURATE, AND ACTIONABLE DECISIONS FOR FOOD SECURITY & AGRICULTURE

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Agricultural markets have become increasingly volatile, threatening food security and human livelihoods. Access to timely, accurate, transparent, and actionable information about crop condition and production can help stabilize markets and provide early warnings of crop failure, thereby promoting food security. In 2011, the Group of Twenty (G20) Agricultural Ministers developed the G20 Action Plan on Food Price Volatility and Agriculture that includes the launching of the Agricultural Market Information System (AMIS; www.amis-outlook.org), and the Group on Earth Observations Global Agricultural Monitoring initiative (GEOGLAM; www.geoglam.org), the latter utilizing Earth observations (EO) for improved information about crop condition and production. In June 2016, the G20 reaf-firmed its support of GEOGLAM.

GEOGLAM's primary objective is to reinforce the international community's capacity to produce and disseminate timely, accurate, and actionable information on and forecasts of agricultural production at national, regional, and global scales through the use of satellite and in-situ Earth observations. Through the coordination of satellite, in-situ, and agrometeorological observations, and through the transparent sharing of methods and information, GEOGLAM aims to strengthen national, regional, and global monitoring systems and improve access to timely, accurate, and actionable information.

This presentation will highlight GEOGLAM's successful application of satellite data to empower science-based decision making in main producer countries as well as in countries at risk of food insecurity.

A0.2-0003-18 MONITORING EARTH'S CHANGING MOUNTAINS WITH THE GROUP ON EARTH OBSERVATIONS INITIATIVE-GLOBAL NETWORK FOR OBSERVATIONS AND INFORMATION IN MOUNTAIN ENVIRONMENTS (GEO-GNOME)

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Earth's mountains are cover more than 20% of the global land surface and occur on all continents, in all latitude zones. Compared with other regions, mountain contribute a disproptionate amount of ecosystem services such as clean and abundant water, timber, hydropower; they also are the source of severe hazards such as floods, debris flows, and volcanic eruptions. Mountains are considered "sentinels of climate change" because of elevation dependent warming and disappearing ice but data from mountain observations are sparse and not necessarily spatially representative. The Group on Earth Observations Initiative - Global Network for Observations and Information in Mountain Environments (GEO-GNOME) is an international effort that aims to address the paucity of observations and information on mountains. GEOGNOME partners include the countries of Austria, Belgium, Brazil, Canada, China, Colombia, Denmark, EC, Ethiopia, France, Italy, Japan, Kazakhstan, Mexico, New Zealand, Pakistan, Russian Federation, Slovakia, South Africa, Switzerland, Uganda, UK, and USA. The goal of GEO-GNOME is to compile and provide data, both related to historical conditions and to future projections that support examination of the drivers, conditions and trends at a variety of different scales, from that of a single mountain range to that of the planet as a whole. Remote sensing plays a key role in GEO-GNOME mountain observations. Importantly, remote sensing experts are mapping and characterizing changes in snow and glaciers, vegetation, and land surface temperature in mountain regions. However, there remains a critical need to calibrate and validate these satellite observations with airborne and ground-based data. Such validated data need to be transformed into readily accessible information for developing informed policies and decision-making affecting mountain regions.

A0.2-0004-18 GEO-C: THE GEO CARBON AND GREENHOUSE GAS INITIATIVE

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CMCC Foundation – Euro-Mediterranean Center on Climate Change, Viterbo, Italy GEO-C Team

Canadell J., Crisp D., DeCola P., Dolman A.J., Heiskanen J., Noda A., Obregón A., Saigusa N., Venkataraman S., and the entire GEO-C Team

Despite the recent progress, the budgets of carbon and greenhouse gases (GHGs) are still not closed and their spatial resolution and uncertainties undermine their use for decision making. Significant improvements are required in long-term for both in situ and space-based observing systems within and across the atmospheric, oceanic, terrestrial and human domains, as well as for the analytical and modelling tools, to reliably quantify GHG sources and sinks, to support the development of climate policies, and project future climate change. A coordinated global carbon and GHG observing system can provide valuable data and services in support to the Paris Agreement and other emission reduction policies, by assessing the needed emission reduction targets, contributing to the global stocktake and monitoring the effectiveness of the adopted climate change mitigation measures. The importance of satellite-borne sensors for GHG gas concentration measurements and their use for estimating carbon stocks and fluxes has been increasingly recognized. Satellites provide a synoptic view of the global carbon cycle and help to fill gaps between sparse in situ observations. Satellites, together with a robust in situ observing system and model analyses capabilities, can play an important role under the transparency framework and global stocktake of the Paris Agreement, for example by providing support to nations interested in tracking and managing their progress toward their Nationally Determined Contributions (NDCs). Currently, four GHG monitoring satellites are in operation (GOSAT, OCO-2, TanSat, Feng Yun 3D and Sentinel-5P) and other relevant missions are under development or in planning stages (GOSAT-2, OCO-3, MERLIN, MicroCarb, Sentinel-5, GeoCarb, Gaofen-5, and others). It is expected that this set of space-borne sensors will provide observations at significantly improved temporal and spatial resolutions all over the globe, particularly useful in estimating emissions from “hot spots”, advancing the scientific understanding of carbon and GHG cycles and their impacts to climate change, and supporting policy decisions. GEO-C acts as a common and open forum that promotes the inclusion of existing monitoring efforts, such as the WMO/UNEP Integrated Global Greenhouse Gas Information System (IG3IS) and others, into a coherent framework to plan and implement joint strategies and activities at the global level from science to policy. Special attention is dedicated to the domain interfaces, the complementarity and integration between ground and space-based observations, and the development of the analytical and modelling capacities. The intention is to obtain a comprehensive, coherent, globally coordinated, carbon and GHG observation and analysis system.

A0.2-0005-18 SUMMARY OF THE A0.2 SCIENTIFIC EVENT

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The A0.2 scientific event will gather GEO science leaders who will describe current developments and future activities and promote opportunities for COSPAR Associates to participate in GEO projects. This summary talk will review and highlight the main findings of the session. It will draw some concluding remarks from the expected enlightening discussion that will have taken place after the presentations on GEOGLAM, GEO Carbon and GEO-GNOME.

SPACE STUDIES OF THE EARTH'S SURFACE, METEOROLOGY AND CLIMATE (A)

IMPROVING THE UNDERSTANDING OF THE CARBON CYCLE WITH SATELLITE OBSERVATIONS AND MODELING (A0.3)

A0.3-0001-18 MEASURING GREENHOUSE GASES FROM SPACE: PROGRESS TOWARD AN OPERATIONAL CONSTELLATION

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Space based observations are providing new tools for measuring the sources emitting carbon dioxide (CO2), methane (CH4) and other greenhouse gases into the atmosphere, and the natural sinks that absorb these gases. These measurements are particularly challenging because both high precision and accuracy are essential to capture the small (< 0.25%) concentration changes associated with their surface sources and natural sinks. High resolution spectroscopic measurements of reflected sunlight at shortwave infrared wavelengths are well suited for this application because they can be analyzed to yield surface-weighted estimates of the columnaveraged dry air mole fractions of CO2 and CH4 (XCO2 and XCH4). Recent efforts to analyze the data collected by the pioneering EnviSat SCIAMACHY, GOSAT TANSO-FTS, and OCO-2 instruments have begun to demonstrate the precision needed to resolve anthropogenic as well as natural fluxes of CO2 and on scales ranging from individual power plants, to cities, to regional scales. Comparisons of space-based XCO2 and XCH4 estimates with ground-based standards such as the Total Carbon Column Observing Network (TCCON) are showing continuing improvements, with accuracies approaching 0.25% over most of the globe. In spite of this progress, space-based GHG sensors do not yet provide the spatial or temporal resolution and coverage needed to provide timely, quantified guidance on progress towards emission reduction targets at national scales. Three factors are limiting their performance: (i) Existing spatial sampling strategies acquire measurements at low spatial resolution (SCIAMACHY), at discrete points separated by large distances (GOSAT) or along narrow ground tracks, separated by large distances (OCO-2). (ii) Optically thick clouds and aerosols preclude full-column measurements of XCO2 and XCH4 for more than 90% of soundings collected by these systems. (iii) Passive remote sensing systems that retrieve XCO2 and XCH4 from reflected sunlight can only return data over this sunlit hemisphere, precluding observations of the variations in these species over the diurnal and seasonal cycle. To address the first of these shortcomings, future sensors in low Earth orbit could acquire measurements over a broad (> 200 k) swath, producing twodimensional (2-d) "images" of XCO2 and XCH4. The spatial sampling and revisit times will be reduced further in the early 2020's when the NASA GeoCarb mission begins returning 2-d images of XCO2, XCH4 and XCO over North and South America from Geostationary orbit. To improve the coverage of the night side and high latitudes in the winter hemisphere, active sensors (lidars), such as the CNES/DLR MERLIN mission are needed. The resolution, coverage and repeat frequency could be improved further if all available missions can be integrated into an ad-hoc constellation, and their data can be cross-calibrated and cross-validated to produce a harmonized data product. This presentation will summarize the lessons learned from the first

generation of greenhouse gas monitoring satellites, the methods needed to integrate their results into a common product, and the developments needed to support future, purpose-built greenhouse gas constellations.

A0.3-0002-18 USE OF THE 1.27 μM O2 ABSORPTION BAND FOR CO2 AND METHANE MIXING RATIO ESTIMATES IN NADIR VIEWING FROM SPACE: POTENTIAL AND APPLICATION TO MICROCARB

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Monitoring CO2 from space is essential to characterize the spatio/temporal distribution of this major greenhouse gas, and quantify its sources and sinks. The mixing ratio of CO2 to dry air can be derived from the CO2/O2 column ratio. The O2 column is usually derived form its absorption signature on the solar reflected spectra over the O2 A-band (OCO-2, Tanso/Gosat). As a result of atmospheric scattering, the atmospheric path length varies with the aerosols load, their vertical distribution, and their optical properties. The spectral distance between the O2 A-band (0.76 μm) and the CO2 absorption band (1.6 μm) results in significant uncertainties due to the varying spectral properties of the aerosols over the globe. There is another O2 absorption band at 1.27 μm with weaker lines than in the A-band. As the wavelength is much nearer to the CO2 and CH4 bands, there is less uncertainty when using it as a proxy of the atmospheric path length to the CO2 and CH4 bands. This O2 band is used by the TCCON network implemented for the validation of space-based GHG observations. However, this absorption band is contaminated by the spontaneous emission of the excited molecule O2*, which is produced by the photo-dissociation of O3 molecules in the stratosphere and mesosphere. From a satellite looking nadir, this emission has a similar magnitude as the absorption signal that is used. In the frame of the CNES Microcarb project, scientific studies have been performed in 2016-2017 to explore the problems associated to this airglow emission and methods to correct it. The intensities observed by SCIAMACHY/ENVISAT in limb viewing have been compared to a model of the emission based on the chemical-transport model Reprobus. The airglow intensities depend mostly on the Solar Zenith Angle and the agreement data/model is quite good. It was shown that, provided the spectra is acquired with a sufficient spectral resolution and SNR, the contribution of the O2* emission at 1.27 μm to the observed spectral radiance may be disentangled from the lower atmosphere/ground absorption signature. The

CO_2 mixing ratio may be retrieved with the accuracy required for quantifying the CO_2 sources (pressure level error < 1 hPa, mixing ratio error < 0.4 ppmv). As a result of these studies, it was decided to include such a band in the Microcarb design, although keeping the O_2 A band for reference. Some detailed results of these O_2^* studies and their 2018 update will be presented. We advocate for the inclusion of such a band in other GHG monitoring future space missions, such as GOSAT-2 and EU/ESA CO2M missions, for a better GHG retrieval.

A0.3-0003-18 OPTIMAL DESIGN OF OBSERVATIONAL NETWORK OVER INDIA FOR MAXIMUM INDIAN SUBCONTINENTAL CO2 FOOTPRINT

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An exhaustive set of ensemble simulations are carried out with a state of the art Lagrangian particle dispersion model (LPDM) FLEXPART to identify an 'optimal set' of ground based observation stations exclusive to Indian subcontinent to capture a maximum sub-continental footprints of CO_2 source and sinks. The Indian subcontinent is divided into a regular 20 x 20 grids assuming at least one station within each of these grids a priori. A suite of weekly ensemble backward trajectories from each of the a priori stations at every 7 day interval for 5 years (2010-2015, comprising of a total of 18,615 ensembles) were simulated. An optimal set of receptors wherein the boundary layer air from 'most' part of the Indian subcontinent during 'most' part of the year arriving have been identified by examining the ratio of area swept by the ensemble potential emission sensitivities (PES) to the area of the total Indian land mass. The same has been repeated by dividing the Indian subcontinent into 5 major zones to identify contribution from each zone. The positions of existing greenhouse gas observation stations relative to the 'optimal set' of stations are discussed further.

A0.3-0004-18 ESTIMATES OF CO2 CONCENTRATION FROM SATELLITE AND GROUNDBASED MEASUREMENTS OVER THE INDIAN REGION AND COMPARISON WITH FLEXPART SIMULATIONS

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The distribution of carbon dioxide (CO2) concentration over the Indian region and the surrounding oceanic regions during 2009-2012, was studied using measurements from satellites viz., Greenhouse gases Observation SATellite (GOSAT) and Atmospheric Infra-Red Sounder (AIRS), Carbon Tracker (CT) model simulations and flask measurements from two Indian stations Sinhagad (SNG) (73.75ºE 18.36ºN) and Cape Rama (CRI) (73.9ºE 15.1ºN). The concentration of CO2 was observed to be maximum during pre-monsoon. A decreasing phase was seen during the post-monsoon season. In a regional scale, it was found that the Indo-Gangetic plain and northern India have relatively higher concentrations compared to the other regions. The probability distribution of the concentration differences shows that for most of the time, the differences lie between ±3 ppm between GOSAT and CT. The comparison between the CO2 flask measurements over SNG and CRI with respect to that of GOSAT and CT clearly reveals that the differences in CO2 are as high as 10 ppm between the ground and satellite based measurements. FLEXPART model simulations were carried out to understand the source-receptor relationship over CRI, SNG, and over the equatorial Indian ocean. From the simulations, it is understood that the source contributions from the northern and eastern continental regions of the Indian region has more influence over SNG compared to CRI. Model simulations also revealed that the equatorial Indian ocean has less influence from the continental source and therefore has a reduced seasonal variability compared to the other regions considered in the present study, thereby lending support to the significant observations in the region.

A0.3-0005-18 THE GEOCARB MISSION

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This paper presents a discussion of the GeoCarb Mission, which was selected in December of 2016 as NASA's Earth Venture Mission-2. GeoCarb will fly an instrument that will provide measurements of atmospheric carbon dioxide (CO2), methane (CH4), and carbon monoxide (CO) from geostationary orbit at roughly 85°W. The GeoCarb mission will deliver daily maps of column integrated mixing ratios of CO2, CH4, and CO over the observed landmasses at a spatial resolution of roughly 5 x 8 km.

The instrument exploits four spectral regions: The oxygen A-band for pressure and aerosols, the weak and strong bands of CO2 near 1.61 and 2.06 microns, and a region near 2.32 microns for CO and CH4. The O2 and CO2 components are very similar to the instrument aboard OCO-2, and so we envision OCO-2 in geostationary orbit with the addition of a fourth channel to measure CO and CH4, but without an oceanic capability. The chosen spectral channel for pressure and aerosols (0.765μm) permits measurement of Solar-Induced Fluorescence (SIF), which provides direct information about photosynthesis.

The 85°W slot allows observations of major urban and industrial regions in the Americas, large agricultural areas, and the expansive South American tropical forests and wetlands, which will help resolve flux variability for CO2 and CH4. As noted, the GeoCarb mission will produce daily maps at a spatial resolution of 5-8 km of the carbon gas concentrations and SIF. We believe that these persistent observations will provide the basis for a transformational improvement in our understanding of the carbon cycle, including climate-critical insights into the carbon-climate connection.

A0.3-0006-18 FORWARD MODELLING OF SOLAR INDUCED FLUORESCENCE FROM THE JULES LAND SURFACE MODEL

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Solar induced fluorescence (SIF) is becoming widely used as a proxy for gross primary productivity (GPP), in particular with the advent of its measurement by Earth Observation satellites such as OCO and GOSAT. A major attraction of SIF is that it is independent of the assumptions embedded in light use efficiency based GPP products derived from satellite missions such as MODIS. The assumptions in such products are likely not compatible with any given land surface model and hence comparing the two is problematic. On the other hand to compare land surface model predictions of GPP to satellite based SIF data requires either (a) translation of SIF into estimates of GPP, or (b) direct predictions of SIF from the land surface model itself. The former typically relies on empirical relationships, whereas the latter can make direct use of our physiological understanding of the link between photosynthesis and fluorescence at the leaf scale and is therefore preferable.

Here I use a two stream model for fluorescence that is capable of translating between leaf scale models of SIF and the canopy leaving radiance taking into account all levels of photon scattering and use it to forward model SIF observations from JULES (the Joint UK Land Environment Simulator) which is the land surface model of the new UK Earth System Model (UKESM). The model is run at a number of sites where SIF measurements are available from both field and satellite observations. Results show that it is possible to reproduce the observed SIF signal, but that understanding the magnitude of non-photochemical quenching is key to making correct predictions.

A0.3-0007-18 UTILIZING POLSAR AND POLINSAR FOR FOREST ABOVE-GROUND BIOMASS MAPPING - CASE STUDY OVER INDIAN TROPICAL FORESTS

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Synthetic Aperture Radar (SAR) data has been extensively utilized for mapping and monitoring of forests. It has been shown that SAR data is sensitive to the structure, dielectric properties as well as the density of the forests among other factors. SAR remote sensing has been utilized for estimation of forest biophysical parameters such as forest stand height and forest above-ground biomass (AGB). Forest AGB is a critical factor, recognized by the UNFCC as an indicator of understanding climate change process. SAR data can be related to forest AGB using various empirical as well as physics-based models. However, for all the models, it is observed that the longer wavelength SAR signals (P-, L-band) are better suited for AGB estimation due to higher saturation values. Physics based models such as the water cloud model (WCM) as well as random volume over ground (RVoG) models can be utilized for AGB estimation, however the model parameters are empirically derived for each forest site, hampering global applicability. In forestry, the forest stand height can be related to the forest AGB using allometric equations unique to each species and geographic location. These equations provide an AGB estimate with much higher accuracy than model-based AGB estimates. With advanced SAR remote sensing techniques such as Polarimetric SAR Interferometry (PolInSAR), accurate estimation of forest stand height is possible. With the launch of TerraSAR-X/TanDEM-X platforms, PolInSAR data with zero temporal gap provides the opportunity to accurately estimate forest stand height without temporal decorrelation. Various studies have been carried out across boreal, temperate, tropical as well as peat-swamp forests to demonstrate the capability of TanDEM-X data for accurate forest height estimation. This study utilizes fully-polarimetric L-band ALOS2/PALSAR-2 SAR data to obtain backscatter as well as G4U child parameters over two Indian tropical forests. Further TanDEM-X forest stand height is measured and validated over these forest test sites. Then we combine the L-band PolSAR parameters and height estimated using the X-band data to estimate forest AGB using simple linear regression modeling. We show that the forest AGB is estimated with RMSE ranging between 25% and 30% of the mean forest AGB when modeled for a low-AGB (mean AGB 150 t/ha) and a high-AGB (mean AGB 350 t/ha) forest range. We also carried out cross-site validation where the model is trained on one site and applied on the other. This study shows a simple regression model based AGB

estimation combining the PolSAR and PolInSAR techniques. As the model shows more flexibility for cross-site applicability, it has potential for AGB estimation over larger regions.

A0.3-0008-18 ROLE OF CLIMATE VARIABILITY AND LAND USE ON FIRE EMISSIONS OF CARBON GASSES IN THE 21RST CENTURY

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Large scale reductions in biomass burning are observed across the globe from 2002 through the present through measurements of burnt area and carbon monoxide. These reductions are likely due to shifts in land-use changes as most declines are related to agricultural expansion. However, these reductions are in the context of environmental variability that can create dry conditions in Indonesia and the N. American Western states and possibly increased lightning in the Boreal forest that in turn can create large-scale fires. The changing character of fires has also altered the expected emissions. For example, emissions from fires in 2007 from South America were found to be larger than those in 2010 despite increased burnt area in 2010, likely because of changes in biomass density and combustion efficiency. Across the tropics, emissions in CO are decreasing faster than burnt area, also suggesting that the widespread shift in land-use is resulting in (not unexpectedly) changing fire combustion characteristics. Here we use data from the Terra MOPITT, Aura TES, OCO-2, and MODIS instruments as well as a state-of-the art land/atmosphere/ocean carbon cycle modeling data/model system to quantify emissions of carbon gasses using CO emissions and the range of emission factors up-scaled from vegetation type. We show that at least over the last two decades, until the 2015 El Nino, these changes in land-management practices has a substantial effect on the fire-component of global respiration that is larger in aggregate than environmental variability.

A0.3-0009-18 LEGACY EFFECT OF AMAZONIAN DROUGHT DELAYS THE SEASONAL TRANSITION FROM DRY TO WET

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The long-term drought effect on forest coverage, so-called legacy effect, has been observed in ground and remote sensing measurements. Drought and forest loss may amplify each other through vegetation-atmosphere feedbacks. In this study, we investigated the impact of the reduced growth of southern Amazonian forest from the 2005 drought on dry-to-wet season transition and its variations in 2005 and 2006. We quantified the precipitation changes by using the Tropical Rainfall Measuring Mission (TRMM), which showed postponed wet season onset (WSO) for both 2005 and 2006 compared to the WSO in 2007. We further investigate the mechanism of vegetation-atmosphere feedbacks with data-constrained evapotranspiration (ET) and HDO/H2O observations from the Tropospheric Emission Spectrometer (TES). Our results show that postponed WSO is associated with the ET reduction over southern Amazonia, and the reduction of ET and its delaying effect on dry-wet season transition is further confirmed with TES HDO/H2O measurements. We also quantified the vegetation-atmosphere feedbacks with the Community Atmosphere Model version 5 (CAM5) with a control and a sensitivity experiments. The ensemble CAM5 simulations show that the WSO in southern Amazonian forest was delayed by 10 days in 2006 with drought induced leaf carbon pool reduction. Overall, this study demonstrates that the postponed WSO is triggered by the reduction of ET but amplified by change of large-scale circulation.

A0.3-0010-18 CONSTRAINING THE TERRESTRIAL CARBON CYCLE THROUGH ASSIMILATION OF EARTH OBSERVATION DATA INTO A MODEL OF THE TERRESTRIAL CARBON CYCLE

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CO2 is the most important anthropogenic greenhouse gas contributing to about half of the total anthropogenic change in the Earth's radiation budget. About half of the anthropogenic CO2 emissions stay in the atmosphere, the remainder is taken up by land and oceans. In the context of climate change it is of paramount importance to understand CO2 sources and sinks and their spatio-temporal distribution. This information is needed to improve the projections of future trends in carbon sinks and sources, and thus the potential magnitude of climate change. However, there are large uncertainties in the quantification of the terrestrial carbon sinks arising mainly from uncertainties in the underlying models used for the quantification of these sinks. A major source for these model uncertainties are uncertainties in their parameterisations and parameter values. Reducing these uncertainties is critical for reducing the spread in simulations of the global carbon cycle, and hence in climate change projections. The Carbon Cycle Data Assimilation System (CCDAS) is a system designed to optimise model process parameters based on the assimilation of multiple data streams. Besides deriving an optimal set of parameters for the underlying process-based terrestrial biosphere model, here the BETHY model, a main feature of CCDAS is its capability of determining posterior parameter uncertainties consistent with the observational uncertainties of the assimilated data. These parameter uncertainties are then propagated onto the target quantities such as the net atmosphere surface exchange flux (NEP). In this presentation, I will report on CCDAS studies that assimilate various Earth Observation data such as, e.g. XCO2, FAPAR, soil moisture, solar induced fluorescence. The assimilation of the various data streams allows to derive net and gross carbon fluxes (NEP and GPP) including uncertainty ranges consistent with the observational uncertainties.

A0.3-0011-18 HYPERSPECTRAL REMOTE SENSING OF FIRE: STATE-OF-THE-ART AND PERSPECTIVES

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Fire is a widespread Earth system process with important carbon and climate feedbacks. Multispectral remote sensing has enabled mapping of global spatiotemporal patterns of fire and fire effects, which has significantly improved our understanding of interactions between ecosystems, climate, humans and fire. With several upcoming spaceborne hyperspectral missions like the Environmental Mapping And Analysis Program (EnMAP), the Hyperspectral Infrared Imager (HyspIRI) and the Precursore Iperspettrale Della Missione Applicativa (PRISMA), we provide a review of the state-of-the-art and perspectives of hyperspectral remote sensing of fire. Hyperspectral remote sensing leverages information in many (often more than 100) narrow (smaller than 20 nm) spectrally contiguous bands, in contrast to multispectral remote sensing of few (up to 15) non-contiguous wider (greater than 20 nm) bands. To date, hyperspectral fire applications have primarily used airborne data in the visible to short-wave infrared region (VSWIR, 0.4 to 2.5 μm). This has resulted in detailed and accurate discrimination and quantification of fuels, fire temperatures and emissions, fire severity and vegetation recovery. Many of these applications use processing techniques that take advantage of the high spectral dimensionality such as advanced spectral mixture analysis. So far, hyperspectral VSWIR fire applications are based on a limited number of airborne acquisitions, yet techniques will approach maturity for larger scale application when spaceborne imagery becomes available. Recent innovations in airborne hyperspectral thermal (8 to 12 μm) remote sensing show potential to improve retrievals of temperature and emissions from active fires, yet these applications need more investigation over more fires to verify consistency over space and time, and overcome sensor saturation issues. Furthermore, hyperspectral information and structural data from for example light detection and ranging sensors are highly complementary. Their combined use has demonstrated advantages for fuel mapping, yet its potential for post-fire severity and combustion retrievals remains largely unexplored.

A0.3-0012-18 DEVELOPING METHODS FOR ESTIMATING THE ANTHROPOGENIC CARBON DIOXIDE AND METHANE EMISSIONS BASED ON GOSAT AND OCO-2 SATELLITE OBSERVATIONS

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We apply a statistical method of comparing anomalies in global atmospheric CO2 and CH4 (2009-2014) fields due to anthropogenic activities, using GOSAT observations of column-averaged dry air mole fractions (XCO2 and XCH4) with simulations by Lagrangian transport model FLEXPART. The CO2 and CH4 concentration enhancements due to anthropogenic activities, are estimated with the transport model for GOSAT observations using high-resolution emission inventories (ODIAC and EDGAR respectively). To account for strong vegetation signal we add biospheric CO2 fluxes simulated with VISIT model at 0.1° resolution. Based on these simulated values, anthropogenic greenhouse gas abundance is calculated using GOSAT observations as anomalies from clean background observations. These anomalies are binned and analysed for continental scale regions and countries. For CO2, we have found linear relationships between model and observed anomalies especially for the globe, Eurasia and North America. The analysis for East Asian region showed systematically higher observed enhancements (around 15%) that is comparable in magnitude to the reported uncertainties in emission inventories in that region. In the case of CH4, we found a good match between inventory-based estimates and GOSAT observations for continental regions. The inventory-based estimate over North American region is biased upward (around 35%) which is in qualitative agreement with recent reports. The results indicate the potential utility of GOSAT observations in monitoring reported anthropogenic emissions over different regions of varying spatial scales.

We use the same kind of high resolution transport modeling for the analysis of the CO2 emission signatures in the total column XCO2 data observed by OCO-2 satellite in 2014-2016. To reduce computational load, the OCO-2 observations are aggregated into 1 second averages prepared separately for two groups (left and right) made of simultaneously measured eight OCO-2 observations (footprints). Each group has surface footprint size of approximately 0.1°x0.1°. Same as for GOSAT, with OCO-2 data we have found linear relations between model and observed anomalies. Enhancements observed by OCO-2 match the simulated ones with a regression slope close to unity for global domain. Even after aggregation of OCO-2 data the number of enhanced XCO2 observations by OCO-2 is larger than that of GOSAT more than 15 times for same time period. The result confirms high potential of using OCO-2 observations for analyzing anthropogenic emission signatures. To fully exploit OCO-2 capability of observing narrow CO2 plumes emitted by individual power plants we prepare high resolution (1 arc min) global simulation of the CO2 transport with emissions based on ODIAC gridded emission inventory (30″ resolution) by applying a forward Lagrangian modeling approach. Preliminary results for 2015 demonstrate good correlation of the forward simulations with XCO2 enhancements observed by OCO-2 in dormant season, when correction for vegetation fluxes is not critical.

To extend the methane emission analysis made with GOSAT data we apply global highresolution methane flux inversion based on the Lagrangian-Eulerian coupled tracer transport model, aiming at estimating global methane emissions using atmospheric methane data collected at global in-situ network, which is archived at WDCGG, and GOSAT satellite observation. For better accounting for anthropogenic emissions, localized around in large cities, we use the Lagrangian particle dispersion model FLEXPART to model local tracer transport at 0.1° spatial resolution. FLEXPART is coupled to a global atmospheric tracer transport model

(NIES-TM). The adjoint of the coupled transport model is used in an iterative optimization procedure. High-resolution prior fluxes were prepared for anthropogenic emissions (EDGAR), biomass burning (GFAS), and wetlands (VISIT). High resolution wetland emission dataset was constructed using a 0.5° monthly emission data simulated by VISIT model and wetland area fraction map by Global Lake and Wetlands Database (GLWD). Inverse model optimizes corrections to two categories of fluxes: anthropogenic

and natural (wetlands). Biweekly methane emissions at high spatial resolution are estimated for the period of 2009 to 2012. The inverse model provides optimized fit to the ground-based observations around the globe. Notably, the coupled transport model manages to better reproduce the ground based continuous observations in midand high latitudes in winter, due to resolving both anthropogenic emission plumes and near-surface transport in the shallow boundary layer. Forward simulation with surface fluxes optimized by assimilating ground-based observations is used for reducing mismatch with GOSAT Level 2 XCH4 data. The monthly mean difference between GOSAT data and optimized forward simulation estimated for each 10x10° latitude-longitude box is subtracted from

GOSAT data before including the GOSAT data in inversion. The inverse modeling using combined ground-based and GOSAT data show the bias correction scheme is successful in retaining good fit to the ground-based observations. The suggested correction removes large scale biases in GOSAT data with respect to model simulation, while retaining local scale variability that contains most information on anthropogenic emissions, so it favors information on localized high emissions of anthropogenic origin over large scale atmospheric signals from natural fluxes.

A0.3-0013-18 RESPONSE OF ATMOSPHERIC CARBON-DI-OXIDE AT DIFFERENT GEOGRAPHICAL LOCATIONS OVER THE GLOBE DURING STRONG EL-NINO (2015-2016)

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Carbon-di-Oxide (CO2) is considered to be the most important green-house gas in the Earth's atmosphere. The increase in the concentration is mainly caused by the human activities (anthropogenic) which intensifies the global warming. It has a significant linkage with each of the biogeochemical processes involved in the earth's system. The tropical climate variability consists of two dominant modes El-Nino and La-Nina. In general, El-Nino Southern Oscillation (ENSO) affects the global climate by creating anomalous weather patterns even though it occurs over the Western Pacific. It also affects the global carbon cycle. It is indeed important to understand the relation between El-Nino and CO2. The present study focuses on the variability of CO2 concentration over different geographical locations over the Globe using Total Column Carbon Observatory Network (TCCON) that utilizes Fourier Transform Spectrometers and GLOBAL VIEW CO2 Network that uses flask measurements. In addition observations from OCO-2 and GOSAT are also utilized. The analysis shows that the response of El-Nino on the CO2 concentration is observed to be different over different geographical locations. The details will be presented in the upcoming workshop.

A0.3-0014-18 DETECTING DROUGHT IMPACT ON TERRESTRIAL BIOSPHERE CARBON FLUXES OVER US WITH SATELLITE OBSERVATIONS

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Drought events have significant impact on regional carbon balance and global atmospheric CO2 growth. In this study, we quantified the impact of the 2011 Texas drought and the 2012 Midwest drought on Net Biome Exchange (NBE), and its components including Gross Primary Productivity (GPP), fire, and total ecosystem respiration (TER) using multiple satellite observations. The NBE was constrained by column CO2 (XCO2) observations from the Greenhouse Gases Observing Satellite (GOSAT) using the NASA Carbon Monitoring System Flux (CMS-Flux) carbon cycle data assimilation system, while GPP was estimated with Solar Induced Chlorophyll Fluorescence (SIF) from GOSAT, and biomass burning was computed from CO emissions constrained by Measurements of Pollution in the Troposphere (MOPITT). Total ecosystem respiration (TER) was calculated as a residual term. We found that both drought events greatly increased NBE (i.e., reduced net uptake) due to reduced GPP and increased respiration during the peak, but had quite different sensitivity to temperature and soil moisture anomalies due to different geographic locations. The annual NBE was increased by 0.2 ± 0.10 GtC over the drought region in both 2011 and 2012 droughts, but the dominant drivers were different. The increase of NBE due to the 2011 and 2012 drought impact was 50% and 25% respectively of the regional annual fossil fuel emissions. The results show that natural carbon cycle interannual variability needs to be considered in order to accurately relate carbon mitigation strategies to regional and global CO2 growth rates.

A0.3-0015-18 AN INTRASEASONAL VARIABILITY IN CO2 OVER THE ARCTIC INDUCED BY THE MADDEN-JULIAN OSCILLATION

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Variability of atmospheric CO2 must be well understood for us to better characterize the anthropogenic CO2 release from the surface. A previous study revealed the influence of the Madden-Julian Oscillation (MJO) to tropical midtropospheric CO2 via convection. In this work, the observations by NASA's Atmospheric Infrared Sounder are used to further examine the MJO impact on the CO2 concentration over the Arctic. A composite analysis shows that the CO2 north of 60°N varies with a peak-to-peak amplitude of 1.2 0.2 ppm over the MJO cycle. An empirical correlation analysis is applied to examine possible effects of retrieval bias and dynamics on the MJO-related CO2 anomalies. It is shown that the spatial pattern of the MJO-related Arctic CO2 anomalies closely resembles that of the isentropic potential vorticity anomalies at 475 K.

A0.3-0016-18 IMPACT OF CALIFORNIA WILDFIRES ON ATMOSPHERIC CO2

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The 2017 California wildfires were the largest in the state's history. There were 9000 wildfires, burning 1.2 million acres, destroying more than 10 thousand structures, and killing 46 people. Using NCEP2 Reanalysis data, it is found that the averaged surface temperature in California has increased by 1.7 K during the past 39 years. An increased temperature and recent severe droughts contribute to stronger wildfires. Based on the CO2 retrievals from OCO-2, it is found that atmospheric CO2 increased by 2 ppm after the California wildfires for the first time. Results in this study can help us better understand wildfires and their impact on atmospheric CO2 in the California region.

A0.3-0017-18 INTERACTIONS BETWEEN CARBON DIOXIDE, SOLAR-INDUCED FLUORESCENCE, AND PRECIPITATION

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To better understand the CO2 annual cycle and interaction between the biosphere and the atmosphere, we studied the column CO2 and solar-induced fluorescence (SIF) from Orbiting Carbon Observatory -2 (OCO-2). A negative correlation is found between atmospheric CO2 and SIF. SIF value is high during summer when there is more photosynthesis, which will lead to a low atmospheric CO2. Using precipitation data from TRMM and evaporation data from ECMWF, it is found that SIF can be influenced by the difference of precipitation and evaporation, suggesting there is more CO2 uptake by vegetation when more water is available. Results obtained from this study can help better understand the carbon cycle and the interaction between the biosphere and the atmosphere.

A0.3-0018-18 SPATIOTEMPORAL VARIABILITY OF ATMOSPHERIC CARBON MONOXIDE OVER THE ASIAN REGION AND RELATIONSHIP WITH QBO IN A CHEMISTRY-CLIMATE MODEL AND MACC REANALYSIS

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Carbon monoxide (CO) is one of the major air pollutants in the atmosphere produced due to the anthropogenic activities which cause incomplete fossil fuel (wood, coal and oils) burning emissions. CO plays a major role in the tropospheric oxidative chemistry and affects concentrations of tropospheric ozone and hydroxyl radical (OH) which is a primary sink for many species like CH4. The seasonal concentrations of CO are different across the globe depending on the sources and atmospheric transport through wind circulations. Forest fires, agricultural burning and industrial emissions are the most important sources of carbon monoxide pollution over the Asian region. The uncertainties in the location and drivers of these carbon uptakes, and their interactions with climate systems are the major constrains in the future climate projections. The trace gases such as carbon monoxide can directly affect the carbon cycle process and its interactions with climate systems. In the present analysis we made an attempt to understand the recent changes (spatial and temporal) in the atmospheric carbon monoxide over the Northeast Asian region (the major source region of CO) using chemistry-climate model CHASER (MIROC-ESM) simulations and MACC (Monitoring Atmospheric Composition and Climate) Reanalysis for the period 2003-2012. The CO concentration shows maximum (> 350 ppb) in winter and minimum (<100 ppb) during June to August months over this region. During summer (JJA) and Autumn (SON) seasons another peak region of CO is seen near to the equator over the Southeast Asian region (Singapore and Malaysia) due to the biomass burning. The short-term (10 year) pressure level trends of CO shows negative (-0.03 ppb/mon) at the surface and positive at the Upper Troposphere (UT) and reaches to the maximum near to tropopause level (0.08 ppb/mon) then becomes negative (-0.02 ppb/mon) at the Lower Stratospheric (LS) region. The CO distribution is modulated by stratospheric quasi-biennial oscillations (QBO) with positive and negative CO anomalies in phase coherences with westerly (+4 ppb) and easterly phases (- 4 ppb) of the equatorial lower stratospheric zonal wind. The lower tropospheric CO shows high positive correlation (0.8) with surface ozone implying that its role in the surface ozone (bad ozone) production through oxidative chemistry and negative correlation (-0.6) over the LS regions suggesting that CO is not largely contributing to the stratosphere ozone production processes.

A0.4-0001-18 OBSERVING THE CHANGING ANTHROPOCENE FROM SPACE: SOME RESULTS, CHALLENGES AND NEEDS

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The rapid growth of human population, since the industrial revolution, has been accompanied by a much increased standard of living, the bountiful production of food and a dramatic increase in mobility. The dominant energy source sustaining these developments has been fossil fuel combustion. However, the use of this energy source, coupled with the related growth of the transport and heavy, chemical and agrochemical industries, has resulted in unprecedented air and water pollution. The latter now spans all scales of the Earth System from the local to the global. As a result there have been significant impacts on air quality, water quality, human health, ecosystem services, stratospheric ozone and climate change. The impacts can be sudden and also slowly accumulate over time in the long term. The Earth has entered a new geological epoch, which is called the Anthropocene. Although already beginning at hte neolithic revolution, the impact of man has dramatically increased since the 1950s. This coincided with the birth of the space age, which subsequently led to pioneering efforts to establish an adequate technology to delivers an adequate and evolving Earth Observation measurement capability. Over the past four decades this system has been evolving. Specifically there is a clear need for a space segment, which can separate the impact of anthropogenic activity from that of natural phenomenon. This talk introduces this topic of the use of the space segment to deconvolve the changes from human activity and natural phenomena in the earth system.

A0.4-0002-18 THE MOPITT INSTRUMENT AS A PROTOTYPE FOR LONG-TERM SPACEBASED ATMOSPHERIC MEASUREMENTS IN THE ANTHROPOCENE

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One of the major characteristics of the Anthropocene will be changes in all the Earth systems on many timescales. Changes that occur within a generation will be very significant for policy decisions and these will require measurements on corresponding timescales from space-based instruments, but these times are long compared to traditional satellite lifetimes.

Whether by luck or by good design there are now a number of satellite missions that are recording data over long time periods. With a single instrument, decadal and longer time series of relevant atmospheric parameters have been achieved and the Measurements Of Pollution In The Troposphere (MOPITT) instrument is one such instrument. Launched on 18th December 1999 on the Terra spacecraft, MOPITT has now completed more than 18 years of operation measuring carbon monoxide (CO) over the planet and the mission continues. Given that the Terra spaceacraft is still in good condition, it is entirely possible that these measurements will span more than two decades before completion.

MOPITT therefore offers a case study of a very long single-instrument time series, albeit one with challenges because this longevity was not part of the original design criteria: The original design specified about a five year life and this has already been considerably exceeded. MOPITT does enable us to look at long term trends and intermittent phenomena over the planet for an extended period of time encompassing an entire solar cycle and many cycles of El Niño and other quasi-periodic phenomena. This presentation will consider, with examples, some of the advantages and some of the problems of these long-term space measurements with an eye to the future and the needs of future generations.

MOPITT was provided to NASA's Terra spacecraft by the Canadian Space Agency and was built by COMDEV of Cambridge, Ontario. Data processing is performed by the MOPITT team at the National Center for Atmospheric Research, Boulder, CO. Instrument control is by the MOPITT team at the University of Toronto.

A0.4-0003-18 SATELLITE AND IN SITU OBSERVATIONS OF TRENDS IN TROPOSPHERIC AIR POLLUTANTS: POLICY RELEVANT SCIENCE

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Anthropogenic emissions of gaseous pollutants such as NO2, HCHO, SO2, NH3 and resultant O3 and particulate matter (PM) are associated with substantial adverse impacts on the environment and human health. A recent review (Landrigan et al. it Lancet, 2017) stated "Diseases caused by pollution were responsible for an estimated 9 million premature deaths in 2015 - 16% of all deaths worldwidethree times more deaths than from AIDS, tuberculosis, and malaria combined and 15 times more than from all wars and other forms of violence." Concentrations and emissions of air pollutants have changed substantially over recent decades, but not in uniform ways. North America and Europe have seen substantial improvement in NO2 and the near elimination of SO2 while East Asia has experienced mixed results and South Asia appears to show increases. One untended consequence of acid gas control has been increases in gaseous ammonia. Observations from in situ and satellite-borne sensors can guide numerical models to evaluate the efficacy of control measures and to provide policy relevant science.

A0.4-0004-18 AIR POLLUTION IN EAST ASIA: VIEWS FROM SPACE, GROUND AND MODELS

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Human emissions of pollutants and long-lived greenhouse gases into the atmosphere have caused dramatic transformations of the Earth, altering air quality, climate, the cryosphere, elemental cycles and nearly every ecosystem worldwide. Better understanding the global atmospheric chemistry requires an international network of the observations, and satellite observations from space provide global picture of trace gases and aerosols across geographical boundaries, thus being compliment to the observations from the ground and by other platforms such as aircraft or balloons. Air quality is now one of the most pressing global environmental issues, as the World Health Organization recently stated that air quality is the top environmental cause of premature deaths in the world, in particular, for people living in megacities of the developed countries as well as in developing countries. Here we present some highlights from the past research and its findings on air quality in east Asia, with particular emphasis on tropospheric ozone and its precursors including nitrogen oxides and volatile organic compounds, as revealed by the observations from space (e.g., GOME, SCIAMACHY and OMI satellites) and the groundbased network (e.g., EANET, GAW, and other research-based monitoring), with the aid of state-of-science global or regional chemistry-transport models.

A0.4-0005-18 THE CLIMATE OF THE 21ST CENTURY FROM AN INFRARED PERSPECTIVE: FIFTEEN YEARS OF THE ATMOSPHERIC INFRARED SOUNDER AIRS

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While the early 21st century has seen dramatic changes in climate, it has also been the golden age of satellite observations of the Earth's climate. During this period, climate has been observed from space with revolutionary detail and, in particular, climate change has been monitored in unprecedented ways. Due to its high spectral resolution, hyperspectral infrared observations from space are capable of measuring a multitude of components of the climate system. Since its launch in 2002 (as part of the Aqua mission), the Atmospheric Infrared Sounder (AIRS) has played a key role in weather and climate science by, among other contributions, helping to dramatically improve the accuracy of numerical weather prediction, leading to the discovery of new source regions of atmospheric gravity waves, and monitoring key trends in our climate such as the increase of carbon dioxide. In this presentation, we will discuss some of the most significant aspects of the global climate in the 21st century. We will focus on the dramatic changes that we have been witnessing, from changes in atmospheric composition e.g. greenhouse gases and clouds - to the impact in terms of polar temperatures and extreme weather. At the end of the presentation, we will report on recent efforts to try to guarantee continuity of these essential measurements to monitor our planet's climate.

A0.4-0006-18 EFFECTIVE UTILIZATION OF SATELLITE-BASED AIR POLLUTION DATA AT KILOMETER-CLASS SPATIAL RESOLUTION: INTEGRATION WITH MAXDOAS OBSERVATIONS AND CHEMICAL TRANSPORT MODELS

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Our recent project activity is summarized, aiming to demonstrate effective utilization of satellitebased air pollution data (e.g., NO2) at kilometer (km)-class spatial resolution for robust science and policy on air quality and short-lived climate forcers (SLCF) management. Highlights are on (1) validation and integration of satellite observations with ground-based Multi-Axis Differential Optical Absorption Spectroscopy (MAX-DOAS) observations and (2) sophisticated methodology in emission estimation. More than 100,000 vertical profiles of NO2 were collected from MAX-DOAS network over Russia and Asia (MADRAS, Kanaya et al., ACP 2014) for more than 10 years since 2007 and were used for systematic validation of TropoNO2VCD from OMI (DOMINO v2). For simple cases with very small cloud fraction, presence of aerosol shielding effect was ascertained when tropospheric averaging kernels (AK) were taken into account. We attempted to derive near-ground NO2 concentration map over Tokyo-Yokohama metropolitan area from satellite observations, with recalculated air mass factors based on realistic vertical profiles of NO2 simulated with ADMER-PRO chemical transport model (CTM) at 2-km spatial resolution with correction terms to retain consistency with MAX-DOAS. Full suite of satellite observations of ozone and precursors were assimilated to a global CTM CHASER to derive tropospheric chemistry reanalysis data set (TCR-1 and 2) with optimized emission inventory. Estimation of NOx emission rates from single point sources based on recent satellite observations will also be discussed.

A0.4-0007-18 WHAT WE CAN SAY ABOUT THE ROLES OF NATURAL AND ANTHROPOGENIC AEROSOLS IN CLIMATE CHANGE

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Although particles from natural sources dominate the globally averaged aerosol load, it is widely understood that human activity has added significantly to the atmospheric aerosol inventory in many regions. Anthropogenic contributions include pollution particles from industrial activity, transportation, cook-stoves, and other combustion sources, smoke from agricultural fires and those wildfires that result from land-management practices, soil and mineral dust mobilized in regions where overgrazing, severe tilling, or overuse of surface water resources have occurred, and biogenic particles from vegetation planted and maintained by the populance. The history of human influence is complex - in the 18th and 19th centuries agricultural burning tended to dominate the anthropogenic component in most places, whereas more recently, fossil fuel combustion leads the human contribution is many areas.

However, identifying and quantifying the anthropogenic aerosol component on global scales is a challenging endeavor at present. Most estimates of the anthropogenic component come from aerosol transport models that are initialized with aerosol and precursor-gas source locations, emission strengths, and injection heights. The aerosol is then advected based on meteorological modeling, possibly modified chemically or physically, and removed by parameterized wet or dry deposition processes. Aerosol effects on clouds are also represented in some climate models, but with even greater uncertainty than the direct aerosol effects on Earth's radiation balance. Even for present conditions, aerosol source inventories are deduced from whatever constraints can be found, along with much creativity and many assumptions.

Aerosol amount (i.e., aerosol optical depth) is routinely measured globally from space, but observational constraints on the anthropogenic component require some knowledge of the aerosol type as well, a much more difficult quantity to derive. As large-swath, multi-spectral, singleview instruments such as MODIS can provide some information about fine-mode vs. coarsemode dominated aerosol over dark water, early efforts to constrain aerosol type assumed that some or all the fine-mode fraction is anthropogenic. However, this information is not sufficient to make the key anthropogenic vs. natural distinction in most places where the likely answer is not already known. Instruments providing more detailed measurements, such as multi-spectral, multi-angle and polarimetric imagers and multi-channel lidars, can offer tighter aerosol-type constraints in some circumstances, though generally not enough to specifically identify anthro- pogenic aerosols. The best we seem to be able to do with current data is to combine satellite and suborbital observations with models. And for the "pre-industrial" period, the analogy is usually made to the "natural" component of present-day aerosol, although there are ambiguities in our ability to distinguish natural from anthropogenic particles on regional-to-global scales, and the natural component itself might have changed over time. This talk will review where we stand, and what might be possible to say in the future.

A0.4-0008-18 IASI SATELLITE OBSERVATION OF POLLUTANTS: BEST OF 2017-2018

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IASI LATMOS & ULB

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The IASI family of instruments has been sounding the atmosphere since 2006 onboard the Metop satellite series. Using the radiance data recorded in the thermal infrared spectral range, concentrations for atmospheric pollutants such as carbon monoxide (CO), ozone (O3), sulfur dioxide (SO2) and ammonia (NH3) can be derived. IASI CO and O3 fields are currently assimilated in regional and global models in order to predict air quality over Europe; SO2 alerts are delivered when exceptional levels are encountered, and NH3 source hotspots are tracked throughout the globe.

Near-real time observation of these atmospheric pollutants allow to follow them at city, country and continent scales. This talk will present the findings for 2017-2018, with a focus on fire events, exceptional pollution episodes, and other unexpected features. Progresses to expect with the arrival of IASI on Metop-C and current limitations to derive long term trends will also be discussed.

A0.4-0009-18 LONG-TERM H2O TRENDS IN THE MIDDLE ATMOSPHERE OBSERVED BY SABER ON THE TIMED SATELLITE

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The primary science goal of the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) experiment on the TIMED satellite is to achieve major advances in understanding the structure, energetics, chemistry, and dynamics in the atmospheric region extending from 60 to 180 km altitude. The SABER instrument has been observing the atmosphere nearly continuously since data collection began in January of 2002 using the technique of spectral broadband limb emission radiometry applied in 10 infrared spectral bands ranging from 1.27 to 17 μm. Four CO2 bands - three in the 15 μm region and one in the 4.3 μm band - are used to retrieve temperature and CO2 concentrations and to correct retrievals for spacecraft motion effects. The remaining bands are used to retrieve O3, H2O, [O], [H], energetics parameters, and to observe atmospheric heating and cooling. The measured limb emission profiles are being processed on the ground to provide vertical profiles of these parameters with 2 km altitude resolution. Measurements are made both night and day over the latitude range from 52 degrees to 83 degrees with alternating hemisphere coverage every 60 days. Water vapor is measured over the range from near the tropopause to 80km altitude. This paper provides results of recent research to improve the H2O data product, describes data validation studies and presents long-term trends in H2O over the 16-year period from January 2002 to January 2018.

A0.4-0010-18 NICT PRIORITIES FOR OBSERVING THE ANTHROPOCENE FROM SPACE

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Air pollution causes important risk to health. The aim of NICT project is to provide a robust prediction system of air quality over Japan with km-class spatial resolution using satellitebased air pollution data, such as short-lived climate forcers (SLCF), NO2. The system is assumed to use for health care, health tourism by company and policy makers. Currently, we are developing 1. a forecasting modeling including PM2.5, oxidants (tropospheric ozone), NOx, SOx and so on with multi-modal area systems to realize both highspatial resolution in Japan and wide coverage of Asian/global scales, since significant pollutions are coming from cross-border transport from the continent. 2. Health impact estimation using hospital data and air-quality data. I will introduce overview, target, current status in detail in the presentation.

A0.4-0011-18 NASA LANGLEY RESEARCH CENTER CONTRIBUTIONS TO ADVANCING UNDERSTANDING OF EARTH'S ATMOSPHERIC COMPOSITION

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The Science Directorate at NASA Langley Research Center (LaRC) emphasizes an end-toend approach for small and medium flight and sub-orbital projects where technology development; mission formulation and implementation; calibration and validation activities; and data analyses are carried out with the goal of deriving scientific information from space-based and sub-orbital observations for decision support. This work includes scientific leadership in space-based missions; technology development; laboratory, surface, on-orbit (satellite and ISS) and sub-orbital (research aircraft) measurements; research and analyses projects; atmospheric science data stewardship; applied sciences research in developing decision support tools; and education and outreach activities, all in support of NASA's Science Mission Directorate (SMD). The LaRC Science Directorate strengths include Earth observation, interdisciplinary research, Earth system modeling, data processing systems, and advanced technology development, with an overall focus on atmospheric science, atmospheric composition and climate. The Directorate also provides significant support to the SMD Applied Sciences program, particularly in areas of air quality management, energy forecasting, aviation safety and earth science disaster response. In the context of Observing the Anthropocene from Space this presentation will reviewing the current and future portfolios of on-orbit and sub-orbital missions and research analysis projects in one of our key strength areas, measuring and characterizing atmospheric composition, including descriptions of space-based assets, airborne field campaigns, and small satellite concepts.

A0.4-0012-18 THE 2017-2027 NATIONAL ACADEMIES DECADAL SURVEY FOR EARTH SCIENCE AND APPLICATIONS FROM SPACE: AN OVERVIEW OF THE REPORT

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A pre-publication version of the final report of the 2017-2027 National Academies' decadal survey for Earth Science and Applications from Space ("ESAS 2017") was delivered to its agency sponsors on December 31, 2017; publication of the edited version is expected in Spring 2018. Like the inaugural survey, which published its final report in 2007, ESAS 2017 was requested by NASA, NOAA, and the USGS. The survey's overarching objective was to develop consensus recommendations from the environmental monitoring and Earth science and applications communities for an integrated and sustainable approach to the conduct of the U.S. government's civilian space-based Earth observation programs. The survey co-chairs will review the report's findings and recommendations and discuss its implementation. A PDF of the report is posted at www.nas.edu/esas2017 where details about the survey may also be found.

A0.4-0013-18 SAGE III INSTRUMENT ON THE INTERNATIONAL SPACE STATION

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A much-improved Stratospheric Aerosol and Gas Experiment (SAGE III) instrument was launched on February 19, 2017 from NASA's Kennedy Space Center aboard the SpaceX CRS-10 Dragon Spacecraft. It subsequently docked with the International Space Station (ISS), completed commissioning on July 1, 2017, and is now in its Mission Operations phase. SAGE III-ISS combines the experience and capabilities of its successful predecessor satellite instruments SAM II, SAGE, SAGE II, and SAGE III-Meteor-3M to measure aerosols, clouds, O3, H2O, and NO2 profiles from the upper troposphere through the stratosphere, and in the case of ozone, through the mesosphere. In addition to solar and lunar occultation with vertical resolutions of about 1.0 km, SAGE III-ISS is making limb scattering measurements on the solar side of each orbit greatly expanding the measurement coverage per spacecraft orbit, which ties the very high resolution and precise solar occultation measurements with the limb scattering measurements. The programmable readout array detector enhances its measurement capability and should allow for experimental data products like BrO, and IO, and along with a single photodiode detector, the measurement of larger aerosols. The wavelengths covered by SAGE III-ISS range from 280 to 1050 nm with 1 to 2 nm spectral resolution using a grating spectrometer. The single photodiode extends measurements to 1550 nm. This talk will describe the measurement capabilities of SAGE III, and include data and validation examples for its first year in orbit, its additional modes and increased geographical coverage, its calibration and characterization, and data archival and validation approach.

A0.4-0014-18 OUR CHALLENGE FOR ESTIMATING ANTHROPOGENIC GHG EMISSION FROM DIFFERENT SOURCES USING GOSAT

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Satellite observation is the only method to monitor greenhouse gases distribution globally and frequently. We launched the Greenhouse gases Observing SATellite (GOSAT) in 2009. Decade long data set of carbon dioxide (CO2) and methane (CH4)with the Thermal And Near infrared Sensor for carbon Observation Fourier-Transform Spectrometer (TANSO-FTS) are available. In addition to grid observation points, we are optimizing observation pattern by uploading pointing locations every day to estimate anthropogenic emission from various sources. We will demonstrate methane flux estimation from large point sources using GOSAT and wind speed data. We will also present how to reduce uncertainty and show test results with next generation instruments.

A0.4-0015-18 THE COPERNICUS PROGRAMME AND ITS CLIMATE CHANGE SERVICE (C3S): A EUROPEAN RESPONSE TO CLIMATE CHANGE

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This paper provides an overview of the European Union's flagship Earth Observation Programme, Copernicus, dedicated at monitoring the planet Earth and its environment for the benefit of all European citizens. The Programme offers information services based on satellite Earth observations, in situ (non-space), and modelling data. The paper focuses on one of the six Copernicus Services, the Copernicus Climate Change Service (C3S), which provides comprehensive climate information covering a wide range of components of the Earth-system (atmosphere, land, ocean, sea-ice and carbon), maximising the use of past, current and future earth observations (from in-situ and satellite observing systems) in conjunction with modelling, supercomputing and networking capabilities to produce a consistent, comprehensive and credible description of the past, current and future climate, via the generation of a large number of Essential Climate Variables (ECVs), as well as key generic (CO2 trend, reducing glaciers) or customisable (number of degree days, windstorm statistics, growing seasons, etc.) climate indicators for relevant economic sectors, such as energy, water management, agriculture, insurance, health, etc. The wealth of free and open data that C3S provides, supports users in making informed choices for their business decisions, thus delivering a more energy efficient and climate aware economy. These sound investment decisions now do not only stimulate growth in the short term, but reduce the impact of climate change on the economy and society in the future. Although the C3S portfolio is much broader than Earth Observation based climate information (multi-model seasonal forecasts, climate projections at global and regional level, sectoral impact indicators, etc. are also included in the Service) this paper focuses on monitoring aspect of the Service and in particular the Earth Observation based information. By monitoring a number of key ECVs, C3S ambitions to strongly contribute to the newly published implementation plan of GCOS (Global Climate Observing System). C3S is now becoming operational, the technical infrastructure is being developed and the first industrial activities have been kicked off. Climate monitoring information is routinely produced and available at climate.copernicus.eu, and the ECVs are being generated either via global reanalyses (this is the case for most of the atmospheric variables) or through the production of long term climate data records (CDRs). Although progressively, these CDRs will greatly benefit in the future from the family of Sentinel missions, they currently heavily rely on third party missions from NASA, NOAA, ESA, EUMETSAT and other Space Agencies. The importance of combining satellite, in situ and modelling information to ensure an Earth System approach

to monitoring the Anthropocene and guaranteeing consistency across the main Earth cycles (water, energy, carbon) will also be highlighted in this paper.

A0.4-0016-18 OBSERVING IMPACTS OF HUMANITY ON THE EARTH SYSTEM

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The vantage point of space provides a unique way of studying the Earth in its entirety - both spatially and in terms of its interacting components (atmosphere, ocean, land surface, cryosphere, biosphere, etc.). This space-based perspective, accompanied by complementary measurements from surfaceand ground-based instruments, allows for characterization of both the direct forcings that human civilization imposes on the Earth system and the indirect responses from the Earth system, together with its inherent variability that then create our global environment. The combination of these observations with models that support quantitative hypothesis testing, prediction of future evolution, and preparation of comprehensive data sets for scientific study enhances the value of these observations for study of the present and future Earth. In this talk, recent results of NASA's Earth Science Division's programs (flight, research and analysis, applied sciences, and technology) will be summarized and their significance in helping to observe the Anthropocene will be discussed

A0.4-0017-18 COSPAR CONTRIBUTIONS TO SPACE-BASED OBSERVATIONS FOR GLOBAL INTEGRATED EARTH SYSTEM SCIENCE

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The Committee on Space Research (COSPAR) established in 1958 by the International Science Council (formerly ICSU) commissioned a study group to prepare a roadmap on satellite observations for integrated Earth system science for 2016-2025, as a contribution to the intergovernmental Group on Earth Observations (GEO), which was established in 2005. The roadmap focused on the use of integrated observations and modelling to address the functioning, predictability and projected evolution of the Earth system on timescales out to a century or so to enable enhanced sustainable development. The COSPAR roadmap was published in ASR, 57, n°10, 15 May 2016 and acknowledged with gratitude by the GEO Plenary. COSPAR is a Participating Organization in GEO since 2007 and has contributed notably to its Science and Technology Committee and its Data Sharing Working Group, through the COSPAR Task Group on GEO gathering of about 150 scientists from its Scientific Commission A. COSPAR is a founding member of the GEO Program Board and is actively pursuing the strengthening of the science, technology, and observing systems sustainability and enhancement. Within the GEO Program Board, COSPAR is leading efforts to evaluate the strengths and weaknesses of the global integrated in situ and satellite observing system over the past ten years. The present COSPAR Scientific Assembly program, as it relates to Earth sciences, shows the COSPAR support to the Paris Agreement on Climate Change. COSPAR, as an independent, academic organization, supports the Paris Declaration "Towards a Space Climate Observatory." The Declaration was adopted in December 2017 by senior leaders of over 25 space agencies worldwide (see the April issue of SRT). Without interfering in scientific debates, COSPAR recognizes the strength of the climate diagnostic posed by the Intergovernmental Panel on Climate Change and the high value of the results and recommendations of its sister organizations World Climate Research Program and Global Climate Observing System within the ISC. The space agencies involved in the Committee on Earth Observation Satellites and Coordination Group for Meteorological Satellites are progressing in their strategic analysis of observational needs for the weather-to-climate continuum and other aspects of the global integrated Earth system. COSPAR Scientific Commission A and sub-Commissions A1, A2 and A3 will continue to work through the COSPAR Scientific Assembly and other forums at promoting international collaboration to enhance and sustain space-based observations for improved understanding of global integrated Earth System science.

A0.4-0018-18 CURRENT STATE AND FUTURE NEEDS OF SPACE-BASED MONITORING OF THE EARTH

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Influence of mankind on Earth's climate is evident. The growing population using the resources available, especially by burning goal, oil and gas, changes the composition of the Earth's atmosphere with the result of a continuously increasing temperature. Effects are not limited to the regional scale but are evident on the whole planet, meanwhile named Anthropocene. According to this global influence, it's necessary to also extend monitoring to the entire planet. Space-based observation systems are not limited by any artificial borders and are in principle able, to cover the whole Earth. In principle, two different ways of observation can be selected: Either a dedicated spacecraft will be send into low earth orbit (LEO) or existing platforms are used. Advantages of satellites are the more or less freely selectable orbit (with orbits covering also the polar regions) and the possible adaption of spacecraft platform for the dedicated instrument. On the other hand platforms like the ISS space station enable continuous long term coverage with different instruments. The drawback of an only limited coverage based on the orbit inclination is made up by the possibility to service systems on the station. Furthermore different generations of sensors can be run in parallel and therefore cross calibrated if needed. This paper reviews the currently available sensors types and discusses potential future needs. Included in this discussion is the international space station as an already available platform for earth observation. Furthermore, discussion should also take into account, that an increasing number of constellations with dozens or even thousand satellites are planned. Are these constellations also an option for an increased temporal and spatial monitoring of the Earth?

A0.4-0019-19 ESA'S EARTH OBSERVATION PROGRAMMES IN THE CONTEXT OF SPACE

4.0 AND WITH A VIEW TO THE CHANGING ANTHROPOCENE

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The Earth system behaves as a single, highly coupled system comprising physical, chemical and biological components and processes, on which humanity is having significant effects. There are complex interactions and feedbacks between the Earth system components that cut across disciplinary boundaries of the Earth sciences and take place over a wide range of spatial and temporal scales. Even in the absence of external forcing, the Earth system exhibits considerable natural variability, which needs to be understood and distinguished from human-induced trends.

The societal challenges that humankind faces require a strategic and sustained response also in the view of new Earth Observation techniques such as data analytics and artificial intelligence, as well as the advent of Big Data. This presentation will give an overview of ESA's Earth Observation programmes with its major 'pillars', its relevance to studying the anthropocene and provide a look into the future in the context of Space 4.0.

ESA's Earth observation missions are mainly grouped into three major categories: The operational Sentinel satellites in the context of the European Copernicus Programme, the scientific Earth Explorers and the meteorological missions, which ESA is jointly developing with Eumetsat. Developments, applications and scientific results for the different mission types will be addressed, along with overall trends and strategies.

The Earth Explorers, who form the science and research element of ESA's Living Planet Programme, focus on the atmosphere, biosphere, hydrosphere, cryosphere and Earth's interior. The Earth Explorers also aim at learning more about the interactions between these components and the impact that human activity is having on natural Earth processes.

The Sentinel missions provide accurate, timely, long term and uninterrupted data to provide key information services, improving the way the environment is managed, and helping to mitigate the effects of climate change. The operational Sentinel satellites can also be exploited for scientific studies of the anthropocene. ESA's meteorological programmes include the geostationary (Meteosat) and low-Earth polar orbit Meteorological Operational (MetOp) satellites, both of which have been developed in cooperation with Eumetsat. In the anthropocene human activities affect the whole planet and space is a very efficient means to measure their impact, but for relevant endeavours to be successful they can only be carried out in international cooperation. ESA maintains long-standing partnerships with other space agencies and institutions worldwide. In running its Earth observation programmes, ESA responds to societal needs and challenges and to requirements resulting from political priorities set by decision makers. Activities related to Climate Change are a prime example. Within ESA's Climate Change Initiative, Essential Climate Variables are constantly monitored to create a long-term record of key geophysical parameters.

A0.4-0020-18 A ROUND TABLE DISCUSSION WITH AKIHIKO KUZE (JAXA) JEAN-NOEL THERAPAUT (EU COPERNICUS) JACK KAYE (NASA) JEAN-LOUIS FELLOUS (COSPAR) HANSJOERG DITTUS (DLR) JOSEF ASHCBACHER/ MICHAEL RAST PRESENTING (ESA)

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A round table discussion with Akihiko Kuze (JAXA) Jean-Noel Therapaut (EU Copernicus) Jack Kaye (NASA) Jean-Louis Fellous (COSPAR) Hansjoerg Dittus (DLR) Josef Ashcbacher/ Michael Rast presenting (ESA) with John Burrows and David Halpern, Christian von Savigny and Ralph Kahn as moderators

SPACE STUDIES OF THE EARTH'S SURFACE, METEOROLOGY AND CLIMATE (A)

USING QUANTIFIED OBJECTIVES FOR PRIORITIZING GLOBAL ENVIRONMENTAL CHANGE MEASUREMENTS (A0.5)

A0.5-0001-18 EVIDENCE OF CLIMATE CHANGE: MASS AND ENERGY BALANCE IN NARADU GLACIER BASIN, WESTERN HIMALAYA, INDIA

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Glacier mass balance is treated as the proxy for understanding the impact of changing climate hence it is one of the essential variables required for climate system monitoring. The study represents the six years of annual mass balance using most accurate glaciological measurements on the Naradu glacier, western Himalaya. To support this result an energy balance model based on meteorological parameters like air temperature, wind speed, net radiation etc. have been used to compute mass balance. This study also finds the robustness of the energy balance model over the glaciological method. The glaciological mass balance for 2011-17 has shown a continuous negative specific balance of -1.09, -1.15, -0.86, -0.79, -0.72 and -0.41 meter water equivalent (m w.e.) during respective years of 2011-2017 showing decrease in the negativity of mass loss. The calculation of energy balance also shows the negative mass balance of -1.36, -0.92, -0.79 and -0.68 m w.e. for the year 2012-13, 2013-14, 2015-16 and 2016-17 respectively showing the reducing trend of mass loss. The mass balance deduced by energy balance model is very closely in agreement with the glaciological mass balance. The continuous negative mass balance in the region is reflecting the influence of the weather parameters especially the high net radiation along with the increasing temperature in the region are the major controlling factors for glacier mass balance.
Key words: Climate change, Mass balance, Energy Balance, Western Himalaya, increasing temperature and Naradu Glacier

A0.5-0002-18 CLIMATE CHANGE AND ITS IMPACT IN WESTERN HIMALAYA (NARADU VALLEY)

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Present study uses MERRA data to analyse the trend of temperature and snowfall for the period of 1979/80 to 2012/13 in Naradu Valley, western Himalaya. An attempt has also been made to find the snowline by establishing a multiple regression equation by taking annual temperature and precipitation and corresponding snowline of few years into consideration. Long-term trend direction and magnitude of change over time (annual and seasonal) were detected and analyzed by Mann-Kendall test, Spearman Rank Correlation, Sen's slope estimator and Sequential MannKendall (SQMK) test. Temperature trend analysis shows the rise of 0.9 C whereas snowfall trend analysis shows decrease of 112.03 cm and the estimated annual snowline shows an increase of 75.65 m for study period. All statistical tests show significant increase in annual temperature and snowline data whereas significant decreasing trend was found in annual snowfall data. SQMK test shows that 1997/98 is the beginning of the change point for temperature and snowline whereas this test fails to deduct any beginning of the change point in case of snowfall.

Key Words: Climate Change, Temperature Trend, Precipitation Trend, Snowline Trend and Western Himalaya

A0.5-0003-18 RESPONSE OF HIMALAYAN GLACIERS TO CLIMATE CHANGE

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Climate change is a natural phenomenon, but the rate at which it is happening is completely unprecedented. This accelerated rate has been attributed to anthropogenic sources like fossil fuel burning, industrial activities, wildfires as a part of land management etc. To monitor the effect of climate change on the natural resources, glaciers form one of the best models of study owing to their sensitivity towards changing climate. Although the glaciers constitute only 1% of the supply to the freshwater system, they are one of the major contributors to the sea-level rise today. Further, Indian Himalayas have been established to have a major contribution when this cryosphere component (Mountain glaciers) is taken into consideration. For understanding the effect of climate change, long-term glacier studies i.e. continuous monitoring is required. However, the rugged terrain and steep slopes render it impossible to carry out ground-based surveys at regular intervals especially in the Himalayan terrains. Remote sensing has the advantage of providing a synoptic coverage on a multi-temporal scale. Apart from long-term monitoring, there is a need for prediction of future scenarios as well. With the help of climate modeling, the dynamics of the glaciers can be simulated in real-time. But, for modeling the future scenarios of the glacier dynamics, certain specific parameters of the glacier are required. For example, terrain slope, thickness change, mass balance, and local temperature and precipitation conditions. With the advent of high spatial resolution dataset both in optical (ALOS AVNIR and Sentinel: 10m) and microwave (TerraSAR-X/TanDEM-X: 7m), most of these above-mentioned parameters can be well estimated, which can act as an input for the developed climate models. In this paper, we present a time-series analysis of glacier attributes such as elevation change and mass balance with a level of accuracy comparable to ground measurements. This shows the applicability of the remotely sensed data as a useful alternate even for the highly steep topography of the Himalayas. Hence, this study would facilitate studies for assessing the contribution of the Indian Himalayas towards the melt-water for the early twenty-first century and eventually help quantify the sea-level rise at a global scale.

A0.5-0004-18 ASSESSING WATERCOURSE REHABILITATION PROGRAMS IN SINDH USING GEOSPATIAL TECHNIQUES

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Indus Basin Irrigation System (IBIS), the largest contiguous irrigation system of the world, loses around 41 percent of its total water derived from the river through seepage and leaks. About 40 percent of this loss is through the tertiary channels called watercourses. To encounter this problem, the irrigation system rehabilitation programs in Pakistan, including National Program for Improvement of Watercourses (NPIW) and Sindh On-Farm Water Management Project (SOFWMP), were initiated focusing on improvement of canal system at the watercourse level. Under these programs more than two third of the total watercourses have been improved in the province of Sindh. In this paper, a study is presented that evaluated the effectiveness of these programs in Sindh. Changes in the cultivable command areas before and after the improvement work and the availability of water at the tail end have been selected as the efficiency indicators of the improved watercourses in Larkana, Mirpurkhas, Khairpur and Thatta districts. Relevant data were acquired from National Program for Improvement of Watercourses (NPIW), Pakistan Space and Upper Atmospheric Research Commission (SUPARCO) and Sindh irrigation department. Google Earth archive images of 2004 and 3013 were utilized to identify the changes in the cultivable command areas of the watercourses. A recognizable expansion in the cultivable lands in the command areas of the improved watercourses was identified. Study results were validated from field survey in which farmers' point of view regarding the effectiveness of the improvement programs were recorded. Majority of the farmers and landowners were found satisfied with the improvement work and confirmed the availability of water at the tail end. They also endorsed the study results in terms of increased cultivable command areas.

A0.5-0005-18 APPLICATION OF SATELLITE REMOTE SENSING TO OBSERVE AND ANALYSE TEMPORAL CHANGES OF COCOA PLANTATION IN ONDO STATE, NIGERIA.

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This study examined the changes in the area of land occupied by cocoa plantation in Ondo state in order to provide useful and adequate information for effective agricultural policy to increase cocoa yield as the leading export agricultural commodity in Nigeria. Satellite remote sensing technique was employed using satellite imagery of year 2000, 2002, 2014 and 2015 respectively acquired from Landsat-7 ETM+ and Landsat-8 TIRS. The land cover of the study area was classified into six classes of cocoa plantation, forest, light forest and grassland, water body, bare surface and rock outcrop as well as settlement area. The result revealed that cocoa plantation occupied 31.3% in 2000, 32.7% in 2002, 41.4% in 2014 and 41.6% in 2015 respectively which depicts gradual increased in the area of land covered by cocoa plantation and its yield at the expense of other land cover classes which prove the potency of this tree crop of generating huge amount of foreign earning for supplementing revenue derived from crude oil in Nigeria. Key words: cocoa plantation, satellite imagery, land cover classes, change in area of land.

A0.5-0006-18 IMPACT OF LOWER TROPOSPHERIC STABILITY ON THE REGIONAL VARIABILITY OF INDIAN SUMMER MONSOON RAINFALL

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Asian summer monsoon that mainly affects India and its surrounding regions during June to September and that contribute more than 75% of the annual total rainfall. It exhibits large variability on temporal scale ranging from diurnal to multidecadal. In addition to the temporal fluctuations, rainfall exhibits spatial fluctuations manifesting the higher amount of rainfall in the west coastal belts and northeast regions of India and less amount of rainfall in the northwest and southeast regions. These variabilities are influenced by many factors from topography to oceanic and atmospheric factors including teleconnections. So studying the variability of summer monsoon rainfall especially in regional scale is very important and useful to the Indian society and thus to the economy. This paper mainly aims to explore the regional variability of Indian summer monsoon rainfall especially over west coast, north east, north west and central India for the period 1948-2016, by identifying its relationship with the lower tropospheric stability (LTS) and moisture flux over the monsoon domain. LTS and moisture flux are calculated using wind, potential temperature, humidity at different atmospheric levels form NCEP/NCAR reanalysis data set during the period 1948 to 2016. The variations in LTS have a major impact on cloud fraction and thus the summer monsoon rainfall. The moisture flux is a measure of amount of water in the atmosphere to precipitate and hence that can be correlated for different regions to explore the ideal relationship with rainfall. We used CRU rainfall data for the same period to evaluate the variability during the summer monsoon season. We found that the linkage between the LTS and rainfall is nonlinear in space and time. The LTS is negatively correlated with rainfall over Western Ghats, however, positive correlation is observed with rainfall in other Indian regions. Therefore, it can be concluded that relation between lower atmospheric stability with monsoon rainfall and moisture flux during the monsoon period is different over different regions with different influencing mechanisms.

A0.5-0007-18 POLLUTION PLUMES TRANSPORTED FROM EASTERN GHAT AND INDOGANGETIC PLAIN AFFECTING MARINE AIR QUALITY OVER SUNDARBAN AT THE NORTH-EAST COAST OF BAY OF BENGAL

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A study was conducted on the interaction between the marine and the anthropogenic aerosols over remote and pristine Sundarban mangrove forest at the north-east coast of Bay of Bengal. Size segregated aerosols were collected using a nine stage cascade impactor over Sundarban mangrove forest during winter, 2014 and premonsoon, 2015 and 2016. Collected samples were chemically analyzed for major water soluble ionic spices using Ion Chromatograph. The degree of interaction was quantified through the chloride depletion from sea-salt particles originated from the Bay of Bengal It was observed that the chloride depletion occurred mostly in ultra fine (UFP, Dp < 0.4 μm), accumulation (AP, 0.4<Dp<1.1 μm) and super fine (SFP, aerodynamic diameter, Dp, 1.1<Dp<2.1 μm) mode compared to the coarse mode (CMP, 2.1<Da<10 μm) particles. Satellite observation revealed the presence of elevated smoke, polluted dust and marine aerosol over the region during pre-monsoon. Air mass back trajectories have shown the influence of biomass burning plumes transported from Eastern Ghat regions on the size distribution of aerosols during premonsoon. High loading of non-sea-SO42- and NO3- was observed over this marine ecosystem with their significant contributions to the depletion of chloride from sea-salt particles. In addition to the transported biomass burning plumes from Eastern Ghat, anthropogenic aerosols were also found to be highly loaded over the region transported from the highly polluted Indo-Gangetic Plain (IGP) during winter. Overall we observed that pollution plumes from Eastern Ghat regions and the Indo Gangetic Plain regions significantly affected the pristine marine ecosystem.

A0.5-0008-18 METHODOLOGY OF PROCESSING SATELLITE IMAGERY TO IDENTIFY OIL-DERIVED WATER POLLUTANTS

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Publication presents determination of optimal methods for processing satellite imagery to provide information on marine oil derivative pollutants. As a part of the research, a series of operations were conducted to extract thematic information about the oil spill. Starting from techniques that improve the visual properties of the interpretation and ending with semi-automatic techniques or automatic extraction of thematic information.

The comparative analysis of the methods used was directed both at the effectiveness and speed of their execution. Multispectral data recorded by the ETM + sensor was used for the purposes of the research. Processes were conducted to enhance the content of individual images as well as the full set of channels. Information about the oil spill was extracted on the basis of acquired imagery. The result of the research is the selection of optimal Landsat 7 satellite spectral channels for detecting crude oil in the marine environment and the selection of the best digital image processing methods to extract leak information from the image. The information obtained, allowed to determine the location of oil spots, and also confirmed the usefulness of Landsat images recorded in SLC-off mode for performing such analyzes.

A0.5-0009-18 NOVEL METHOD OF SATELLITE IMAGE CORRECTION FOR MULTI-TEMPORAL ANALYSIS OF ENVIRONMENTAL CHANGES PURPOSES

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Multi-temporal, long-term environmental analyzes require imagery that are diverse in terms of spatial, radiometric and spectral resolution. Satellite imagery acquired with various sensors over more than 30 years are usually used for such analysis. To carry out analyzes it is necessary to perform the correction of archival images. The classical radiometric correction (including solar, topographic and atmospheric correction) is not sufficient for correct analysis of such data set. The classic radiometric correlation is only the initial stage of the total correction of the set. In order for the results of multi-temporal analyzes to be reliable and more precise, it is necessary to bring the data to the same spatial, spectral and radiometric resolutions.

Resampling the spatial resolution in the context of multi-temporal analyzes of the environment is not the only process. Except that also the extraction of characteristic details to further analysis mandatory. The publication presents a new method of image resampling based on wavelet analysis. Resampling will standardize the resolution of the spatial set. In addition, spectral image resolution also plays an important role in the detection of environmental changes. It is crucial that the subsequent images have a similar spectral resolution. A new spectral resolution correction algorithm based on sequential fusion of images acquired in subsequent dates was proposed, where the resulting images are a weighted average of the data to be integrated. The weights depend on the content of spatial and spectral information in the processed images. As part of the research experiment, new corrected spectral channels of images were determined, the same for all images in a given integration sequence. The similarity of corrected images to original images is over 60%, which guarantees that important spectral information recorded in each subsequent image is preserved.

A0.5-0010-18 MONITORING OF CHANGES OF THE SHORELINE OF GLACIERS AND CONTINENTAL ICE SHEETS BASED ON ARCHIVAL AND MODERN OPEN SOURCE SATELLITE IMAGERY

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In the study of environmental changes, the continuous monitoring of land changes in the glacier is now a very important aspect. The use of correct archival data from the first remote sensing satellites is a key issue in the study of global environmental changes. Archival satellite data, in a sense, stand out from the modern images. The necessity to do the temporal analyzes based on these images and, consequently, the development of the shoreline of glaciers and ice sheets is only a seemingly simple task. When we want to achieve high accuracy, we need to apply the appropriate methods of image processing. Due to the low resolution of the open source satellite scene, an algorithm based on wavelet analysis for extracting shoreline details was proposed in the publication. This approach will enable accurate determination of changes in the coastline, which occurred over 30 years.

Because the shelf of ice shelf is getting smaller, the glacier that supports inland can slip off into the ocean faster and thus lose mass faster than it gains. This situation is referred to as the “negative mass balance” and it leads directly to the sea level rise. It is estimated that shelf glaciers are the most important factor affecting the stability of the Antarctic ice sheet. Therefore, thanks to the developed method, it will be possible to conducts detailed analysis and documentation of the changing coastline of glaciers, and this will enable research into the change of glaciers and oceans, which is of great importance to the modern world.

A0.5-0011-18 ANALYSIS OF THE POSSIBILITY OF USING POINT CLOUDS GENERATED ON THE BASIS OF ARCHIVAL SATELLITE IMAGERY IN ENVIRONMENTAL ANALYZES

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The paper presents an innovative method of a dense image matching of archival satellite imagery for the purposes of generating accurate point clouds representing Digital Surface Models (DSMs) of the Earth surface. On the basis of these point clouds advanced analyzes of environmental changes (eg. icebergs, glaciers, etc.) will be conducted. This approach will allow the development of accurate models of icebergs resulting from the division of the glacier and a comparison of this changes over time. For the ocean areas, no stereo images were ever acquired, but only this support 3D models production. We propose a novel algorithm that will allow to get a dense point cloud of a glaciers based on the Structure from Motion (SfM) algorithms. By using selected image matching descriptors, it will be possible to create the 3D surface geometry from archival satellite imagery. The proposed method will be effective also when satellite scenes will be acquired at different time. The article presents a new approach in obtaining 3D information based on dense image matching (DIM) in application to archival satellite imagery. Our method will be based on SIFT and SURF descriptors and the RANSAC algorithm. In the proposed solution, in each iteration RANSAC randomly selects several matched pairs of points to obtain the best matched transformation matrix. In the case when selected pairs of points are compatible with the matrix, they are treated as correctly matched. After many iterations, the transformation has the largest number of valid matches, which are treated as the final result of the algorithm. The proposed algorithm will allow to increase the accuracy of the accuracy of whole point clouds and 3D models developed on their basis. As a result of the experiment, based on the proposed algorithm, several DSMs were developed based on archival satellite imagery of Landsat. The comparative analyzes were carried out. The results of the experiment showed that the predicted accuracy of the models was 1-2 pixels of source images. Thanks to this approach, 30 years glaciers and icebergs can be analyzed now. It will also be possible to determine exactly how much glaciers have been melted with accuracy of a few meters (depending on the original spatial resolution of archival satellite imagery).

A0.5-0012-18 ESA'S SCIENCE DATA EXPLOITATION PROGRAMME

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This paper will present the main opportunities and plans offered by ESA to the scientific community in the timeframe 2017-2021, where the scientific exploitation of the Sentinels represents a priority.

The Scientific Data Exploitation element represents the main instrument for scientific innovation of ESA exploitation activities, addressing the RD needs and requirements of the EO and Earth system science communities in terms of novel observations, advanced scientific tools, innovative retrieval methods and products and new Earth system science results.

The programme will be articulated through five main action lines:

Engaging International Science Communities ESA's structured dialogue with international EO science communities will be strengthened through regular series of dedicated conferences, thematic workshops and user consultations. EO scientists, Earth system scientists, and modellers will be brought to together in a continuous exchange of ideas. As a result various multidisciplinary expert communities will periodically assess the state-of-art in their fields and prepare research roadmaps jointly with relevant international scientific programmes, recommending priority topics for future ESA projects and work plans.

Developing Open Science Practices and Tools Open source science practices will be developed to enlarge the user base for European Earth Observation and broaden participation. EO data, information and tools will be made readily accessible to scientists from other fields. Open source scientific toolboxes will be developed to animate science communities, capitalising on various ESA multi-mission toolboxes experiences and assets. Citizen science and crowd-sourcing projects will be launched, as appropriate. On-line courses, science blogs and social media will address the general public. The EO applications platforms will be developed for these purposes.

Advancing EO Methods and Techniques Targeted research projects will develop cutting-edge methods, novel algorithms, new EO products, and extend the use of Earth Explorers into domains beyond their primary mission objectives. The overall aim is to stimulate widespread scientific use of open data from research and operational missions by pioneering the development of new EO methods to harvest the full scientific potential of these missions. When validated, such new techniques will be made available to other research communities and programmes, and new prototype products will be transferred to operational frameworks and systems.

Advancing Earth System Science The specific goal is to maximize the scientific impact of ESA and European missions in terms of new discoveries in Earth system science and thereby ensure a major ESA contribution to global Earth Science endeavours. Dedicated projects will research priority questions posed by international Earth System Science communities and will explore new research avenues opened up by the ESA EO science strategy. These activities will strengthen and extend ESA's cooperation with the major international global research programmes.

Translating Exploitation into Novel Mission Concepts The role of exploitation results as a catalyst for novel mission concepts and future observational principles will be reinforced. Projects will explore, develop, and consolidate the scientific aspects of novel mission concepts, and thereby stimulate ideas for future generation EO missions.

A0.5-0013-18 CLOUD CHARACTERISTICS OVER TIBETAN PLATEAU REVEALED BY CLOUDSAT AND GROUND-BASED W/KA CLOUD RADAR

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Tibetan Plateau plays important role to local, eastern Asia and even global climate. To understand its function of dynamics, radiation and heat flux, water cycle, and surface emissions transpart via long range horizontal and terrian induced/convective transport from earth surface to the stratosphere, its is needed to investigate the cloud structure and their temporal and spatial distribution over the Tibet and surrounding area. Satellite observation, in particular Cloudsat, TRMM, and GPM have supplied systimatic products of cloud parameter for the Tibeten plateau and surrounding areas, including cloud vertical structure, macro and micro physical characteristics. Since 2018, a ground-based W/Ka cloud radar system with Doppler ability and dual-polarization has been deployed and started continuous observation at Yangbajing field observatory, a site near Lhasa with 4300 m ASL. In this paper we will analyze the satellite products combined with our surface-based radar observation and thus reveal the cloud characteristics over Tibet plateau, including regional, seasonal and diurnal variation. The function of clouds over Tibet will be analyzed.

SPACE STUDIES OF THE EARTH'S SURFACE, METEOROLOGY AND CLIMATE (A)

SPACE-BASED AND SUB-ORBITAL OBSERVATIONS OF ATMOSPHERIC PHYSICS AND CHEMISTRY (A1.1)

A1.1-0001-18 LONG TERM SURFACE TEMPERATURE CHANGES OVER INDIAN REGION AND SOLAR VARIABILITY

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Variations of solar energetic electromagnetic and charged particle radiations are known to be correlated with the 11-year solar cycle of sunspot numbers. However, except for a specific period between 1645 and 1715 when the solar activity was very low (Maunder Minimum) associated with severely cold winter seasons also known as 'little ice age', the overall climate system of the earth does not show any statistically significant response to variations in solar activity. This paper deals mainly with a detailed investigation of possible correlation with long term surface-air temperatures. The grid point temperature data for 1970-2009 over the Indian region has been analysed along with solar activity parameters such as sunspot numbers, galactic cosmic ray fluxes (GCR) and El Nino Southern Oscillation (ENSO) indices. A better correlation of 0.21 has been seen between long term temperature change and GCR fluxes. The change in annual temperatures for the 40 year period is found to be about 0.5 °C over the whole Indian region with considerable latitudinal variation of ±0.2 °C with latitudes higher than 20° N showing greater warming signals. The mean annual temperature curve for the whole period shows higher frequency temperature excursions of ± 0.5 °C that are quite regular and present in all latitude regions with good coherence. These relatively short-period temperature variations need to be studied further for a better assessment of the warming due to climate change.

A1.1-0002-18 DETECTION OF SOLAR CYCLE SIGNAL IN THE TROPOSPHERIC TEMPERATURE USING COSMIC DATA

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Influence of the solar cycle on temperature structure is being investigated using radio occultation measurements by COSMIC/FORMASAT-3. Observations from January 2007 to December 2015 comprising of 37,64,728 numbers of occultations, which are uniformly spread over land and sea, have been used to study temperature changes mainly in the troposphere along with the solar cycle over 60°N - 60°S geographic latitudes. It was challenging to identify the height level at which the solar cycle signal can be seen in temperature perturbation as different atmospheric processes contributes towards temperature variability. Using high spatial resolution data set from COSMIC satellite we are able to detect signal of solar cycle in the mean temperature profiles near surface at 2 km and upward. A consistent rise in the inter-annual variation of temperature is observed along with solar cycle. The change in the temperature structure showed a latitudinal variation from southern to northern hemisphere over a period of 2007-2015 with a significant positive influence of sun spot numbers in the solar cycle. It is concluded that solar cycle induces the changes in temperature by as much as 1.5°C. However, signal of solar cycle in the stratospheric region could not be identified as the region is dominated by large scale dynamical motions like QBO which suppress the influence of solar signal in temperature perturbations due to its quasi-periodic nature.

A1.1-0003-18 MODELLING AND VALIDATION OF THE WEIGHTED MEAN TEMPERATURE IN THE TROPICAL REGION OF TAHITI: IMPLICATIONS FOR PRECIPITABLE WATER MONITORING

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Water vapor is the primary greenhouse gas in Earth's atmosphere, and is a key ingredient in climate modelling. Delays of propagation of GPS signals in the atmosphere are now routinely used as a tool to monitor the water vapor contents of the atmosphere, in the form of precipitable water (PW), as a complement to radiosounding (RS) measurements. One of the main parameter to obtain PW estimates from GPS Zenith Wet delays (ZWD) is the so-called weighted mean temperature (Tm), a weighted average of the troposphere temperature with respect to the water vapor contents over a given atmospheric column. Currently, the most used model is the linear model of Bevis et al. (1992) based on the surface temperature, but developed for mid-latitude regions. In this study, a new site-specific Tm model is proposed, specially tailored to tropical regions, based on the comparison of RS and ZWD data collected between January 2014 and

December 2016 in the Tahiti Island (149°25'W, 17°40'S) located in the South Pacific. Our

ZWD data was estimated by using the Bernese 5.2 package with VMF1/ECMWF dry model and VMF1 dry and wet mapping functions. We recomputed high precision PW RS from raw balloon data from Météo-France, up to altitudes of 25,000 m for the balloons. We show that, in our case, this new Tm model leads to a better estimation of the PW from GPS measurements than the standard Bevis et al. model. Finally, the correlation between the fluctuations of ENSO Index and the time series of PW are presented based on the local El Niño events.

A1.1-0004-18 DIURNAL VARIATION OF IWV VALUES OBTAINED FROM GNSS AND MERRA OVER CENTRAL AND SOUTH AMERICA

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Water vapor has an important role in radiative balance, hydrological cycle, in transport of large amounts of latent heat energy and instability and convective activity. Therefore, the quantity of the integrated of water vapor (IWV), along a vertical column, must be well known in order to understand, associate and forecast environmental processes. The IWV values obtained from Global Navigation Satellite System (GNSS) observations with a 30 minutes sampling allow us to have a better knowledge of water vapor variability at high frequency. The diurnal variations of IWV are studied in Central and South America region during the period 2007-2013. The analysis was performed in 69 GNSS tracking sites (GPS + GLONASS), which have more than 5 years of data. The selected area involves different climate types, from polar to tropical, with different diurnal variations of the integrated total humidity content. This study describes the main characteristics of the diurnal cycle obtained at every station by using Principal Component Analysis (PCA). Our results highlight the global main behaviors for all stations in its first and second PCA mode. They are are associated to the most relevant causes that induce diurnal variations in atmospheric water vapor: the surface evapotranspiration, atmospheric large-scale vertical motion and atmospheric low-level moisture convergence. Then, the diurnal cycle is analyzed for each stations separately. As a consequence seasonal and local variations that spotlight the breeze regime are detected among other characteristics. Afterwards, IWV values obtained from the reanalysis model MERRA (Modern Era Retrospective-Analysis for Research and Applications) produced by NASA are also analyzed using the same numerical procedure described before. We perform the first analysis of IWV diurnal anomaly realized in Central and South America, consequently our contribution is important to improve the knowledge of water vapor global variability in the Earth atmosphere. Besides, the numerical tool employed to isolate the before mentioned variabilities is also an original application in this topics.

A1.1-0005-18 REGIONAL ANALYSIS OF GNSS-DERIVED IWV IN CENTRAL AND SOUTH AMERICA: COMPARISON WITH NWM REANALYSIS DATA

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Seven years (2007-2013) of Integrated Water Vapor (IWV) data derived from the geodetic processing of GNSS data (GPS + GLONASS) in Central and South America were regionally analyzed comparing it with respect to IWV values from two different reanalysis: the European Centre for Medium-Range Weather Forecast (ECMWF) reanalysis data (ERA Interim) and the Modern-Era Retrospective analysis for Research and Applications (MERRA2) from the National Aeronautics and Space Administration (NASA). Although the statistical analysis of the differences was performed in 110 GNSS sites, the most interesting results came from the 73 sites which have more than 5 years of data. The study was performed spatially discriminating not only areas that involve different climate types from polar to tropical, but also different topography characteristics by classifying the rank of geopotential height differences between the different data sets. Besides the comparison was also performed on several time scales: from hours to years. Finally a correction is suggested for the lack of consistency of IWV values from reanalysis in mountain areas. This work provides information about the regional performance of reanalysis models based on complex processes of assimilation of a large number of data from different techniques, in a region where the scarce coverage of operational radiosonde stations is noticeable. In addition, considering that atmospheric water vapor has a complex and variable distribution, and that its knowledge is essential for local meteorological studies and predictions, this study also provides information about IWV from GNSS as a source of data to improve simulations and forecasts in regional models.

A1.1-0006-18 VARIABILITY OF RELATIVE HUMIDITY IN THE TROPOSPHERE USING SAPHIR ON-BOARD MEGHA-TROPIQUES

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The variability of global relative humidity (RH) and its distribution is studied during different seasons using a new global satellite, SAPHIR (Sounder for Atmospheric Profiling of Humidity in the Inter-tropical Regions) using data from 2012 to 2017. SAPHIR has six channels viz., S1(183.31±0.2), S2(183.31±1.1), S3(183.31±2.8), S4(183.31±4.2), S5(183.31±6.8) and

S6(183.31±11.0), that has peak contribution respectively in the six altitudinal layers viz., 1000- 850, hPa (layer-1), 850-700 hPa (layer-2), 700-550 hPa (layer-3), 550-400 hPa (layer-4), 400-250 hPa (layer-5), and 250-100 hPa (layer-6). The monthly mean of all the years during January and July shows the migration of Inter-tropical convergence zone (ITCZ). The tropical northern (southern) latitudes are found to have humidity higher than 90%, during July (January). The equatorial central pacific show dry compared to the other tropical regions. The upper tropospheric humidity (UTH) is high over the Indian and the surrounding oceanic regions compared to the other tropical regions. Further analysis is carried out by calculating Probability Density Function (PDF) by dividing the globe into different latitudinal sections extending from equator to the tropics in both the hemispheres. The distribution shows unimodal in the deep tropics and bimodal in the tropics. Further the analysis is also extended to delineate the difference in the distribution of RH during El-Nino and normal years. The details will be presented in the workshop.

A1.1-0007-18 ESTABLISHMENT OF A NEW RELATIONSHIP BETWEEN THE DYNAMICS OF THE INTEGRAL MOISTURE CONTENT OF THE ATMOSPHERE AND THE SEASONAL COURSE OF SECONDARY COSMIC RAYS (MUONIC COMPONENT)

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This paper presents the first analysis to be carried out of the dynamics of the integral moisture content of the atmosphere (W) with the seasonal course of the muonic component of cosmic rays, as observed on the ground. The data of ERA-Interim reanalysis is used, which is based on regular meteorological observations, aerological and satellite information, as well as data from cosmic ray detectors of Yakutsk and Nagoya stations. A sufficient correlation value of the mean monthly moisture values for the year between the muonic component of cosmic rays has been found.

A1.1-0008-18 ASSESSMENT OF AMBIENT AIR POLLUTANTS LEVEL DURING ANTHROPOGENIC EPISODE I.E., DIWALI FESTIVAL ACTIVITIES OVER WESTERN SEMI-ARID TROPICAL SITE, UDAIPUR, INDIA

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The influence of fireworks display emissions of anthropogenic activity during the Indian Diwali festival on the ambient atmospheric gaseous as well as material pollutants levels, such as Surface ozone (O3), Nitrogen Oxides (NOX), Carbon monoxide (CO) and Suspended fine size particulate matters of size less than 2.5 µm (PM 2.5) have been assessed for main episode as well as before to after Diwali days as control daus over Udaipur i.e., a western Indian tropical typical urban and semi-arid site. The comparative study of derived air pollutant source identification parameters namely, angstrom absorption coefficient of Black Carbon (BC) (abs) and ratio of CO by NOx values have been investigated for direct influence of extra firework crackers, lightening due to various kind of burning of chemical materials in such specific human made activities. In overall, unusual degradation of ambient air quality level and altering the share of different air pollutant emission source types of burning materials such as biomass and fossil fuel ignition materials are more visible, especially at night time Diwali festival event in relative to their in sunlight hours. A significant enhancement by three to four time folds in the average daily PM2.5 levels (about 165 µg m-3) is unusually recorded especially in the Diwali day relative to their respective normal days values, which is exceeding more than four time value above from the healthy NAAQSL of PM2.5 concentration, (ii) during main Diwali celebration activity period, of sunset to pre midnight hours, the magnitude of NOx, CO and O3 along with abs and ratio of CO to NOx showed remarkable enhancement by 1.5 to 3 times higher as compared to those of their normal day level in the same interval. It obviously gives an clear manifestation about the modulation in origin as well as changes in the anthropogenic source strength. But, their prevailed maximum amount of air pollutants gas species in Diwali episode do not reach to go beyond above from their already reported peak values of O3, CO and NOx at major polluted, populated and urban industralised regions. Moreover, during sunlight hours, the elevated level of averaged O3 value only is also recorded as high as the high their extreme value of 67.5ppbv in Diwali eve period, which is greater than double value relative to their observed values on the similar interval on non-festival days, (vi) a wide temporal variations in air pollutant source discrimination parameter values, such as abs and CO/NOx segregated based on the magnitude of above 1.1 and 150, respectively, have given an evidence and clear insight in changing the potential origin of air pollutant source emission materials characteristics in the night and day-time festival celebration. The majority observed abs

values above 1.1 and CO /NOx exceeding of 150 gave an obvious indication and support of the view of predominant nature of production of atmospheric pollutants due to bio-mass and bio-fuel activity emission processes in Diwali episode, while in non festival period, their calculated values are found to be lower than above the prescribed limit magnitude and, hence, gave the confirmation of the predominance abundance of the inefficient combustion of fossil fuel ignition materials.

A1.1-0009-18 MESOSCALE MODELING OF SEA BREEZE INDUCED CONVECTION OVER SOUTH EAST COAST OF INDIA

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Sea breeze is a mesoscale phenomenon occurs over coastal region. The dynamic interactions of sea breeze with the prevailing synoptic flow can give rise to meteorological conditions conducive for the occurrence to the convection over coastal and adjoining regions. We have studied sea breeze cases over the south-east India using the satellite data and its mesoscale modeling with the objective of understanding the underlying physical mechanism of initiation of such convection. A set of meteorological observations obtained from microwave radiometer profiler, eddy covariance flux tower system, satellite sounder and imager observations and Doppler weather radar, are used for investigating the convection genesis characteristics. In conjunction with observations, to bridge the gap of lack of high-resolution spatial observations, the high-resolution (2km) model analysis is developed using Weather Research and Forecasting (WRF) model and four-dimensional variational data assimilation technique. The analysis of thermodynamical and dynamical indices carried out from the model analysis as well as insitu and satellite observations. The results obtained from these studies indicated the presence of a wind discontinuity line, and a warm air advection from the north Indian region towards south-east coast, causes the boundary layer hot dry and convectively active. We found that the inland penetration of sea-breeze front caused advection of moist and cold air over warm and dry region. It leads to convection and thunderstorms over the coastal region. Different physical mechanisms will be discussed in this presentation. The study has potential implications in identifying and early prediction of thunderstorms.

A1.1-0010-18 UPPER TROPOSPHERIC OZONE TRANSPORT FROM THE SUB-TROPICS TO TROPICS OVER THE INDIAN REGION DURING ASIAN SUMMER MONSOON USING SPACE BORNE AND IN SITU OBSERVATIONS

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In this study, we investigate the role of Asian summer monsoon (ASM) anticyclone in the ozone distribution over the tropical Indian region using Microwave Limb Sounder (MLS) onboard the Aura satellite and in situ ozonesonde observations. We present the horizontal and vertical structure of ozone in the upper troposphere and lower stratosphere (UTLS) region. In addition, the role of tropical tropopause derived from the vertical profiles of temperature obtained from the "Constellation Observing System for Meteorology Ionosphere and Climate" (COSMIC) satellite in the distribution of ozone in the UTLS region is also investigated. Results show that the ASM anticyclone region has low ozone, more water vapour, high cold-point tropopause (CPT) altitude, and low CPT pressure, compared to the other ASM regions during boreal summer. Southern side of ASM anticyclone, i.e. the tropical Indian region shows a remarkable high ozone concentration in the UTLS region during summer. Ozone concentration in the upper troposphere increases with strength of the tropical easterly jet, which is an outcome of the ASM phenomena. The mechanism responsible for the enhancement of ozone concentration in the UTLS region over the tropical Indian region has been discussed in this paper. The in situ ozonesonde observations from six Indian stations also support the space-based AuraMLS observations, concluding that ASM anticyclone effectively transport ozone from the midlatitude stratosphere to the tropical upper troposphere over the tropical Indian region. The detailed results will be presented in the upcoming symposium.

A1.1-0011-18 BENCHMARKING CHEMISTRY-CLIMATE MODELS' TOP-OF-ATMOSPHERE FLUX IN THE 9.6-MICROMETER OZONE BAND USING AURA TES INSTANTANEOUS RADIATIVE KERNEL

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Increases in tropospheric ozone from pre-industrial to present day add radiative forcing (RF) to the climate with a widely range of estimates from +0.2 to +0.6 Wm-2 by IPPCC chemistryclimate models. About 80% of O3 RF is due to O3 longwave absorption and 97% of this longwave absorption is in the 9.6-m O3 band [Rothman et al., 1987]. The global outgoing fluxes at the top-of-atmosphere (TOA) over 9.6-m ozone band have strong geographic and seasonal variations. The variations of TOA fluxes highly depend on the distributions of ozone, water vapor, air temperature, and surface temperature. The biases in these quantities are sources of biases in both the O3 band TOA flux and O3 RF. Benchmarking present day O3 band flux is the first step for understanding climate feedbacks from O3 forcing.

An instantaneous radiative kernel (IRK) represents the sensitivity of TOA fluxes to the vertical distributions of the geophysical variables, such as ozone, water vapor, temperature, and so on. The products of 9.6-m ozone band IRK for ozone, water vapor, air temperature, surface temperature, and etc., have been developed with observations by AURA TES and could be extend the record by MetOP-IASI and SNPP-CrIS Fourier Transform spectrometer (FTS) measurements. In this study, we demonstrate the method of using the observations of tropospheric compositions, atmospheric state, and IRK from TES to attribute the biases of the fluxes in a suite of CCMI models to these key parameters. In this way, we show the TOA flux biases differs significantly between models and for different reasons. We found the principle contributors governing the variation for each model are under different processes or over different regions, and also provided quantitatively estimates of the influence from ozone, water vapor, and temperature bias in models.

A1.1-0012-18 MONITORING OF UNUSUAL OUTGOING LONGWAVE RADIATION (OLR) DURING THE MAY, 2015 NEPAL EARTHQUAKE USING SATELLITE OBSERVATIONS

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Earthquake preparation processes start within the earthquake preparation zone much prior to the occurrence of the main event. The preparation processes begin from the ground surface and can be detected from different layers of the atmosphere with a time delay from the ground surface to upper heights. There are several channels through which this coupling process, generally termed as the Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) mechanism can happen, such as the thermal channel, the electromagnetic channel, the acoustic channel and the chemical channel. Outgoing Longwave Radiation (OLR) is an important parameter for understanding this LAIC mechanism. In the present study, we monitored the OLR data as archived by NOAA satellites, prior, during and after the major earthquake that took place in Kodari, Nepal on May 12, 2015 with Richter scale magnitude M = 7.3. The data was downloaded from NOAA website on a two degree grid basis with a temporal extent of 45 days from April 16, 2015 to May 30, 2015. This exercise was done because the May earthquake was preceded by another major earthquake on April 22, 2015 with Richter scale magnitude M = 7.9. As the April earthquake was followed by several aftershocks that might get superimposed with the May earthquake, the data was downloaded for that period also and the spatial extent was chosen to include both the epicenters. 'Eddy field calculation mean' was performed on the data and singularities in the daily Eddy field around the earthquake epicenters was found two/three days before both the earthquakes that exhibited a general trend of fading away after the events. The OLR data for the whole month of January, 2015 was also analyzed to check its distribution over the same operational area during a seismically quiet scenario and the values were found to be pretty low. Thus, the sudden intensification of the Eddy field just few days prior to the earthquake days and their fading away after the events can be attributed to the release of a huge amount of energy during the earthquakes.

A1.1-0013-18 3D TOMOGRAPHY OF UTLS WITH GLORIA IR LIMB SOUNDER: TECHNIQUES AND SOME RECENT RESULTS

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The Gimballed Limb Observer for Radiance Imaging of the Atmosphere (GLORIA) is an aircraft-based Fourier transform spectrometer with a 2D detector array jointly developed by Forschungszentrum Jülich and Karlsruhe Institute of Technology. The measured IR spectra can be used to retrieve air temperature and volume mixing ratios of various trace gases. GLORIA can be panned between 45° and 135° w. r. t. the flight direction. Using this capability and/or flight paths that encircle the observed atmospheric region, multiple measurements of the same air mass are performed, allowing for 3D tomography of the atmosphere with a vertical resolution down to 250 m and horizontal resolution of around 25 km.

3D tomography is a large ill-posed inverse modeling problem, which requires the introduction of some general prior knowledge about the atmosphere by means of a regularisation algorithm. We present a physically motivated (without unphysical ad-hoc parameters) variant of Tikhonov regularisation based on first-order and second-order spatial derivatives. It is implemented efficiently using irregular grids and Delaunay triangulation. Compared to simpler, ad-hoc Tikhonov regularisation schemes, this approach requires less parameter tuning for each use case and has some advantages in retrieval quality.

GLORIA instrument flew aboard the German HALO research aircraft during the Wave Driven Isentropic Exchange (WISE) measurement campaign held in Ireland in September/October 2017. Among other phenomena, Rossby-wave breaking events were observed on multiple flights, some of them showing a lot of stirring, filamentation, strong tropopause inversion layers and wet air masses lifted to high altitudes by warm conveyor belts. We present some of the data products, including HNO3, O3, and water vapour volume mixing ratios both as 2D curtains and 3D tomographic retrievals. These results can be used to quantify the

length scales of filamentation and mixing. Several cross-sections of some filaments were recorded over the course of the two flights, allowing for analysis of their development timescales as well as possible identification of transport pathways.

A1.1-0014-18 LATITUDINAL IMPRESSIONS OF QBO VARIABILITY AND ITS ASSOCIATION WITH TEMPERATURE IN THE UPPER TROPOSPHERE OVER A PERIOD OF 2007-2017 USING COSMIC SATELLITE DATA

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The effect of Quasi-Biennial Oscillation (QBO) on the temperature of cold point tropopause (T-CPT) and its height (H-CPT) is being investigated using radio occultation measurements by

Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC/FORMOSAT3)during 2007-2017. The disruption of QBO in temperature data during 2016, which is unprecedented, is shown. In general, T-CPT is found to be the coldest in February and warmest in August. The H-CPT also shows a maximum between December and February and minimum during July -August in both the hemispheres. Interestingly, however, the H-CPT shows off-equatorial maxima (beyond 20°N or 20°S) as we move from equator to middle latitude in both the hemispheres during all the seasons. The increase in H-CPT at off-equatorial region is higher (1.0 km) during Northern Hemisphere (NH) winter as compared to monsoon season (0.5 km). Inter-seasonal variation in T-CPT and H-CPT is found to be clearly influenced by QBO wherein the westerly (easterly) phase favors warm (cool) T-CPT with a decrease (increase) in H-CPT. It is concluded that QBO induces the changes in T-CPT by as much as 2°C and in H-CPT by 0.5 km. Unique feature of QBO over the different longitude sector are observed. The feature of QBO over the different longitude sectors shows the great potential of COSMIC mission.

A1.1-0015-18 ENHANCED DAYTIME OCCURENCE OF CLOUDS IN THE TROPICAL UPPER TROPOSPHERE AND OBSERVATIONAL EVIDENCE FOR RADIATIVELY DRIVEN CONVECTION

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The space-borne active sensors (e.g., CloudSat and CALIPSO) enable direct observation of the global 3-dimensional distribution of clouds. While the CloudSat observation can provide the 3-dimensional structure and evolution of thick clouds, the CALIPSO can provide information on the vertical profile of thin clouds. A combined product of CloudSat-CALIPSO has the potential to provide a more comprehensive picture of the clouds. These satellites data are used to address the day-night changes in the occurrence of clouds in the tropical upper troposphere. This study investigates:(i) contrasting day-night variations in the altitude distribution of optically thick tropical convective clouds in the upper troposphere and the convective region, and (ii) cloud radiative heating rates and their potential impact on the enhanced daytime vertical growth of clouds in the upper troposphere. It has been observed that the combined occurrence of all cloud types maximizes in the nighttime throughout the middle and upper troposphere. However, the CloudSat observations reveal contrasting day-night variations in the frequency of occurrence of clouds in the upper troposphere (above sim12 km) and below. While the altitude region below sim12 km exhibit a pronounced nighttime peak in cloud occurrence, the upper tropospheric cloud occurrence above sim12 km shows a distinct enhancement during the daytime over both land and oceanic regions. Enhancement during the daytime arises from the more frequent occurrence of thick cirrus and deeper penetration of daytime convective clouds to the upper troposphere, as evidenced from larger probability of occurrence of deep convective clouds having thickness of sim9-16 km during the daytime. Further to this, the magnitudes of the net cloud radiative heating rate and its vertical gradient in the upper troposphere are largest and the altitude of peak cloud radiative heating is highest during the daytime in all seasons. These are conducive for the occurrence of thicker cirrus as well as deeper penetration of convection in the upper troposphere. The above inferences are further supported by the mean vertical wind profiles derived from reanalysis data. These observations illustrate the role of radiationinduced convection in the vertical growth of convective clouds to the upper troposphere during the daytime.

A1.1-0016-18 RELATIVE ROLE OF CONVECTION AND DYNAMICS IN MAINTAINING UTLS AEROSOLS AND TRACE GASES OVER INDIAN REGION OBSERVED BY GROUND BASED AND SPACE BORNE MEASUREMENTS

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Knowledge on the vertical distribution of aerosol and trace gases is essential to estimate its radiative effects on the atmosphere. Several studies have been carried out on the vertical and spatial distribution of these pollutants using both ground based and space borne observations. However, large uncertainity is still existing in considering the effect of aerosols on radiation budget, clouds, climate prediction due to limited observation data. We have investigated the long-term variabilities of the upper troposphere and lower stratosphere (UTLS) aerosols and trace gases (Ozone, Water Vapor, Carbon monoxide) over the Indian monsoon region (IMR) using the long term data constructed from multi satellite observations. We also make use of long-term data obtained from ground based lidars located at Gadanki (13.5oN, 79.2oE) to support the satellite observations. Special emphasis is given to see the variability of these aerosols and trace gases in the anticyclone region which will persist during ISM over the Indian region. A distinct maximum in the aerosols and all the trace gases has been noticed during monsoon season. Dominance of annual oscillation, quasi-biennial oscillation and ENSO is found in these UTLS pollutants suggesting that dynamics play major role on the vertical distribution of these pollutants. Transport of tropospheric aerosols and trace gases from boundary layer through tropical deep convection during ISM is thought to be the main mechanism for the observed enhancements in the UTLS region. However, detailed analysis suggests that the tropospheric aerosols undergo several removal mechanisms like rainout and wash out in the troposphere itself. If yet all any traces of these are remained, strong vertical shear in the horizontal wind arising due to monsoon level jet (at 850hPa) and tropical easterly jet (at 100 hPa) does not allow anything to penetrate above 500 hPa. Back trajectory analysis further revealed that the observed UTLS enchantments in these aerosol and trace gases are through the long-range transport. Difference in the aerosol types observed in troposphere and UTLS also confirms that they are not from below. This mechanism is true for complete south Indian region. However, deep convection persisting over head Bay of Bengal and north east part of India during monsoon season can be source for transporting boundary layer pollutants to the UTLS region which need to investigate separately.

A1.1-0017-18 PREFERRED SOLAR SIGNAL AND ITS TRANSFER IN THE ASIAN-PACIFIC SUBTROPICAL JET REGION

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Solar impact on the tropospheric subtropical jet (SJ) has been identified previously from a zonally averaged perspective. The zonal mean SJ was observed to be weaker in the high solar activity winters. However, some regional features of solar-induced SJ variations might remain unrecognized. Here it is found that the regional solar signal in the wintertime Asian-Pacific zonal wind at 200 hPa, which exhibits a banded structure (i.e., easterly anomalies within the subtropics and westerly anomalies on the poleward and equatorward sides), greatly resembles the second internal mode of zonal wind within the same sector. Significant response of the Asian-Pacific SJ (APSJ) to solar activity in boreal winter exclusively marks its center region, showing a deceleration in westerlies. Further exploration suggests two possible top-down routes to interpret this particular manifestation of solar signal in APSJ center, a tropical route and a middle-high latitude route. Regarding the tropical route, during the cold season, driven by the solar-associated reduction in Brewer-Dobson circulation, ozone concentration in the tropical lower stratosphere increases evidently within the zonal range of APSJ center. This heats the air here and the tropical tropospheric regional upwelling is thereby suppressed. Consequently, a significant weakened APSJ center is produced via local Hadley cell. Regarding the middlehigh latitude route, in early winter, pronounced strengthened westerlies in the mid-latitude stratosphere created by solar forcing are confined to the longitudinal range of the APSJ center. As winter progresses, through wave mean flow interactions, a resultant weakened APSJ center markedly presents in the middle of winter.

A1.1-0018-18 A FAST VECTOR RADIATIVE TRANSFER MODEL FOR POLARIMETRIC REMOTE SENSING

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Spaceborne remote sensing instruments provide decades of continuous observations of the earth system. Due to limited capabilities of remote sensing instruments and techniques, there are still substantial uncertainties in inferring atmosphere and ocean properties. Spaceborne and airborne polarimetric remote sensing techniques reduce the uncertainties for cloud, aerosol, and phytoplankton concentration retrievals. Because of the large volume of remote sensing observational data, an efficient retrieval algorithm is needed while achieving the accuracy comparable to in-situ measurements. The accuracy and efficiency of the retrieval algorithm depends on the radiative transfer model (RTM) used in the forward calculations. On-line RTM can incorporate atmospheric profiles and surface properties directly into the retrieval system to improve the accuracy, but it is challenging to satisfy the efficiency requirements in remote sensing applications. To fully exploit the capability of the polarimetric instruments, it is imperative to develop an accurate and fast on-line vector RTM. In this study, a fast vector RTM is developed in support of atmospheric and oceanic polarimetric remote sensing. This model is capable of simulating the Stokes vector observed at the top of the atmosphere (TOA) and at the terrestrial surface by considering absorption, scattering, and emission. The gas absorption is parameterized in terms of gas concentration, temperature, and pressure. The parameterization scheme uses a regression method and can be incorporated into multiple scattering computations. With errors less than 0.2 K in terms of TOA brightness temperature, the approach is more than four orders of magnitude faster than a line-by-line RTM. A two-component approach is utilized to solve the vector radiative transfer equation (VRTE). The VRTE solver separates the phase matrices of aerosol and cloud into forward and diffuse parts, and thus the solution is also separated. The forward solution can be expressed by a semi-analytical equation based on the small-angle approximation, and serves as the source of the diffuse part. The diffuse part is solved by the adding-doubling method. The adding-doubling implementation is computationally efficient because the diffuse component needs much fewer generalized spherical function expansion terms. The simulated Stokes vectors at the TOA and surface are as accurate as the counterparts based on numerically rigorous methods. In this presentation, we compare the radiance calculations at the TOA to satellite observations.

A1.1-0019-18 DEVELOPMENT AND FIELD VALIDATION OF THE PANCHROMATIC FOURIER TRANSFORM SPECTROMETER (PANFTS)

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The most recent Earth Science Decadal Survey from the U.S. National Research Council identified several key science questions and observables related to atmospheric composition. These include questions related to vertical profiling of aerosols; emission, transformation and longrange transport of tropospheric pollutants and greenhouse gases that drive radiative forcing. The next generation of instruments and platforms must address the specific requirements that flow from the measurement requirements articulated in the Decadal Survey. The Panchromatic Fourier Transform Spectrometer (PanFTS) is a NASA Earth Science Technology Programfunded development to demonstrate a geostationary instrument capable of meeting or exceeding measurement requirements posed by the Decadal Survey. The PanFTS flight instrument design combines measurement capabilities for the 0.26-15 micron spectral range in a single package. The wide spectral coverage is important for retrieving the entire suite of target molecules, including several in widely different wavebands. Measurement of the same species in different spectral regions significantly enhances the information content of the vertical profile retrievals. PanFTS combines an imaging Michelson interferometer design with several unique features. The PanFTS instrument is a hybrid based on spectrometers like TES (Tropospheric Emission Spectrometer) that measures thermal emission, and those like OCO (Orbiting Carbon Observatory) and OMI (Ozone Monitoring Instrument) that measure scattered solar radiation. As such the PanFTS design has two parallel optical trains, one for infrared wavelengths and one for UV-Vis. These channels incorporate imaging focal planes to meet requirements for high spatial resolution (few km) and large instantaneous field of regard from geostationary orbit. This presentation will discuss the development status and future evolution of the PanFTS instrument. We will present results obtained from versions of the PanFTS instrument located at JPL's California Laboratory for Atmospheric Remote Sensing (CLARS) on Mt. Wilson, California, overlooking the Los Angeles Basin. These will include long-term measurements of greenhouse gas emissions and solar-induced fluorescence from vegetation.

A1.1-0020-18 NASA'S ICECUBE TECHNOLOGY DEMONSTRATION: A PATHWAY FOR FUTURE COST-EFFECTIVE SUBMM-WAVE REMOTE SENSING FROM SPACE

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NASA continues to develop and mature cost-effective submm-wave technologies for various science applications with Earth and planetary remote sensing from space. IceCube is the latest spaceflight demonstration of submm-wave technology on a 3U cubesat using a commercial 883- GHz radiometer for Earth's cloud ice remote sensing. Cloud ice plays important roles in Earth's radiation budget and cloud-precipitation processes. Knowledge of global cloud ice distribution and its variations with the changing climate is a critical part of understanding about the Earth's system as a whole.

The IceCube project took advantage of emerging cubesat opportunities and established effective government-commercial partnerships, to achieve a fast-track development for the 883-GHz cloud radiometer and raise the technology readiness level (TRL) from 5 to 7. The IceCube system was successfully delivered to ISS in April 2017, deployed from the International Space Station (ISS) in May 2017, and acquired the first global 883-GHz cloud map by July 2017. It continues collecting cloud data at present as well as exploring capabilities of cubesat submmwave observations. The maturation of commercial submm-wave radiometer technologies up to 883 GHz opens up a host of cost-effective remote sensing applications for future Earth and planetary sciences. The new results of IceCube 883-GHz measurements and cubesat operation experiments will be discussed in this presentation.

A1.1-0021-18 VALIDATING THE ICE CLOUD PARTICLE MODELS FOR THE TERRESTRIAL ATMOSPHERE BY SPACEBORNE MULTI-ANGLE IMAGES

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Ice clouds in the terrestrial atmosphere occur mostly in the upper troposphere and lower stratosphere. These clouds substantially modulate the energy budget of the planet. Airborne in-situ measurements indicate that the size and shape of ice cloud particles are diverse, and light scattering calculations demonstrate that the single-scattering properties of these particles depend significantly on the particle shape and surface roughness. To accurately estimate the climatic impact of ice clouds, it is necessary to improve the current level of the knowledge about ice particle shapes at the global scale.

To obtain the shape and surface roughness distribution at the global scale, the radiometric measurements from satellite sensors at visible and near-infrared wavelengths are viable. Because of minimal absorption by the atmospheric trace gases and large particle size compared to the wavelength, multi-angle cloud reflectance measurements characterizes the cloud particle properties. The separation of contribution from cloud optical thickness and phase function requires at least two viewing directions for every pixel of measurement, and this is more easily achieved by polar-orbiting satellites.

Two polar orbiting satellite sensors collected multi-angle images at visible/near-infrared wavelength from more than 8 viewing directions: The Multi-angle Imaging Spectroradiometer (MISR) sensor aboard NASA's Terra platform and the Polarization and Directionality of the Earth's Reflectance (POLDER) sensor aboard the Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from Lidar (PARASOL) satellite. These two sensors have different optical systems to measure the reflectivity, thus the different viewing geometries and spectral resolution.

In this presentation, we validate ice cloud particle models using the MISR and POLDER sensors. We first estimate the spherical albedo from multi-angle measurements pixel-by-pixel, and then compute the anisotropic component of the reflectance for every viewing direction. The degree of agreement between the observed and simulated anisotropies is compared. The preliminary results from two satellite sensors are different, particularly in the tropics. The present results are stratified by cloud scene inhomogeneity and pixel selection criteria.

A1.1-0022-18 DETERMINATION OF GLOBAL EARTH OUTGOING LONGWAVE RADIATION AT HIGH TEMPORAL RESOLUTION USING MOON-BASED PLATFORM

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An Earth observation strategy that equipping sensors on the lunar surface have attracted great attention across many scientific communities. Yet the potential and the characteristics of the global Earth outgoing radiation monitoring using such a new platform has not been explored sufficiently. To explore the potential of the Moon-based platform and to reveal the observation parameters requirement for measuring global Earth outgoing radiation, we have developed a new method and conducted a series of simulation experiments. Using idealized active radiometers as an example, we find that the Moon-based platform can monitor global Earth outgoing longwave radiation reliably at hourly time scale, showing the features of planetary spatial scale and high temporal resolution observation.

The Earth system receives energy from the Sun and releases energy via thermal radiation out to space. The detection of variation in the Earth radiation budget at the top of atmosphere (TOA) is essential to our understanding of global change. Measurement of the Earth radiation budget have been made from dedicated missions since 1975, the early Earth Radiation Budget experiments. Now, the Clouds and the Earth's Radiant Energy System (CERES) experiments have provided valuable data for global climate change study. Another platform is Geostationary Earth Radiation Budget (GERB) experiment, which provides outgoing radiation products at a 15-min temporal resolution. Deep Space Climate Observatory (DSCOVR) took the first step in an effort to deep space observatories of the Earth radiation. It offers the data of the sunlit hemisphere of the Earth. Based on the previous research, we will perform extensive simulation experiments to evaluate the possibility and the capability of the Moon-based platform concept for observing Earth outgoing longwave radiation. Similarly to other platforms case, we use the angular distribution model, but necessarily, different angular constraints are applied to make the model. In this paper, the observation angles are defined and the data is binned and averaged in angular bins as functions of cloud fraction and surface type of the observational scope. Then, the angular distribution model is detailed and the results are shown. Finally, our key findings and highlights are summarized.

A1.1-0023-18 BAND SELECTION STUDY FOR SMILES-2

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SMILES-2 is one of the satellite proposal submitted to JAXA/ISAS small satellite program in January 2018, and it is waiting for the first selection scheduled in June 2018 (3 proposals can go to pre-phase-A1B among 8 proposals. If it is selected, 2024/25 launch is expected). SMILES-2 satellite proposal is 600 km, 66 degree, 550 kg satellite carrying SMILES-2 (core instrument, Ochiai et al, 2017), in-situ instruments for ionosphere (Langmuir Probe and Ion Drift Analyzer) and GPS occultation (stratospheric temperature and ionosphere electron density). SMILES-2 will be similar to ISS/JEM/SMILES, with adding 2-3 sub-mm bands using SIS mixer and THz band (1.8 THz for OH, HO2, and O3, and 2.0 THz for O atom) using HEB (Hot Electron Bolometer). SMILES-2 program has four science objectives: (MO.1) To investigate the 4-D space-time structure of the diurnal variations (atmospheric tides) in view of dynamics, chemistry, and electromagnetic processes. (MO.2) To unveil the vertical propagation of planetary scale disturbances from the middle atmosphere (non-migrating tides and stratospheric sudden warming events) to the upper atmosphere. (MO.3) To understand atmospheric variations due to electromagnetic energy input from the magnetosphere (particle precipitation and magnetic storm). (MO.4) To provide benchmarks for whole atmosphere models and climate models with detailed description of the background thermal structure and distribution of minor species. Previously, SMILES-2 was to have 3 sub-mm bands (LO=507 GHz, 566.5 GHz, and 638.075 GHz). After preliminary satellite design study, we should reduce sub-mm antenna size (80-100 cm down to 75 cm) and minimize the size of 4K cooled part. By choosing higher frequency band (LO=763.5 GHz), we concluded almost same (or better) sensitivity other than CO and BrO with (LO=638.075 GHz, and 763.5 GHz). Expected SMILES-2 data are: Horizontal wind (30-150 km), Temperature (15-150 km), O3, all O3 isotopes, O atom (80-150 km), H2O (20-100 km), HO2, OH, HCl, ClO, HOCl, BrO, N2O, NO, NO2, HNO3, CH3CN, HCN, and volcanic enhanced SO2.

A1.1-0024-18 AN OVERVIEW OF THE STRATOSPHERIC AEROSOL AND GAS EXPERIMENT III ON THE INTERNATIONAL SPACE STATION (SAGE III ISS)

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The Stratospheric Aerosol and Gas Experiment III (SAGE III) on the International Space Station (ISS) extends NASA's long legacy of satellite atmospheric occultation measurements with the primary objective to monitor the vertical distribution of aerosol, ozone, and other trace gases to enhance understanding of ozone recovery and climate change processes in the upper atmosphere. The SAGE III payload was delivered to the ISS by the Falcon 9 Commercial Resupply Services 10 mission launched on 19 February 2017 from Kennedy Space Center. The SpaceX Dragon spacecraft berthed and docked with the ISS on 23 February, and the external SAGE III payload was installed on 7 March with first light following on 17 March. The ISS is an attractive platform because power and data service are readily available and because the 52° inclined orbit is ideal for the desired low and mid latitude coverage, similar to the SAGE II mission. Occultation instruments measure the unattenuated balance of light along the lineof-sight to the target to infer the molecular species and aerosol extinction present within the atmospheric path. Although in the visible portion of the spectrum the brightness of the Sun is a million times that of the full Moon, SAGE III can perform both solar and lunar occultations as well as limb scatter events that measure the scattering of solar radiation by Earth's blue sky. The nominal solar science products include vertical profiles of ozone, nitrogen dioxide, and water vapor, along with multi-wavelength aerosol extinction. The standard lunar products include ozone, nitrogen dioxide, and nitrogen trioxide. An overview of the first year of routine operations of the SAGE III ISS mission will be discussed along with the status of validation efforts and science results. The SAGE IV Pathfinder development project will be introduced with thoughts towards the future of SAGE.

A1.1-0025-18 SCIENTIFIC RESULTS FROM THE OMPS LIMB PROFILER SENSOR ON SUOMI NPP SATELLITE

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The Ozone Mapper and Profiler Suite (OMPS) consists of two nadir and a limb-viewing sensor that was launched on the Suomi NPP satellite in October 2011. In this talk we will focus primarily on the OMPS LP sensor that measures limb-scattered solar radiation in the 290- 1000 nm wavelength range at 1.8 km vertical resolution over the entire sunlit globe. These measurements are inverted to produce vertical profiles of ozone and aerosols. There are also plans to derive temperature profiles in the 35-55 km altitude range, and to estimate spectrally resolved short-wave outgoing radiation. We will discuss how well this sensor has captured the evolution of the ozone layer in the past 6 years by comparing with other limb and occultation sensors, and the challenges in monitoring the expected ozone recovery due to phase out of the ozone destroying substances and cooling of the stratosphere due to greenhouse gases. We will show the morphology and evolution of stratospheric aerosols produced by recent volcanoes and intense fires, such as the Pyro-Cb event that occurred in Western Canada in August 2017. Finally, we will highlight merging of data from multiple sensors, including nadir, limb-viewing, occultation, and LIDAR sensors. We will discuss our recent studies to derive long-term dataset of tropospheric ozone column from nadir UV sensors by using EOFs of ozone profiles derived from limb data combined with time series of tropopause height and QBO to constrain the stratosphere. For aerosols studies we will discuss our approach of combining occultation and limb scattered data, with balloon and Lidar data, to constrain the aerosol size distribution parameters.

A1.1-0026-18 RADIATIVE TRANSFER CORRECTIONS FOR OMI BRO

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Global observations of BrO are crucial for monitoring the health of the stratospheric ozone layer, as bromine mediated catalytic destruction cycles have an important impact on the ozone budget. Bromine also plays an important role in the tropospheric chemistry of ozone and mercury. A changing climate is expected to affect the production of ozone, sources of bromine in the atmosphere, and injection of bromine into the stratosphere. It is therefore necessary to monitor BrO, ozone, and related molecules with a high degree of accuracy on a global scale to ensure the recovery of the stratosphere as well as changes in tropospheric composition using satellite instruments such as OMI.

We present results of an intercomparison between the operational OMI BrO data product, OMBRO, and ground-based Differential Optical Absorption Spectroscopy BrO vertical column densitiy, VCD, retrievals from Summit Station, Greenland. Results of this comparison motivated reconsideration of the radiative transfer calculations and a priori approximations used to retrieve OMBRO. We find that the OMI BrO VCD retrievals can be improved by more accurately accounting for the latitudinal variation in the stratospheric BrO profile shape and the presence of tropospheric BrO. We present a simple global correction function for OMBRO based on radiative transfer calculations of several scenarios utilizing a stratospheric BrO climatology. This correction reduces OMBRO measurement errors and better accounts for latitudinal and small-scale variability in the OMI BrO retrievals. The correction improves BrO VCD accuracy and benefits any work that relies on this dataset.

A1.1-0027-18 STRATOSPHERIC AEROSOL CHARACTERISTICS RETRIEVED FROM SPACEBORNE OBSERVATIONS IN LIMB VIEWING GEOMETRY

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Stratospheric aerosols play an important role in the processes relevant to climate change, affecting them both directly and indirectly. The direct effect arises from the scattering of solar radiation back to space and by heating the stratosphere after strong volcanic eruptions through the absorption of thermal infrared radiation upwelling from the troposphere. Besides, stratospheric aerosols influence the Earth's climate indirectly by providing the surface for heterogeneous reactions, which lead to the ozone depletion. Measurements of the scattered solar light in the limb viewing geometry from the spaceborne instruments is a valuable source of global information on stratospheric aerosols. In this study limb observations from two limb-scatter instruments are used: SCIAMACHY on Envisat operated from 2002 till 2012, and OMPSLP on Suomi-NPP, which was launched in 2011 and is operating till now. Here we present stratospheric aerosol data sets developed in the Institute of Environmental Physics, University of Bremen. As aerosol extinction coefficient is widely used to describe aerosol loading in the stratosphere, we provide data sets of this parameter, retrieved from SCIAMACHY and OMPSLP measurements. Furthermore, aerosol particle size distribution (PSD) parameters (mode radius and distribution width) are retrieved using SCIAMACHY observations. Assuming a fixed aerosol particle number density profile, mode radius and distribution width are retrieved with the accuracy of better than 20% and 10% respectively. For a purpose of comparability with the other instruments, we also provide Angström exponents.

These are calculated using PSD data with about 5-10% accuracy depending on the wavelength ratio. The quality of the presented aerosol products is assessed through extensive comparisons with results from other spaceborne instruments (SAGE II and OSIRIS). The data sets are used to analyze the stratospheric aerosol behaviour over the last 15 years.

A1.1-0028-18 MAPPING MAN-MADE CARBON EMISSIONS USING OBSERVATIONS FROM SPACE

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Carbon dioxide (CO2) emissions from fossil fuel combustion (Fossil fuel CO2, FFCO2) is the main input to the global carbon cycle over the decadal time scales. The emissions need to be accurately quantified and monitored in order to deduce the carbon uptakes by natural sinks using atmospheric measurements as well as support emissions reduction and management. The Open-source Data Inventory for Anthropogenic CO2 (ODIAC) is a global, high-spatial resolution, gridded emission data product for FFCO2. We first introduced the combined use of the point source information and satellite-observed nighttime lights data for emission downscaling in order to achieve global 1×1km spatial resolution emission fields. The use of nightlight data allows us to detect dynamic changes in emissions spatial distributions in a timely manner and incorporate these into the high-resolution

emission field. Since its establishment in 2009, the ODIAC emission data product has been extensively used in global and regional flux inversions especially with CO2 data collected by carbon observing satellites such as the Japanese Greenhouse gas Observing SATellite (GOSAT) and NASA's Orbiting Carbon Observatory 2 (OCO-2) and also successfully applied to studies for localized emissions point sources such power plants and cities. The good model reproducibility of the atmospheric CO2 observations in transport model simulations even at a high spatial resolution supports the validity of the ODIAC spacebased emission downscaling. To further improve the accuracy of the emission downscaling, we have explored the use of other space-based data such as NASA's new Visible Infrared Imaging Spectrometer Suite (VIIRS) Nighttime Environmental Product (nightlight) and LandSat data. We confirmed the excellent performance of the VIIRS nightlight data in spatial emission allocations at regional scales as well as spatial pattern depictions of emissions at urban scales from an extensive comparison to a fine-grained country emission inventory as well as high-resolution WRF transport model simulations. A new feature to be incorporated in modeling the distribution and partition of CO2 is a breakthrough by the patented Dense Sampling Method for satellite radar observations of global urbanization in three dimensions, including lateral sprawl and vertical build-up. The ability to create global high-resolution spatial emissions patterns from emissions reported on a country basis is one of the key elements of future Monitoring and Verification Support (MVS) scientific systems that consist of carbon data assimilation. Our advanced satellite-based emission downscaling model holds the promise of playing a critical role in such future systems.

A1.1-0029-18 MEASURING METHANE FROM ORBIT WITH A LIDAR: CHALLENGES AND PROGRESS

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The global and regional quantification of methane fluxes and identification of its sources and sinks has been highlighted as one of the goals of the 2017 Earth Science Decadal Survey. Detecting methane from space with an active (laser) remote sensing instrument presents several unique technology and measurement challenges. The instrument must have a single frequency, narrow-linewidth light source, and photon-sensitive detector at the right spectral region to make continuous measurements from orbit, day and night, all seasons and at all latitudes. It must have a high signal to noise ratio and must be relatively immune to biases from aerosol/cloud scattering, spectroscopic and meteorological data uncertainties, and instrument systematic errors. The technology needed for a spaceborne mission is currently being developed by NASA and industry. At Goddard Space Flight Center (GSFC), we have developed an airborne instrument to measure methane. Our instrument is a nadir-viewing lidar that uses Integrated Path Differential Absorption (IPDA), to measure a methane vibration-rotational line near 1.65 m that is relatively free of interferences from other trace gases. We sample the absorption line using multiple wavelengths from a narrow linewidth laser source and a sensitive photo detector. This measurement approach provides maximum information content about the vertical distribution of CH4, minimum bias, and sensitivity to atmospheric temperature uncertainty in XCH4 retrieval. However, technical and measurement challenges remain. In this paper, we will review our progress to date and discuss the technology challenges, options and trade offs to measure methane from space.

A1.1-0030-18 RETRIEVAL OF ELEVATED ATMOSPHERIC CARBON DIOXIDE CONCENTRATION FROM AVIRIS-NG DATA USING RADIATIVE TRANSFER MODEL: A CASE STUDY OVER A POWER PLANT AT KOTA, INDIA

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Carbon dioxide (CO2) is one of the major greenhouse gases that has increased significantly in pre and post-industrial times and this rise has caused positive radiative forcing resulting in increased global temperature. Observing atmospheric CO2 concentration through spaceborne platform is very important and many Earth observing satellite missions have been designed to detect atmospheric CO2 since mid-1990s. The satellite missions with variety of sensors have the capability to map CO2 concentration on global scale with relatively coarse spatial resolution. However, spaceborne sensors can't provide very fine spatial resolution required to detect CO2 plumes from the point sources. In such cases, airborne hyperspectral instruments with high spatial resolution at each pixel can detect CO2 plumes from the point sources. Imaging spectroscopy through the Airborne Visible/Infrared Imaging Spectrometer Next Generation (AVIRIS-NG) instrument has the capability of retrieving CO2 concentration by measuring the reflected radiance in 380-2510 nm spectral range with a spectral sampling of 5 nm, fine spatial resolution and high signal to noise ratio. Potential of AVIRIS-NG has been used in the present study to retrieve the atmospheric CO2 concentration using radiative transfer modelling from a power plant site located in Kota, India during ISRO-NASA joint airborne hyperspectral science campaign. The method used in the present study involves theoretical simulations of at-sensor radiance in AVIRIS-NG spectral bands by an atmospheric radiative transfer (RT) model. MODTRAN 5.3 was used to simulate the systematic variations occurring in at-sensor radiance due to increased carbon dioxide concentration varying from 25 ppmv to 1600 ppmv. The basis of the retrieval technique is that CO2 absorption lines in the spectrum are related to the CO2 concentration in the atmospheric column, the higher the gas concentration, the deeper are the gas absorption lines. Simulation exercise was performed for the specific scene-sensoratmospheric conditions corresponding to AVIRIS-NG pass over Kota site on 4th February, 2016. In order to incorporate the effect of interfering atmospheric water vapour, a variation in the water vapour values ranging from 0.25 to 4.5 g/cm^2 was also used in the simulations. Using the distinct absorption bands of CO2 in shortwave infrared spectral range of AVIRIS-NG radiance data, a theoretical model was developed between continuum interpolated band ratio (CIBR) and CO2 concentration. Once the set CIBR-CO2 model coefficients for each of the water vapour sub-ranges was developed, it was applied to AVIRIS-NG L1 radiance data over Kota. A CO2 concentration map was generated for the site, which also contains the Kota Super Thermal Power Station (KSTPS). The CO2 concentration (XCO2) ranging from 360 ppmv to 525 ppmv was observed within the scene. Elevated CO2 plumes having XCO2 value more than 500 ppmv were clearly detected near the KSTPS stacks. The study has provided encouraging results for the retrieval of atmospheric CO2 concentration from the AVIRIS-NG data, however detailed analysis is in progress to incorporate the effect of varying surface reflectance in the retrieval. Attempts are also underway to apply the Cluster-Tuned Matched Filter technique for detection of CO2 plumes in AVIRIS-NG data.

A1.1-0031-18 INFLUENCE DUE TO CIRRUS AND THICK AEROSOL ON ESTIMATION OF COLUMN CO2 AND CH4 WITH GOSAT/FTS DATA

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Influence due to cirrus and thick aerosol on estimation of column CO2 and CH4 with GOSAT/FTS data Kohei Arai1, Takashi Higuchi1, Hiroshi Okumura1, Hirofumi Ohyama2, Shuji Kawakami3, Kei Shiomi3 1: Saga University, 2: National Institute of Environmental Science, 3: JAXA Influence due to cirrus and thick aerosol on estimation of column CO2 and CH4 with GOSAT/FTS data is clarified. Relatively large estimation errors are observed in column CO2 and CH4 retrievals with FTS data in some atmospheric conditions. In order to find such cases, retrieval results and quality/cloud flags in the GOSAT/FTS data products are checked. Through the investigation, it is found that relatively large error is caused by convergence problem due to cirrus clouds and thick aerosols. In the proposed paper, some of the cases of which relatively large estimation error is occurred at the Saga TCCON site are investigated. Also, a comparative study is conducted between standard products provided by NASA/JPL and the Levenberg-Marquardt based least square method of column CO2 and CH4 retrieval. It is suggested that some improvements of estimation accuracy of column CO2 and CH4 retrieval with GOSAT/FTS data can be expected.

A1.1-0032-18 SEASONAL AND ANNUAL VARIATION OF AIRS RETRIEVED CO2 OVER INDIAN REGION DURING 2003-2016

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The present study shows spatio-temporal variability in carbon dioxide (CO2) in the midtropospheric region over India (0-32N, 60-100E) during 2003-2016. CO2 data used in the study is retrieved from Atmospheric Infra-Red Sounder (AIRS). Analysis of 14 years of data shows that the CO2 exhibits a linear increasing trend of 2.01 ppm/year. Besides displaying the linear increasing trend, data show strong seasonal and annual variability. Concentration of CO2 is observed to be highest around April-May (summer months), which decreases by 4-5 ppm during the monsoon months. Seasonal decrease in CO2 concentration appeared to be influenced by the monsoonal activity. Low OLR (proxy of convection) associated with high rainfall during summer monsoon via increasing vegetation index (NDVI) appears to be the primary cause for the seasonal decrease in CO2 through photosynthesis. Correlation coefficient between Co2 and NDVI is of the order of -0.90 suggesting vegetation as a seasonal sink of Co2. Decrease in Co2 concentration takes place at a delay of 2-3 months of rainfall. However, convection seems to be another component, which causes uplifting of Co2 during dry summer (April-May) making high concentration in the mid troposphere as shown by increase in the planetary boundary layer (PBL) height in this period. Eastward propagating intra-seasonal oscillations with period 30-40 days in OLR anomalies are found to modulate (with a fluctuation of 1-2 ppm) mid-tropospheric CO2. Analysis of seasonal anomalies in CO2 over four different regions (Northern, Southern, Western and Eastern) of India is also being investigated. The regional variability of CO2 in northern region show marginal larger values suggesting more anthropogenic activities especially during late winter.

A1.1-0033-18 OPERATIONAL GEOPHYSICAL VALIDATION OF COPERNICUS SENTINEL5P TROPOMI

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The European Union's Copernicus Earth Observation programme provides operationally advanced information services on our environment and security based both on satellite and nonspace data. Launched on October 13, 2017, European Space Agency (ESA)'s Sentinel-5 Precursor (Sentinel-5p) is the first atmospheric composition satellite of this programme. On board, developed jointly by ESA and the Netherlands Space Office (NSO), the UV/VIS/NIR/SWIR spectrometers of TROPOspheric Monitoring Instrument (TROPOMI) measure on the global scale, on a daily basis, and at unprecedented horizontal resolution the atmospheric abundance of species related to air quality, climate forcing, ozone, UV radiation and volcanic hazards: O3, NO2, HCHO, SO2, CO, CH4, clouds, aerosols. The Sentinel-5p ground segment development has been funded by ESA and with national contributions from The Netherlands, Germany, and Belgium. Part of this ground segment, the Validation Data Analysis Facility (VDAF) of the Sentinel-5p Mission Performance Centre (MPC) aims at providing a routine TROPOMI validation service to ESA, Level-2 data developers, Copernicus services and other data users. Building upon the heritage of two decades of geophysical validation applications for precursor instruments (GOME, SCIAMACHY, OMI, GOME-2) and on recent advances in Cal/Val practices and operational validation systems, VDAF has been tailored to the TROPOMI and Copernicus needs. It ingests Fiducial Reference Measurements (FRM) archived at ESA's Validation Data Centre (EVDC) and collected from high-quality ground-based monitoring networks (GAW GO3OS, EARLINET, NDACC, TCCON.), and it compares them to TROPOMI data following community-endorsed protocols.

In this paper we present plans for the operational geophysical validation of TROPOMI data, with highlights on the heritage and the advances implemented in the VDAF system, and with illustrative initial results. Nine months only after the launch of the satellite, those initial results are based on preliminary (not fully calibrated/validated) Sentinel-5p data that will still change in the near future.

A1.1-0034-18 LONG-TERM VALIDATION FOR THE ATMOSPHERIC CHEMISTRY EXPERIMENT (ACE) SATELLITE MISSION

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The Canadian-led Atmospheric Chemistry Experiment (ACE) satellite mission has completed fourteen years of measurements from orbit. It uses infrared and UV-visible spectroscopy to investigate the chemistry and dynamics of the Earth's atmosphere. The two instruments on-board are the ACE Fourier Transform Spectrometer (ACE-FTS), a high-resolution (0.02 cm−1) FTS operating between 750 and 4400 cm−1, and a dual UV-visible-NIR spectrophotometer called ACE-MAESTRO (Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation), which extends the ACE wavelength coverage to the 280-1030 nm spectral region. The ACE instruments make solar occultation measurements from which altitude profiles of atmospheric trace gas species, temperature and pressure are retrieved. The 650 km altitude, 74 degree circular orbit provides global measurement coverage with a focus on the Arctic and Antarctic regions. This paper will describe recent validation results for the ACE-FTS and ACE-MAESTRO data sets and describe the analyses that are being undertaken to characterize the ACE-FTS data to enable the generation of climate data records.

A1.1-0035-18 SPARC-LOTUS: QUANTIFICATION OF THE LONG-TERM STABILITY OF GROUNDAND SPACE-BASED STRATOSPHERIC OZONE DATA RECORDS

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Our understanding of the stability of ground-based and space-based ozone profile data records remains an important issue in monitoring the state of the atmospheric ozone layer. Recent assessments by WMO and by LOTUS (Long-term Ozone Trends and Uncertainties in the Stratosphere), a research activity supported by SPARC (http://www.sparc-climate.org/activities/ozonetrends), have concluded that there is now substantial observational evidence of increasing upper stratospheric ozone concentrations since the late 1990s, although magnitude and significance of the positive trend vary depending on the data record considered (WMO, 2014; SPARC, 2018). This observational variance in upper stratospheric data limits our ability to test and refine chemistry-climate model predictions for policy making. Also, a recent analysis of satellite measurements indicated, quite unexpectedly, that lower stratospheric ozone has declined continuously since the mid 1980s at mid and low latitudes (Ball et al., 2018). If the latter finding is correct, it may uncover an unexpected gap in our understanding of the physical and chemical processes that govern ozone. Obtaining independent confirmation by analyses

of other data records, e.g. from ground-based instruments, and by using different analysis techniques will be key in establishing observational evidence for this decline. Both issues illustrate the need for continued investigations of the agreement between available ozone profile data records, in order to identify potential issues in the data records and determine their strengths and limita- tions. This should ultimately pave the way to improved data records and lead to more informed interpretation of analysis results.

We present results of a coherent, comprehensive comparative analysis of present ozone profile data records acquired from space (limb and occultation sounders) and from the ground (GAW/NDACC/SHADOZ-affiliated sonde, stratospheric lidar and microwave radiometer sites). We show updated estimates of drift of individual satellite data records relative to ground-based network data (Hubert et al., 2016). This analysis was recently extended -in the framework of ESA's Climate Change Initiative and the EC Copernicus programme - to gridded, monthly averaged profile data. We present first results of the stability of ten gridded single-sensor and of the merged SAGE-CCI-OMPS stratospheric ozone datasets (Sofieva et al., 2017). In return, the satellite data are used to identify inhomogeneities in time and space in the ground-based time series. Some of these coincide with known instrument or measurement changes in the network, other features have -so farno clearly identified cause. Such changes add to the challenge to derive unbiased ozone trends from ground-based observations and they impede our ability to constrain satellite drift to the level required for current and future ozone trend assessments. This clearly shows the need to continue ongoing efforts to homogenise the ground-based data records.

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A1.1-0036-18 OSSSMOSE: MULTI-PURPOSE SIMULATOR WITH EXPLICIT METROLOGY FOR GLOBAL OBSERVING SYSTEMS OF ATMOSPHERIC COMPOSITION

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The geographical and vertical distribution of atmospheric species is monitored on the pseudoglobal scale by complementary satellite remote sounding instruments and by airand groundbased networks. Due to its particular spectral range, viewing geometry and other properties, every measurement technique samples and smoothes differently the vertical and horizontal distribution of an atmospheric species. Those sampling and smoothing properties can affect the interpretation of the data, as well as the comparison of two different data sets for validation purposes, in data merging, and in chemical data assimilation schemes. While vertical sampling and smoothing properties of atmospheric remote sensing have been studied for decades and are usually taken into account in scientific applications, horizontal smoothing has become a subject of interest more recently with the advent of high resolution satellite instruments like Sentinel-5p TROPOMI launched in October 2017 and the future constellation of geostationary air quality satellites (GEMS, TEMPO and Sentinel-4). On top of the sampling and smoothing properties of a single measurement, every global measurement system also samples differently the structures, cycles, trends and other features of the global atmosphere. Therefore, Observing System Simulation Experiments (OSSE) have been developed to better account for the different sampling properties of global observing systems and to better understand their value added in applications like chemical data assimilation.

Coupling the OSSE approach with recent advances in the multi-dimensional metrology of atmospheric remote sensing, "Observing System of Systems Simulator for Multi-missiOn SynErgies" (OSSSMOSE) is a versatile software environment designed to provide realistic simulations of the output of both real and hypothetical global observing systems for atmospheric composition. It is based on a suite of: (i) state-of-the-art description of multi-dimensional sampling and smoothing properties of key measurement techniques; (ii) recent developments in metadata catalogues of global measurement systems; and (iii) the OSSE approach based on global reanalysis data sets (ERA, MERRA.) OSSSMOSE will be described and its application illustrated in a few domains of current interest: the quantification of sampling and smoothing errors in global data records of atmospheric ECVs, the error budget closure of atmospheric data comparisons, and the design of satellite validation strategies including optimization of co-location criteria.

A1.1-0037-18 VALIDATION OF MOBILE IN SITU MEASUREMENTS OF DAIRY HUSBANDRY EMISSIONS BY FUSION OF AIRBORNE/SURFACE REMOTE SENSING WITH SEASONAL CONTEXT FROM THE CHINO DAIRY COMPLEX

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University of Maryland Baltimore County, Baltimore, Maryland, United States Mobile in situ gas concentration and meteorology data were collected for the Chino Dairy Complex in the Los Angeles Basin by AMOG (AutoMObile trace Gas) Surveyor on 25

June 2015 to characterize husbandry emissions in the near and far field in convoy mode with MISTIR (Mobile Infrared Sensor for Tactical Incident Response), a mobile upwards-looking, column remote sensing spectrometer. MISTIR provided reference fluxes to validate AMOG plume inversions, which considered different levels of information including multiple gases, Google Earth, and airborne trace gas remote sensing data. Long-term (9-yr.) satellite measurements by the Infrared Atmospheric Sounding Interferometer provided spatial and temporal context.

For the Chino Dairy Complex (one to two hundred thousand cattle), MISTIR-AMOG ammonia (NH_3) agreement was within 5% (15.7 versus 14.9 Gg yr^{-1}, respectively) using all information sources. The remaining discrepancy could be accounted for by increasing the turbulence class by 5%, likely due to higher turbulence from structures. CH_4 emissions were 30 Gg yr^{-1}.

Single dairy inversions were less successful, with 57% AMOG-MISTIR agreement due to wind heterogeneity (convergence and divergence) from downwind structures in these near-field measurements, along with emissions unsteadiness. AMOG CH_4, NH_3, and CO_2 emissions were 91,

209, and 8200 Mg yr^{-1}, implying 2480, 1870, and 1720 head of cattle. Plumes were fingerprinted and attributed to likely source locations that included manure storage, cowsheds, and a structure with probable natural gas combustion.

NH_3 downwind of Chino showed seasonal variation by a factor of ten, three times larger than literature suggests. Higher emissions were proposed to result from legacy soil emissions resulting from a century of husbandry. This conclusion was supported by airborne remote sensing data showing widespread emissions from neighborhoods that were dairies 15 years prior, and also combined AMOG and MISTIR observations. Seasonal variations provide insights into the implications of global climate change and must be considered when comparing surveys from different seasons.

A1.1-0038-18 TEMPERATURE AND WIND MEASUREMENTS IN THE STRATOAND MESOSPHERE BY LIDAR: GRAVITY WAVES AT THE POLAR NIGHT JET.

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Measurements of wind and temperature in the stratosphere and mesosphere are crucial for understanding the dynamics in the middle atmosphere. However wind measurements covering the range of 20 to 70 km are challenging and only very few methods are capable to derive winds and temperatures with sufficient vertical and temporal resolutions for gravity-wave studies.

It was recently found that the polar vortex in the stratosphere (polar night jet) is linked to the global surface temperatures and that the vortex is affected by energy and momentum transported by planetary and gravity waves. Waves in the atmosphere are usually seen as perturbations of wind and temperature. For gravity waves the relation between the quantities is simple in an atmosphere at rest. For example the time evolution of a vertical profile of temperatures gives enough information to deduce upward and downward energy transport. In a situation with atmosphere motions, eventually changing with altitude and time, the relation between wind and temperature perturbations is more complicated. Such situations are typical in the vicinity of the polar night jet. Combined temperature and wind observations enable characterization of inertia-gravity waves (IGW) even in changing background wind situations.

In this work we use the phase relation between both zonal and meridional wind components, and temperature. The method is based on localized linear theory of gravity waves and has been used to determine the intrinsic frequency, propagation direction, and phase velocity of IGW. The main challenge for this method is the identification of nearly monochromatic waves. We developed an approach that isolates one dominating wave in a limited altitude range. This allows analyzing IGW individually and subsequently applying different averaging to selected IGWproperties. We show measurements performed at the ALOMAR research station in northern Norway (69°N, 16°E) in winters 2012 to 2016. In January 2016 the observations were performed while the polar night jet introduced a large shear above the lidar station leading to a complicated but striking situation for up and downward propagating gravity waves.

A1.1-0039-18 VARIATION OF HO2 AND HCL IN MLT (MESOSPHERE AND LOWER THERMOSPHERE) REGION

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Chemical and Dynamical behavior of HO2 radical, a key atmospheric oxidant, and HCl, oxidant depleting species, has an important role for the chemistry in the mesosphere and lower thermosphere (MLT) region. There has been no observation evidence for the vertical behavior of HO2 and HCl simultaneously near the mesopause region. We retrieve vertical profile of HO2 and HCl up to about 100km with new algorithm from spectra measured using the Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) on the Japanese Experiment Module (JEM) of the International Space Station (ISS) between 12 October 2009 and 21 April 2010. We improved the internal consistency between vertical profile of atmospheric species, temperature/ pressure, and altitude to use of "one" atmosphere for from ground to upper thermosphere from the model named GAIA (Ground-to-topside model of Atmosphere and Ionosphere for Aeronomy) for the retrieval calculation. New products are named SMILES NICT level 2 product version 3.0.0 (L2 ver. 3.0.0). The quality of the L2 ver.3.0.0 were assessed t by comparing with several model calculations. We for the first time revealed a diurnal variation of HO2 in the mesosphere and mesopause. The interesting chemical mechanism of HO2 in mesopause is explained by comparing with simple 1D model calculations by us, qualitatively. We also found the cause of latitudinal and seasonal variation of HCl in the lower thermosphere is due to various dynamical process in the MLT region, including semi-annual oscillation and intraseasonal oscillation.

A1.1-0040-18 SEASONAL, INTERANNUAL AND LONG-TERM VARIABILITIES AND TENDENCIES OF WATER VAPOUR IN THE UPPER STRATOSPHERE AND MESOSPHERIC REGION OVER TROPICS (30°N-30°S)

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Tropical water vapour volume mixing ratio (WVMR) data for October 2004-September 2015 obtained from the Microwave Limb Sounder are used to study its long-term variabilities and tendencies in the height region 12.1-0.002 hPa. Above 0.01 hPa, the WVMR shows minimum March-May and September-November (0.7-0.8 ppmv) and maximum during June-August. It shows a large interannual variability at 31-64 km. The results from multivariate regression analysis show an increasing trend with maximum value of 0.045 ppmv/yr at 1.21-0.41 hPa. It shows a significant negative solar cycle response at mesospheric heights.

A1.1-0041-18 N2O PRODUCED IN THE MESOSPHERE - LOWER THERMOSPHERE AND ITS EFFECT ON O3 AND NOX IN THE MIDDLE ATMOSPHERE

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The satellite limb sounder ACE-FTS (Atmospheric Chemistry Experiment - Fourier Transform Spectrometer) is a solar occultation instrument that has been measuring trace gases and temperatures in the atmosphere since February 2004 and is still in operation. Throughout the mission, ACE-FTS has been measuring N2O concentrations in the mesosphere - lower thermosphere (MLT), which increase with altitude in the mesosphere. N2O has been hypothesised to be produced at high latitudes through energetic particle precipitation, and this study will compare the ACE-FTS N2O time series to simulations with the Whole Atmosphere Community Climate Model (WACCM) in different configurations to test possible N2O production mechanisms. WACCM-D (version with detailed ion chemistry in the lower D region of the ionosphere) will be used in a specified dynamics mode where temperature and wind values below 60 km are nudged towards reanalysis fields. The SD-WACCM-D runs will be modified to include the ion chemistry that can lead to N2O production in the MLT. In separate experiments, an updated version of WACCM but with simplified ion chemistry will be used to look at the potential additional role of photoelectrons in producing the MLT N2O, particularly at extra-polar latitudes. For both model versions, runs spanning the ACE-FTS time series with and without the relevant N2O production chemistry will be compared to ACE-FTS profile measurements in order to better understand how N2O is created in the MLT and its effects on O3 and NOx budgets throughout the middle atmosphere.

A1.1-0042-18 CUAD: CONSTELLATION FOR UPPER ATMOSPHERE DYNAMICS

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The dynamical coupling of lower to upper atmosphere has become an intense research topic. It is now quite clear that the lower atmosphere continuously imprints its dynamical state onto the upper atmosphere in the form of winds and waves. This signature from the dense lower atmosphere dynamically expands into the thin upper atmosphere like tsunamis coming ashore. The resulting waves and winds, if adequately observed, could be used not only to reveal their effects on the upper atmosphere, but to help monitor and forecast the evolution of lower atmosphere weather. This would require global observation from orbit, quite a challenge due to the required space and time resolution. Until now, such observations have been limited to Earth limb sensors (ex: GPS-RO and thermal imagers), which have an intrinsic horizontal resolution of 100 to 200 km. As a result, wave field measurements are smeared in time and space to the point of limited value for forecasting. But, if these upper atmosphere signatures could be resolved, it has been shown by a variety of groups that those wave and wind fields would act as powerful boundary conditions on forecast models. We show that new and enabling technologies, and a novel observation technique (gas filtered Doppler scanning, see Gordley and Marshall 2011), now make it possible to observe these parameters at resolutions required to fill this measurement deficiency. The proposed Constellation for Upper Atmosphere Dynamics (CUAD) could observe the upper atmosphere on a global scale at a resolution sufficient to resolve the dynamical connection of lower to upper atmosphere. This can now be accomplished with four types of simple static broadband emission imagers, two of which are gas filtered. The first sensor is a gas filtered broadband nadir emission imager, HATS™ (High Altitude Thermal Sounder). The second is a simple broadband limb emission radiometer LCER™ (Limb CO2 Emission Radiometer). The third is a gas filtered limb emission radiometer, DWTS™ (Doppler Wind and Temperature Sounder). The fourth is a star field limb imager, TStar™ (Temperature sounder using Star field images). These 4 imagers have a unique synergistic connection that eliminates the need for on-board calibration systems. Plus, each sensor technique, though new in its implementation, has space heritage. Finally, we show results of rigorous performance estimates, and describe how modern detector FPAs, satellite bus ADCS, processor power and downlink bandwidth have come together to enable a complete system calibration anchored to the refractive index of

air. This dramatically simplifies the hardware, and insures reliable observation of long-term trends. The talk will conclude with a list of major CUAD challenges and research needed for their solutions.

Gordley, L. L., Benjamin T. Marshall, "Doppler Wind and Temperature Sounder: A new approach using gas filter correlation radiometry", JARS, Vol 5, 2011.

A1.1-0043-18 MIGHTI (MICHELSON INTERFEROMETER FOR GLOBAL HIGH-RESOLUTION THERMOSPHERIC IMAGING): THE WIND AND TEMPERATURE INSTRUMENT ONBOARD THE NASA IONOSPHERIC CONNECTION (ICON) MISSION

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The Michelson Interferometer for Global High-resolution Thermospheric Imaging (MIGHTI) is one of four instruments on the NASA Ionospheric Connection (ICON) Explorer mission currently scheduled for launch in 2018. ICON will investigate the extreme variability of the Earth's ionosphere with a unique combination of sensors on-board a single low Earth orbit satellite. The MIGHTI instrument will measure the global distribution of neutral winds and temperatures over an altitude range not accessible to in-situ probes using the Doppler Asymmetric Heterodyne Spectroscopy (DASH) technique for the wind measurements and a multi-color photometer technique to measure temperature. In this presentation, we discuss the instrument concept, design challenges and achievements, as-built specifications, and the anticipated data from orbit.

A1.1-0044-18 A HIGHLY MINIATURIZED SATELLITE PAYLOAD FOR THE OBSERVATION OF TEMPERATURES IN THE MESOSPHERE AND LOWER THERMOSPHERE

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A highly miniaturized limb sounder for the observation of faint emissions in the atmosphere is presented. The selected technology is a Spatial Heterodyne Spectrometer (SHS). The throughput of a SHS is orders of magnitude larger than of a conventional grating spectrometer of the same size. Its monolithic design makes it extremely robust against vibrations and shocks. It can be designed to deliver spectra at very high spectral resolution to resolve individual emission or absorption lines, or even Doppler shifts to derive winds. The small mass and low energy consumption makes SHS instruments particularly suitable for the deployment on nano-satellites or as secondary payloads on larger satellites. In this presentation we introduce an instrument design for the measurement of temperature in the mesosphere and lower thermosphere by observing the rovibrational structure of the O2 atmospheric band at 762 nm in limb viewing geometry. This instrument is suited to fly on a 3-6 unit Cubesat or as a secondary payload on a larger satellite. To increase the horizontal resolution of the measurements, new observation strategies to operate such an instrument from an agile satellite platform are discussed.

A1.1-0045-18 THE MATS SATELLITE MISSION - TOMOGRAPHIC STUDIES OF CONSTITUENTS AND GRAVITY WAVE CHARACTERISTIC IN THE UPPER MESOSPHERE AND LOWER THERMOSPHERE

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MATS is an upcoming Swedish satellite mission designed to investigate structures and gravity waves in the mesosphere lower thermosphere. It will do so by observing O2 atmospheric band airglow in the near infrared (759-767 nm) and sunlight scattered from noctilucent clouds in the ultraviolet (270-300 nm). The main instrument is a limb imager with 6 spectral channels. Via tomographic retrieval the observed images will yield 3-dimensional data of airglow, temperature and cloud properties, allowing studies of gravity wave structures, wave parameters and variability. Scheduled for launch next year we are now in the phase where the flight models of the instruments are being assembled, and the data retrieval algorithms are being developed. While focusing on the scientific mission and analysis ideas this presentation therefore also reports on the current status and progress of the project.

A1.1-0046-18 GLOBAL 3D IONOSPHERE OBSERVATION SYSTEM BASED ON THE LEO NANOSATELLITE CONSTELLATION

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Ionospheric variability is strongly affected by the perturbations in the neutral atmosphere, electrodynamics, solar activity, geomagnetic activity and constantly fluctuates in a global scale. To improve and validate ionosphere numerical models, measurements taken by the individual satellite are used. To have higher spatial/temporal resolution, higher accuracy and lower cost than a system utilizing Global Navigation Satellite Systems (GNSS), we propose a constellation of nanosatellites to the LEO to do inter-satellite ranging to measure the total electron content (TEC) along the path. The electron density distribution will be known by the solving the inverse problem from many observations. This system aims at measuring ionosphere density with a spatial resolution of 15 km, a temporal resolution of 30 minutes with 1,000 CubeSats in different orbital planes in LEO. These target values have, much higher accuracy than GNSS and can be achieved with much lower cost than using GNSS system. Inter satellite ranging is the next generation technology that also can improve the accuracy of GNSS positioning. Currently, the first path-finder satellite, SPATIUM-I, is under development. SPATIUM-I will validate the key technologies, such as Chip-Scale Atomic Clock and the spread-spectrum modulated RF signal transmission as well as derivation of TEC.

A1.1-0047-18 A ROAD TOWARDS EARTHCARE: REMOTE SENSING OF ICE CLOUD PROPERTIES USING COMBINED LIDAR-RADAR MEASUREMENTS

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Ice clouds play an essential role in the climate system since they have a large direct effect on the Earth's radiation budget. Their reaction to changes in water vapor concentrations and their interaction with aerosols still constitutes one of the largest uncertainties in climate change predictions. These uncertainties arise from uncertainties associated with the optical and microphysical properties of ice clouds as well as from insufficient knowledge about their spatial and temporal distribution.

Substantial improvement of our understanding of the interconnection of aerosols, clouds and radiation is expected from the combination of multiple instruments exploiting sensitivities at different wavelengths. To this end, the upcoming ESA/JAXA satellite mission EarthCARE will combine a new generation spaceborne lidar system, a cloud radar, and a multi-spectral imager on one single platform. In our work, we investigate the potential to combine lidar and radar measurements to retrieve ice cloud microphysics. For the first time, this study combines the high spectral resolution (HSRL) and differential absorption (DIAL) lidar system WALES and the 35 GHz cloud radar onboard the German High Altitude and LOng range research aircraft to retrieve ice cloud properties. During flight experiments over Europe and over the extra-tropical North-Atlantic (NARVAL1-2/NAWDEX), collocated measurements with the spaceborne CALIPSO/CALIOP lidar and CloudSat radar are used to investigate the influence of different wavelengths and spatial resolutions on retrieved ice cloud properties.

In our presentation, we will give first results of the synergistic approach using the differential sensitivity of the WALES lidar and the cloud radar to retrieve ice particle size and their concentration. Here, the central focus will be on the coordinated airborne and satellite measurements and on the comparison of retrieved ice cloud microphysics in preparation for the EarthCARE mission. In a

closure study with simultaneous solar radiance measurements and by comparison to in-situ the results of the synergistic approach will be furthermore evaluated.

A1.1-0048-18 MEGHA-TROPIQUES SCARAB OBSERVATIONS OF THE SEASONAL MEAN DIURNAL VARIATION OF CLOUD RADIATIVE FORCING OVER THE TROPICS

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Clouds are the largest modulators of earth energy balance. They play a major role in regulating energy and moisture transport, hydrological cycle and climate of the earth-atmosphere system. Cloud radiative forcing (CRF), defined as the change in radiative fluxes (shortwave, longwave or net) caused by the presence of clouds compared to when they are absent, varies with cloud properties and local time. Model estimation of cloud radiative forcing (CRF) is quite complex. Satellite observations of the upwelling shortwave and longwave radiative fluxes, on the contrary, provide the most reliable observations on CRF at TOA and their spatio-temporal variations. Diurnal variation of CRF cannot be estimated using observations made from polar sun-synchronous satellites. Observations carried out using the ScaRaB payload flown onboard the low-inclination (20°) Indo-French Megha-Tropiques (MT) satellite enable multiple observations of a given geographical location during the day, which can be used to address this objective. The results are in agreement with the CERES observations at 01:30 and 13:30LT (when the latter is available). The LWCRF shows intensification and deepening of organized convection during night, especially over the deep convective oceanic regions. Large meridional gradient of LWCRF occurs across the ITCZ, magnitude of which often exceeds 10 Wm−2 per degree latitude. In contrast, the convection intensity reduces significantly during the morning and noon period. This results in a diurnal variation of LWCRF with amplitude of about 10 to 20 Wm−2, which is over 20% of the magnitude of mean LWCRF over deep convective regions.

Over the deep convective areas (mainly in the ITCZ), though the peak noontime SWCRF exceeds 200 Wm−2, the diurnal mean SWCRF are comparable to the corresponding LWCRF.

The relationship between the instantaneous values of SWCRF and LWCRF for deep convective clouds is distinctly different from the other cloud types. Regions of major cooling are associated

with the occurrence of widespread and thick low level clouds. In addition to this, estimation of CRF during the normal and ElNino years is also investigated.

A1.1-0049-18 A COMPREHENSIVE VIEW ON THE CLOUD TYPE DISTRIBUTIONS IN SYNOPTIC AND MESOSCALE SYSTEMS OVER THE INDIAN SUMMER MONSOON REGION USING CLOUDSAT OBSERVATIONS

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Clouds have an enormous influence on the Earth's energy balance, climate and weather and play a key role in controlling the planet's temperature. The observations of clouds are more important for improving and validating the numerical models of Earth's weather and climate predictions. There has been plethora of studies on the spatial and vertical distribution of clouds using various satellites observations, which have enhanced the understanding of cloud dynamics and their representation in general circulation models. However, one of the outstanding research problems in realms of cloud dynamics is the vertical distribution of various types of cloud and multi-layered cloud distribution and their associated dynamics, which are yet to be understood thoroughly. In this regard, the present study quantifies the frequency of occurrence of the vertical distribution of various types of cloud and their associated dynamics over the Indian Summer Monsoon (ISM) region using CloudSat observations from 2006 to 2010. It provides the preferential regions of occurrence of each cloud type over the ISM region for the first time. The mean distribution of cirrus clouds emphatically showed the role of Tropical Easterly Jet in spreading the anvils of Deep Convective clouds forming over the head Bay of Bengal (BoB). It is observed that the stratocumulus clouds form most frequently over the north Arabian Sea and are confined to a narrow region. The distribution of DC clouds showed a pronounced peak in their occurrence frequency overhead BoB and secondary peaks over western coast, south BoB and central India. The prevailing dynamical features during the ISM period are studied in details to investigate their role in preferential formation of these clouds in a given region.

Further, using CloudSat observations, the distribution of vertically resolved multi-layered clouds and the role of large scale dynamics in controlling the formation of multi-layered cloud are studied. It is observed that over the Indian region one-, two-, three-, fourand five-layer clouds occur about 46, 26, 10, 4 and 2% of the time respectively. High fraction of single layer clouds is observed over the descending limbs of Hadley cell where relatively large lower tropospheric stability is found. It is found that the maximum occurrence of multilayer clouds migrates along with the movement of Inter tropical convergence zone (ITCZ). Apart from the equatorial region, multilayer clouds are observed more frequently over Indian summer monsoon region and mid-latitude storm tracks. The significance of the present study lies in establishing the vertical distribution of various types of cloud and distribution of vertically resolved multi-layer clouds and the role of dynamics

in modulating their distribution for the first time. It is envisaged that the present results may help in better understanding of cloud feedback mechanisms.

A1.1-0050-18 STUDY OF MICROPHYSICAL AND OPTICAL PROPERTIES OF LOW-HEIGHT WARM-CLOUD FROM MODIS LEVEL-2 DATA OVER INDIAN LANDMASS

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Satellite retrievals of cloud properties play very important role in understanding impact of cloud system on earth's radiation budget and on climate systems. Cloud effective radius and cloud optical thickness, estimated from non-absorbing and absorbing wavelengths, are the two most important independent variables retrieved from sensors on-board many satellites including Earth Observing System (EOS) satellites Terra and Aqua. From cloud effective radius and cloud optical thickness other properties can be derived like cloud liquid water path, droplet number concentration etc. In my present study, MODIS level-2 cloud product from Terra have been used to asses micro-physical and optical properties of low-height, single-layer warm-clouds over entire landmass of India. Certain conditions were imposed in selecting cloud scenes to make sure that we choose liquid-only warm-cloud scenes. Cloud top height was set less than 2 km, cloud top temperature was set greater than 0°C and cloud effective radius was chosen to be within 3 to 30 mum. Such cloud scenes of an entire year have been utilized to study cloud effective radius, cloud droplet number concentration, cloud liquid water path and cloud geometrical thickness. MODIS level-2 cloud property data have been assessed for a whole year (2013 Nov 2014 Oct) over entire landmass of India. Data pixels averaged over 0.2 x 0.2 degree grid for latitude 10 to 30 and longitude 70 to 90. Comparative analysis of these properties also carried out for different climatic regions of India. Three different regions from west to east in the Indo-Gangetic plane have been chosen for this study. Three regions were designated as zone-1 to zone-3 respectively and they approximately fall in Arid, Humid subtropical and Tropical wet and dry regions. In our study, it is revealed that annual average cloud effective radius is lowest (7.5 mum) for zone-1 which falls approximately in arid region and highest for zone-3 (9.5 mum) i.e, increases form west to east. Droplet number concentration varies form 320/cc (zone-1) to 200/cc (zone-3). But in case of cloud liquid water path zone-1 shows lowest value (63 g m−2) and other zones more or less same value (sim 75 g m−2). Annual average of cloud optical thickness and cloud geometrical thickness is highest for zone-2. To best of my knowledge, such quantitative estimation and comparative analysis of cloud microphysical and optical parameters for low-lying warm-clouds over this region, is first of its kind.

A1.1-0051-18 SEASONAL VARIATION IN RAINDROP VELOCITY DISTRIBUTION AND ITS VERTICAL PROFILE IN THE WESTERN GHATS MOUNTAIN RANGE

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To study the seasonal variations in raindrop velocity distribution (DVD) and its vertical profile, a Parsivel disdrometer and a micro rain radar (MRR) are operated at a tropical mid altitude site, Braemore (8.5o N 77.6o E, 40 m amsl) in the Western Ghats mountain range for past one year. The site is already reported to be instrumental in Cumulonimbus (Cb) cloud formation (Vishnu et al 2013). Raindrop velocity distribution and its vertical profiles are recorded during pre monsoon (March, April May), monsoon (June, July, August September) and post monsoon (October, November December). Rain intensity RI (mm h–1), Mean diameter Dm (mm), Total number concentration NT (m–3) and Mean velocity VT (m s–1) are calculated in each one minute sampling interval. VT is arranged in 8 velocity bins (1-8 m s–1) of bin width 1m s–1.

Frequency of occurrence and water contribution in percentage are computed for each bin in all seasons. In all seasons maximum water contribution is from V7 (6-7 ms–1) and occurrence maximum in V5 (4-5 ms–1). In pre monsoon, percentage of occurrence in V6 (5-6 ms–1) is high (more than 40%). The relation between mean drop size (Dm) and VT are also analyzed in four seasons and found some preliminary observations. Violations are observed in GunnKinzer relations during pre monsoon, monsoon and post monsoons. Number of small/slow moving drops are more in summer monsoon and number of large/fast moving drops are more in pre monsoon seasons. DVD and its vertical profile are studied using MRR and disdrometer observation for different precipitation type such as convective, stratiform, transition and mixed phases. The effect of orography in precipitation and its seasonal variations are also investigated. Temporal variation of size velocity distribution along with RI, Total number concentration NT, Dm and VT for different rain events in three seasons are also studied. A sample event on June 5th, 2017. It is observed that in initial phase of the rain event the NT (m–3) is high and Dm is less but after this the NT shoot up again with less Dm and thereby less RI. The same is repeated again in the rain event after 25 minutes. Additional events will be investigated for a detailed picture of this kind variations.

A1.1-0052-18 TRANSPORTED AND AGED ANTHROPOGENIC AEROSOLS ACT AS BETTER CLOUD CONDENSATION NUCLEI COMPARED TO SEA-SALT AND FRESHLY EMITTED ANTHROPOGENIC AEROSOLS OVER EASTERN HIMALAYA, INDIA

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The aerosol particles having the ability to form and foster the growth of cloud droplets at atmospheric SS are called cloud condensation nuclei (CCN). CCN has a great ability to perturb the cloud albedo, cloud lifetime, cloud height and other microphysical properties of cloud. Model and field based observations over marine and continental environments have shown the increase in cloud droplet numbers with the increase in CCN concentrations and that in turn increases the cloud reflectivity and cools the climate and suppresses the precipitation as well. A study was conducted on the relative role of freshly emitted and aged anthropogenic aerosols as well as transported sea-salt aerosols on the formation of cloud condensation nuclei over a high altitude (2200 m amsl) station, Darjeeling (27.01 °N, 88.15 °E) at eastern Himalaya in India. Condensation nuclei (CN) and cloud condensation nuclei (CCN) were measured using optical particle counter and CCN counter respectively during premonsoon (March-May) and monsoon (June-September) in 2016 and 2017. Size segregated aerosols were also collected and chemically analyzed in order to investigate the chemical composition of ultrafine aerosols activated to CCN. Sampling events were categorized based on the air mass trajectories. During premonsoon, most of the air masses were found to be arrived from western and central IndoGangetic Plain (IGP) driven by westerly winds. These air masses carried high amount of aged soot particles along with other anthropogenic sulphur and nitrogen species with higher hygroscopicity compared to freshly emitted soot and anthopogenic aerosols from local sources. The transported and aged soot and anthropogenic aerosols activated to CCN to a larger extent (CCN 2000 cm-3 with 45 % activation ratio) compared to the locally generated aerosols (CCN 1200 cm-3 with 25 % activation ratio). It was also observed that the activation of the transported soot and anthropogenic aerosols to CCN was higher than the transported sea-salt aerosols from the Bay of Bengal during monsoon. This could be due to

the fact that the sea-salt aerosols originated from the Bay of Bengal depletes chloride interacting with the anthropogenic SO42- and NO3- before arriving at eastern Himalaya and thus the activation potential decreases significantly. The study enables us to understand the fact that the soot and anthropogenic aerosols serve as better CCN due to atmospheric aging compared to transported sea-salt aerosols and locally generated anthropogenic aerosols over eastern Himalaya. Thus transport of anthropogenic aerosols from IGP is of paramount importance for modifying the cloud microphysical properties and in turn affecting the regional hydrological cycle over eastern Himalaya in India.

A1.1-0053-18 FIRST OBSERVATIONS OF TOTAL COLUMN OZONE, AEROSOL OPTICAL DEPTH AND PRECIPITABLE WATER CONTENT AT VILLAGE ATIGRE

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This paper reports the results related to measurements of total column ozone (TCO), aerosol optical depth (AOD) and precipitable water vapor (PWC) at different wavelength using compact, handheld, multichannel sunphotometer (Microtop-II ozonometer) at Village Atigre. The Village is situated in a tropical region (16.74° N latitude, 74.37° E longitude, 604 meters altitude above sea level) and surrounded by vast agriculture and industry area, thus it is a unique place to study variations in TCO, AOD and PWC by anthropogenic activities. We have been collecting data from 1st September, 2017 and in this paper, we have selected only 45 days for presentation as first observations from 1st September,2017 to 15th October,2017. Overall mean values of TCO, AOT and PWC are 263(±5) DU, 0.25(±0.1) and 3(±0.27) cm respectively are observed in this period. Hourly mean daily variation in TCO, AOD and PWC show different characteristics. The observation of TCO taken on the autumnal equinox day (23rd Sept. 2017) is also presented. We found the negative correlation in daily mean of AOD and PWC. This may happen due to washout of the atmospheric aerosols by water molecules because the period was rainy season. We have compared our results with satellite data, total ozone mapping spectrometer (TOMS) data, from nearby stations, Pune and the results very much agree with TOMS values. We have planned to take observations for long period to study the diurnal, seasonal and annual variations TCO, AOT and PWC as well as natural and anthropogenic activity impacts on them. Keywords: Total column ozone (TCO), Aerosol optical depth (AOD), precipitable water vapor (PWC), Microtop-II ozonometer and TOMS

A1.1-0054-18 CHARACTERIZATION OF AEROSOL LOADING IN URBAN AND SUB-URBAN LOCATIONS: IMPACT ON ATMOSPHERIC EXTINCTION AND RELATIVE HUMIDITY

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Center for Basic Space Science,National Space Deve, Nsukka, Nigeria Aerosol and Energy consumption

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The study of atmospheric aerosols remains a very strong factor in the understanding of the earth's climate and its impact on the environment. Therefore, multiple satellite data was used to study the various aerosol species in Nigeria over a period of 10years. Furthermore, the effects of aerosols on relative humidity (RH) and atmospheric extinction was investigated. The result showed that aerosol loading peaks in the south and middle belt regions during the dry season (NovemberMarch), while the reverse was the case in the north during the rainy season (AprilOctober). It was found out that coarse aerosols prevail all year round within this region, with the rate of occurrence varying with season. The Carbon Monoxide (CO) data from Atmospheric Infrared Sounder (AIRS) satellite was converted to fine aerosols using the fine mode aerosol optical depth (AODf) data from AERONET as the conversion factor. Furthermore, the range of the ratio of coarse to fine aerosol was found to be as high as 19:1 during the rainy season in the north, while it reduced to 3:1 during the dry season. In Abuja and Ilorin, it ranged from 13:1 to 2:1 in both seasons with a similar situation for Port Harcourt and Ikeja at a relative ratio of 13:1 to 2:1 for the coarse to fine aerosol ratio for both the dry and the rainy seasons respectively. The atmospheric extinction values plotted against RH, showed that extinction grows at very low RH of about 45

A1.1-0055-18 MULTI-SATELLITE OBSERVATIONS OF THE TRANSPORT OF AEROSOLS AND MINERAL DUST OVER THE BAY OF BENGAL AND ITS IMPLICATIONS TO THE REGIONAL CLIMATE

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Bay of Bengal is playing an important role in the onset and progress of Indian monsoon through ocean - atmosphere coupling. The atmosphere over Bay of Bengal is more turbid compared to Arabian Sea and Indian Ocean due to the transport of aerosols from the nearby continents. In this context, the vertical distribution of aerosol and dust extinction coefficient over the Bay of Bengal is examined using multi-satellite observations (Cloud Aerosol Lidar with Orthogonal Polarization (CALIOP) and Moderate Resolution Imaging Spectroradiometer (MODIS)) for the period from 2006 to 2017. Distinct seasonal pattern is observed in the vertical structure of both aerosol and dust over the Bay of Bengal with an enhancement of 24 % in the aerosol extinction above 1 km from winter (December, January and February) to pre-monsoon (March, April, and May). Significant contribution of mineral dust is observed over the northern Bay of Bengal during pre-monsoon season where 22 % of the total aerosol extinction is contributed by dust aerosols transported from the nearby continental regions. During winter, dust transport is found to be less significant with fractional contribution of around 10% to 13% to the total aerosol optical depth over the Bay of Bengal. MODIS derived dust fraction (fine-mode based) shows an overestimation up to 2 fold compared to CALIOP dust fraction (depolarization based) whereas the GOCART (chemical transport model) simulated dust fraction underestimates the satellite derived dust fractions over the Bay of Bengal. The long term variation in dust aerosol showed a decreasing trend over the Bay of Bengal. However, significant dust induced heating is observed above the atmospheric boundary layer during pre-monsoon season. This dust induced elevated heating during the pre-monsoon can affect the convection over the Bay of Bengal which will have implication on the monsoon dynamics over the Indian region.

A1.1-0056-18 SPATIO - TEMPORAL VARIATION OF AEROSOL AND ITS INTERRELATIONSHIP WITH LAND USE LAND COVER (LULC) OVER NEW DELHI

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MODerate resolution Imaging Spectro-radiometer (MODIS) on board NASA's Terra and Aqua satellite Level 2 Aerosol Optical Depth (AOD) data is used for aerosol study and LISS III sensor on board Indian Remote Sensing (IRS) Satellite procured from the National Remote Sensing Centre (NRSC), Hyderabad, India was used for vegetation cover estimation over New Delhi and its surrounding regions. Lowest AOD was found in the spring season where highest AOD in summer months. Different dates representing different seasons LISS III imageries were used for generation of land use land-cover (LULC) maps. A seasonal variation in the LULC has been observed. The land cover maps reveal that most of the surrounding areas of Delhi are covered with vegetation in March. By the month of May-June herbs are cut or dry from most of the region surrounding Delhi and the land cover in the surrounding areas changes to bare soil. During the rainy season (July to September) the vegetation cover over Delhi and the surrounding areas increases considerably. In November - December there is dispersed vegetation cover over New Delhi and its surrounding regions depending upon the age of the newly sown crop and ornamental plants. We found that, there is statistically significant negative correlation between AOD and Vegetation in every season. Further, a relatively higher AOD has been observed over the urban settlements and barren area over New Delhi.

A1.1-0057-18 SEASONAL VARIATION OF SOLAR IRRADIANCES AND AEROSOL RADIATIVE FORCING OVER DELHI-NCR

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Present study investigates the variation of the solar irradiances and radiative forcing (RF) during the summer and winter season over an urban and rural location in Delhi and National Capital Region (NCR), India. The solar irradiance (global and direct) measurements were carried out using a handheld FieldSpec Spectro-radiometer (325-1075nm wavelength range). NASA's Clouds and the Earth's Radiant Energy System (CERES) gridded Single Scanner Footprint (SSF) datasets of fluxes at the surface and top of the atmosphere (TOA) as well as Aerosol optical depth (AOD) products from collocated MODerate resolution Imaging Spectroradiometer (MODIS)-AQUA sensor were used to estimate the radiative forcing efficiency due to aerosol load at the Surface and TOA. The solar irradiances, both global and direct, were observed to be higher at the rural site as compared to the urban location in both summer and winter season. However, during the winter season only, the variation in the irradiances, especially direct, was found to be highly significant. TOA radiative forcing was estimated to be higher in summer than winter whereas at surface and in the atmosphere (ATM), RF was estimated to be higher in the winter season compared to summer at both the urban and rural locations. During the summer season, the ATM forcing was estimated to be higher at the rural site than that at the urban location. Whereas, not much significant difference in the ATM forcing during the winter season could be observed at both the sites.

A1.1-0058-18 VARIABILITY OF AEROSOL OPTICAL DEPTH AND ITS EFFECT ON CLIMATIC PARAMETER OVER VARANASI DURING 2011-2016

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Aerosol is highly spatially and temporally variable. Nowadays it is playing an important role to understand the thermodynamics of climate. To study the variability of aerosol and its effect on climate satellite data are used. In our present study we have tried to know the direct or indirect effect of aerosol. Varanasi is highly populated city in the heart of Indo-Gangetic basin (IGB). Variability of aerosol in term of aerosol optical depth (AOD) over Varanasi (25.26° N, 82.99°

E) during 2011-2016 is analyzed and a slight increment has been found in the aerosol optical depth. AOD and surface air temperature are compared and observed that the temperature either found to be decreased with respect to high AOD or vice versa. It may be seasonal effect but over all, there is decrease in temperature on increasing AOD. Further AOD and relative humidity are compared and it is found that relative humidity is increasing on increasing AOD. It is also found that when temperature increases relative humidity decreases and vice versa which assure that AOD and temperature have negative correlation. Long term analysis, for the parameters aerosol optical depth, relative humidity and temperature, has been done. Small increment in these parameters is found during the year 2011-2016 which is contradicted to the results of their mutual comparison. It is to be concluded that no direct impact has been observed on the temperature influenced by AOD. There may be some other parameters which could affect the temperature.

A1.1-0059-18 AEROSOL CHEMICAL CHARACTERISTICS AT ALAKNANDA VALLEY (SRINAGAR) IN THE CENTRAL HIMALAYA REGION, INDIA

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The atmospheric aerosol is linked to poor air quality, adverse health effects and heat balance of the Earth directly through absorbing/scattering the solar radiation, indirectly by influencing cloud microphysics and possibly by changing the heterogeneous chemistry of reactive greenhouse gases. The direct and indirect effects of aerosols depend on size distribution and chemical composition of atmospheric aerosols. Apart from the size of aerosols, assessment of their chemical composition as a function of time is of crucial importance to understand atmospheric processes such as radiative transfer, cloud droplet nucleating ability, acidification, precipitation chemistry and dry deposition. A year-long (2016) ground-based measurements of PMs (PM2.5 and PM10) and its chemical constituents were made over Srinagar, Garhwal, Uttarakhand. Collected samples of PMs were analyzed for major water soluble chemical species such as anions (F-, Cl-, SO42-, NO2-, NO3-) and cations (Na+, K+, NH4+, Ca2+, Mg2+). The concentrations of PM2.5 and PM10 were 78.7 ±25.1 and 111.8 ±23.4 g m-3, respectively during the study period. The measured chemical species were found a large variability in different seasons due to the impact of emissions and meteorological parameters. The measured water-soluble chemical species of PM2.5 and PM10 were 43% (33.7 g m-3) and 57% (64.2 g m-3) during the study period. Higher concentrations of water soluble species were during the winter season followed by summer, monsoon and post-monsoon seasons. A significant correlation among NH4+ and Cl-, SO42-, NO3- in PM2.5 and PM10, respectively indicates its presence in the atmosphere in salt form. Neutralisation of acidic species due to cations was estimated and found that NH4+ play a crucial role in neutralisation in the winter season; however, the contrary feature was observed in the summer season where Ca2+ was responsible for the neutralisation of acidic components in

the PMs samples which were transported from the inland region during the summer. Principal Component Analysis shows that secondary aerosol, biomass burning, and soil-driven dust were the possible sources of the measured species over the station, which was further confirmed with the air mass back-trajectory analysis.

A1.1-0060-18 LONG RANGE TRANSPORT OF AIR MASS FROM THE CROP RESIDUE BURNING (WESTERN PARTS OF INDIA) DURING WINTER SEASON AND ITS IMPACTS ON HUMAN HEALTH AND WEATHER CONDITIONS OVER THE INDO-GANGETIC PLAINS (IGP)

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In this study, we have analysed Aerosols Optical properties over the Indo-Gangetic Plains (IGP) using Ground, Satellite and Aeronet data for the periods 2003-20017 from Lahore, Jaipur, Kanpur and Gandhi College during rice crop residue burning mainly in October-November. The plumes from the crop burning source region, depending upon the meteorological conditions (wind speed, relative humidity and air temperatures) are transported up to the eastern parts of the IGP and over the Bay of Bengal. Pronounced changes in atmospheric and meteorological parameters have been observed when farmers burn their crop residues, as a result dense haze, fog and smog are formed impacting weather conditions (dense haze, smog and fog) and human health. The air quality parameters degrade so fast and enhancement in greenhouse emissions are observed. Weekly analysis of all the parameters during the study period will be discussed. We have found the extent of smoke on the meteorological conditions. While the smoke is transported from the source region, the local dust emissions show strong mixing that is observed from the two AERONET stations (Kanpur and Gandhi College) in the eastern parts of the IGP. During October-November, we have observed changes in the weather conditions that may be related to increasing aerosol loading with the industrial developments and emissions from the coal based power plants.

A1.1-0061-18 TRENDS AND SEASONAL VARIABILITY OF PM10, PM2.5 AND BLACK CARBON IN MEGACITY DELHI: IMPACTS ON RADIATIVE FORCING

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Atmospheric aerosols has gained great attention due to its radiative property, which impacts on climate change at local, regional and global scale. Specially, black carbon is a major contributor of climate change, second to CO2. Continuous and real-time measurements of the mass concentration of particulate matter (PM10, PM2.5) and black carbon (BC) were carried out in CSIR-CRRI, New Delhi. Daily data of aerosol optical depth (AOD), angstrom exponent (AE) and single scattering albedo (SSA) were taken from the space-borne satellite MODISterra at level 2 for the years 2015, 2016 and 2017. The annual mean concentrations of PM10 were observed 193±87, 227±72 and 257±159 gm3; PM2.5 were 172±92, 187±69 and 217±137 gm3; and BC were 4.3±1.8, 4.8±2.1 and 5.8±2.3 gm3 for the years 2015, 2016 and 2017 respectively. The average annual increment of PM10, PM2.5 and BC concentrations were found about 15, 14.3 and 13.8% from year 2015, 2016 and 2017, respectively,. The higher concentration were found during winter (1076, 789 and 10 gm3 of PM10, PM2.5 and BC, respectively) and a minimum were found in monsoon season (36, 17 and 2.7 gm3 of PM10, PM2.5 and BC, respectively) whereas, post and pre-monsoon seasons average concentration of PM10, PM2.5 and BC were 184±62, 87±43 and 4.7±1.7 gm3; and 69±28, 28±16 and 4.4±1.2 gm3, respectively. The BC concentration was found significantly high, nearly doubled during cloudy-sky conditions as compared to during clear-sky conditions. Seasonal trend decomposition were analysed based on locally weighted regression smoothing technique, and identified marginally decreasing trend (Delhi0.0079; Varanasi, 0.0087 DU year-1) due to reduction in monsoon time minima and summer time maxima. The aerosol optical properties like, AOD and SSA were found higher in winter but does not show a significant variation for other seasons, whereas AE exhibits significant seasonal variation, higher during winter and post-monsoon, indicative of high concentration of fine aerosols (BC and PM2.5) and found lower in pre-monsoon and monsoon, when coarser aerosols (PM10) were in abundant. The percentage contribution of BC to the net atmospheric forcing is varied between 54 to 68% during the years 2015-2017, which is supporting to strong radiative forcing of BC, that causing solar dimming to earth surface and global warming at local and regional scale. Key worlds: Black carbon; PM10; PM2.5; MODIS; AOD; Angstrom exponent; Single scattering albedo

A1.1-0062-18 VARIABILITY OF PARTICULATE MATTER AND ITS RELATIONSHIP WITH THE OPTICAL PROPERTIES OF AEROSOLS IN VARANASI, INDIA

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Associations of particulates have often been reported with bad health impacts, visibility reduction, variation in monsoon and change in climate and reduction of agricultural production. Further, information regarding variation of accumulation mode particles is rare over Varanasi, India. Driven by such knowledge gap, variation of particulates was analyzed at Varanasi over middle Indo Gangetic Plain. The particulate matters (PM: PM2.5 and PM10) were observed using two high volume samplers installed at Varanasi, India during November 1, 2016 to June 7, 2017. Space-borne passive (MODIS-Terra) daily observations were simultaneously used with ground based aerosol mass measurement for the winter (November-February) and summer (March-June) months. Exceptionally high aerosol mass loading was recorded for both PM10 and PM2.5, typically exceeding national standard. Wintertime PM2.5 and PM10 were found to be the major air pollutant causing significant deterioration of air quality with mean concentrations of PM2.5 (134.18 ± 47.16 g m3, range 42.83 - 257.76 g m3), PM10 (211.89 ± 79.02 g m3, range 123.23 - 464.52 g m3) and PM10-2.5 (77.71 ± 54.15 g m3, range 3.66 - 206.76 g m3). Wintertime is characterised with frequent events of biomass burning and poor dispersion of PM. During summer season low concentration of PM2.5 (39.05 ± 26.98 g m3, range 4.33 - 105.41 g m3), PM10 (135.95 ± 49.57 g m3, range 2.55 - 212.04 g m3) and PM10-2.5 (96.90 ±

55.55 g m3, range -102.86 ± 175.93 g m3) were found. The correlation coefficient (R = 0.74) was found between PM2.5 and PM10 in the winter season however R = 0.04 was found in the summer season. Very poor correlation between PM2.5 and PM10-2.5 were found in both winter and summer seasons. During summer months dust storms and transboundary emissions are prevalent resulting into persistence of mixed type of aerosols. The mean PM2.5/PM10 ratio was 63% in the winter season, is the indicative of a higher loading of the fine aerosol particles compared to the coarser aerosols in Varanasi. The Angstrom exponent values (> 1.0) over winter season indicating that in winter small aerosols particle are dominant. However, in summer season < 1.0 indicates the existence of bigger size of aerosol particles. A significant correlation between PM2.5 and MODIS-aerosol optical depth (AOD) ie.0.70 and between PM10 and MODIS-AOD i.e. 0.48 was found in the winter season. However a poor correlation was found in the summer season. Concentration Weighted Trajectory analysis show that PM2.5 and PM10 levels at the land stations were influenced by weak to moderate contributions from Arabian Sea, Tropical Indian Ocean and the arid South-west Asia and North-west India, peninsular India and from the polluted Indo Gangetic Plain region. Major source reasons were determined for the winter and summer seasons using back trajectory cluster analysis. Outcomes of the present study may be helpful to improve regional air quality and also for the other particulate source apportionment studies.

A1.1-0063-18 THE ENHANCEMENT OF SOOT PARTICLE, PARTICULATE AND GASEOUS POLLUTANTS ALONG WITH CHEMICAL SPECIES OF FINE PARTICLES DURING THE FOG EVOLUTION IN THE URBAN ATMOSPHERE

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Multiple institution and sophisticated instruments were involved in making observations of atmospheric particulate matter at Indira Gandhi International Airport Delhi during the foggy period of 2016-2017 to understand the physical/chemical mechanism of fog formation that is useful to develop a suitable fog forecasting system and fog dispersal strategy. The observations of atmospheric black carbon (BC), online particulate matter (PM2.5 and PM10), gaseous pollutants (GP: NOx, CO, CO2 and O3) and various chemicals species (CS: F-, Cl-, SO42, NO22-, NO3-, Na+, K+, NH4+, Ca2+, and Mg2+) using a particle-in-liquid sampler for PM2.5 along with meteorological parameters were made during the winter foggy period. During this period, the mean concentrations of equivalent black carbon (eBC) was 11973 ± 5541.7 ng m-3 (12 µg m-3), much higher than most of the other parts of the world. The high values are due to increased emissions combined with poor dispersion conditions. The contributions of BCbb (biomass burning) and BCff (fossil fuel) were estimated to be 14% and 86% of the eBC, respectively, clearly indicating that the fossil fuel combustion BC dominated in Delhi in winter relative to biomass burning. The mean PM2.5 and PM10 concentrations were 139.5 (12 times higher than USEPA standard) ± 132.5 and 279.3 (8 times) ± 195.1 µg m-3, respectively. However, the mean gaseous concentrations were 22.2 ppb (NOx), 1.2 ppm (CO), 332 ppm (CO2), and 32.3 ppb (O3). The contributions of anions (F-, Cl-, SO42-, NO22- and NO3-) and cations (Na+, K+, NH4+, Ca2+ and Mg2+) were 47% and 53%. The highest contributions were Ca2+ (23%) followed by SO42- (18%). Additionally, the source regions and contributions to CS were studied with concentration weighted trajectory analysis. Six major source regions were identified. The concentrations of secondary acidic aerosol species (sulfate and nitrate) were significantly higher when the air masses pass within the Indian subcontinent mostly from Haryana state and the industrial zones of Faridabad and Okhla in Delhi. However, the calcium component was highest when air masses arrive from a long distance including desert areas. The chloride concentrations were highest when air masses arrive from northern Afghanistan, Pakistan during western disturbances in winter season. In overall, the study clearly indicated that the north-west part of India is highly polluted region and suggesting that the stagnant strategy is be required for its mitigation. The detailed findings of the present study will be presented.

A1.1-0064-18 EARTH OBSERVATION WITH THE ORBITAL-HUB FREE FLYER

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In order to perpetuate the achievements of the International Space Station (ISS), DLR has conducted an extensive Post-ISS concept study by means of a series of Concurrent Engineering studies. The outcome design, referred to as Orbital-Hub, is based on a small crewed LEO platform including a human-tended Free Flyer and is centred on financial feasibility and user needs in the frame of human spaceflight. Beside diverse use cases for the Orbital-Hub, such as scientific and commercial µg application, exploration and technology demonstration, one application area comes from the Earth observation and climate measurement community. Within this paper it is elaborated, how the Orbital-Hub's Free Flyer could serve as an observation platform for passive and active atmospheric physics and for optical Earth observation in order to monitor trace gases, aerosols, greenhouse gases, hot spots and analysing the dynamic of our Earth's atmosphere.

A1.1-0065-18 INVESTIGATION OF ATMOSPHERIC ATTENUATION AND INFLUENCES FOR INTERPRETING MSI IMAGERY USING SENTINEL-2

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Each day hundreds of images are taken of the Earth's surface. These images are then used to gain information on topics including spatial planning, disaster management, natural resource sustainability, crop health/agriculture, urban planning, security, and others. Atmospheric effects can drastically affect the generation of physical products from reflected electromagnetic radiation. However, most satellites lack various bands that are required for a full characterization of the atmosphere, and instead model data are used during product generation.

The goal of this research is to investigate how the atmosphere (water vapor and aerosols) change the remotely-sensed image over different land covers and different seasons. The methodology uses two Sentinel-2 MSI products: the S2MSI1C, which is top-of-atmosphere reflectance and the S2MSI2Ap which is bottom-of-atmosphere reflectance. Comparison of the two products allows for quantization of the atmosphere as seen by the Sentinel-2 spectral bands. For this research, the within image atmosphere over three types of land cover is assessed: water, urban area, and forest. Finally, the quantization of the atmospheric attenuation is studied via time-series analysis over multiple images to understand how dynamic atmospheric effects change data and to identify seasonal patterns.

A1.1-0066-18 AMBIENT NEUTRON AND GAMMA MONITORING IN BRAZILIAN TROPICS

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Natural background of gammas (0.2-10.0 MeV) and neutrons were continuously monitored during a period from January 2016 to February 2017 in the region of south Atlantic Magnetic Anomaly (Sao Jose dos Campos, SP, Brazil). During this period abnormal rainfalls at twice of the historical average severity occurred in this location. After that, in February 2017, the region suffered extremely low precipitation and high temperature. Analysis of the data obtained revealed a distinct diurnal variation in the both natural radiation component and the correspondent temperature variation. It was also found that during rainfalls, the gamma radiation intensity increased and the neutron fluxes decreased. The first effect appears to be caused by atmospheric radiation fallout of radon gas accompanying liquid precipitation, the latter one - by cosmic ray neutron thermalization caused by the hydrogen contained in the atmospheric water vapor. A few events of short duration (1 minute); moreover, sporadic enhancements in neutron count rates were also observed. It is possible that these events are related with and modulated by thunderstorm and/or mild sporadic seismic activity in the region.

A1.1-0067-18 DYNAMICS OF NEAR-GROUND THERMAL NEUTRONS OF NATURAL ORIGIN

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Dynamics of near ground concentration of ambient thermal neutrons (TN) was studied using data of neutron detectors of the COsmic-ray Soil Moisture Observing System (COSMOS) network and those of the Laboratory of environmental radiation of the Instituto Tecnológico de Aeronáutica (Brazil). A significant excess of TN count rate over that of rapid neutrons was found in two COSMOS probes located in Brazil and in other sites in North America and Europe. The effect can be explained in terms of neutron production in nuclear (, n) reactions initiated by decay of radon gas comprised in the ground rather than in the lower atmosphere. The monitoring revealed strongly marked diurnal variation of the TN concentration which proved to be in anti-phase with air temperature; a feature that is characteristic for particles in thermal equilibrium with air. A previously unknown effect of saturation of nighttime TN concentration was observed. That effect appears to be explained in terms of a dynamic equilibrium state, which sets in because of the absence of vertical convection between the neutrons escaping from the ground and their losses in nuclear reaction in the air. The results hereby described can potentially be used for the determination of ground concentration of ambient radon and its related dynamics in boundary layer of atmosphere as well as in other geophysical studies.

A1.1-0070-18 STUDY OF LIGHTNING ACTIVITY USING WORLD WIDE LIGHTNING LOCATION NETWORK (WWLLN) OVER BENGALURU, INDIA

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The lightning, thunderstorm and electrical conductivity are the manifestation of electrical nature of the earth's atmosphere. The observations were made by the WWLLN network of USA, which includes a station at Bangalore University, Bengaluru, India. The continuous measurements shows the pronounced lightning activity and exhibits distinct diurnal and seasonal variability. Lightning is most frequent during afternoon hours and will continue till night-time. From recent years, the loss of lives due to lightning activity have crossed 1000 per year over India and the statistical variability of lightning stroke density over Bengaluru confirms the enhancement of activity from recent past. Preliminary study show that in addition to the observations of WWLLN over Bengaluru requires similar ground based and satellite data from/over other low latitude stations and also integrates it with visual and other observations reported in the media. An effort is also made to compare the data with TRMM/LIS to have the distribution of lighting stroke density. The details are discussed in the paper.

A1.1-0071-18 AN AI APPROACH FOR UNCERTAINTY MODELING AND PREDICTION OF AIR QUALITY, BASED ON LANDSAT8 AND MODIS-MISR ASYNCHRONOUS TIME SERIES BIG DATA

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The continuously deteriorating air quality specifically in major developing nations is a challenge for sustainability of healthy human race. One of the worst recent toxic smog formations was in the National Capital Territory of Delhi (NCT) in India during November-December 2017. Finding the multidimensional causality aspects of this dangerously hazardous situation is an important direction of research before devising any practical recommendations; henceforth any resilient solution. Landsat and MODIS satellite data are two of the most valuable data sets available in public domain for vegetation and other land cover changes on the earth's surface, particularly, the study of human influences involving agricultural farming(Cohen et al., 1998; Coiner, 1980; Coppin Bauer, 1994; Seto et al., 2002). The addition of thematic mapping(TM) sensors in 1982 provided additional higher resolution spectral bands. However, the main utility hindrances in these Landsat images are the occlusion by cloud, aerosol and other atmospheric artifacts (Asner, 2001). Estimated by The International Satellite Cloud Climatology ProjectFlux Data (ISCCP-FD), the annual mean cloud cover is approximately 66% at the global scale (Zhang et al., 2004). Therefore correction in cloud, aerosol and cloud shadow occluded band values are essential for any accurate analysis based on these data. This research presents a porotype model for utilization of heterogeneous Satellite and ground-based sensor data sets comprising Air Quality Index (AQI), Satellite retrievals of aerosol optical depth (AOD) and surface reflectance in various bands, to identify the causality patterns(particularly the effect of kharif crop shoot burning in neighboring states of Delhi (NCT) viz. Punjab, Haryana and Uttar Pradesh). The approach comprises Artificial Intelligence (AI) techniques for logical representation of heterogeneous satellite Big Data and data from in-situ ground-based sensors, causality relation weights learning to quantify uncertainty in band values(with/without occlusions), supplemented with inference and prediction capabilities. We have utilized Satellite retrievals of aerosol optical depth (AOD) from Landsat8 and MODIS-MISR (Multi-angle Imaging Spectroradiometer) along with New Delhi Historical data of Air Quality Index (AQI) from AirNow(Environment Protection Agency, USA) and data from Central Pollution Control Board, Government of India. This prototype approach of AI derived process pipeline can be easily replicated for other locations with capabilities such as timely forecast/warning issue and other long-term recommendations.

A1.1-0072-18 COINCIDENT OBSERVATIONS OF SURFACE OZONE AND NMVOCS OVER ABU DHABI

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The vertical profiles of ozone are measured coincidently with non-methane volatile organic compounds (NMVOCs) at the meteorological site located at the Abu Dhabi international airport (latitude 24.45N; longitude 54.22E) during the years 2012 - 2014. Some of the profiles show elevated surface ozone >95 ppbv during the winter months (December, January and February). The ground-level NMVOCs obtained from the gas chromatography-flame ionization detection/mass spectrometry system also show elevated values of acetylene, ethane, propane, butane, pentane, benzene, and toluene. NMVOCs and ozone abundances in other seasons are much lower than the values in winter season. NMVOCs are emitted from an extensive number of sources in urban environments including fuel production, distribution, and consumption, and serve as precursor of ozone. Transport sources contribute a substantial portion of the NMVOC burden to the urban atmosphere in developed regions. Abu Dhabi is located at the edge of the Arabian Gulf and is highly affected by emissions from petrochemical industries in the neighboring Gulf region. The preliminary results indicate that wintertime enhancement in ozone is associated with large values of NMVOCs at Abu Dhabi. The domestic production of surface ozone is estimated from the combination of oxygen recombination and NMVOCs and compared with the data. It is estimated that about 40-50This work is supported by National Research Foundation, UAE.

A1.1-0073-18 SIZE RESOLVED POLYCYCLIC HYDROCARBONS INTRINSIC TO PARTICULATE MATTER IN AMBIENT AIR OF A MEGACITY IN THE LOWER INDO-GANGETIC PLAIN: SEASONAL VARIATION, SOURCE APPORTIONMENT AND HEALTH EFFECT

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An investigation was carried out to better understand the size distribution of particulate matter bound polycyclic aromatic hydrocarbons (PAHs) and their source contribution to the public health in the ambient air of Kolkata (22.33 °N and 88.20 °E), a densely populated megacity in the lower Indo-Gangetic Plain during October 2016 to May 2017. The PM bound PAHs were sampled by a 9-stage Anderson cascade impactor and 18 PAHs were quantified by highperformance liquid chromatography. The results showed that PAHs had bimodal distribution during both post monsoon (October November) and premonsoon (March to May) with mode peaks in the accumulation (0.4 µm < Dp<1.1 µm) and coarse (2.1 µm < Dp<10 µm) size ranges, whereas a sharp unimodal distribution during winter (December to February) in the accumulation size range. Additionally, the slope value of larger than -1 in the plot of log(PAH/PM) vs logDp suggested that the seasonal size distribution of the PAHs was influenced by multiple mechanisms, such as adsorption and absorption. Moreover, the total respiratory deposition flux was calculated to be (5.7 ± 1.2) ngh-1 and upper limit of the incremental lifetime cancer risk (ILCR) was observed to be mostly influenced by the ultrafine (Dp < 0.4 µm) and accumulation mode and the value was estimated to be 4.27 x 10-6. Furthermore, results from positive matrix factorization model indicated contributions of unburned petroleum, incineration, fossil fuel and coal burning at varying percentages as the major sources. The current study added useful information for better mechanistic understanding of size segregated seasonal distribution of PAHs intrinsic to ambient PM of a megacity, as well as the study provided information on its hazardous impacts on public health.

A1.1-0074-18 LONG TERM SATELLITE BASED STUDY ON AEROSOL AND TRACE GASES OVER THE CAPITAL CITY OF ASSAM, GUWAHATI

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The variability and trend in aerosol optical depth (AOD) by using the Moderate Resolution Imaging Spectroradiometer (MODIS) level 3 Collection 6 data at 550 nm for the period January, 2004 to December, 2016 and tropospheric columns of nitrogen dioxide (NO2) and sulfur dioxide (SO2) data by using Ozone Monitoring Instrument (OMI) has been studied for the period October, 2004 to December, 2016 over capital city of Assam, Guwahati. The monthly average AOD value varies from its highest value (0.63±0.09) in March to its lowest value (0.23±0.05) in October for the study period over Guwahati. The seasonally averaged AOD reached its maximum in pre-monsoon (0.61 ± 0.06), followed by winter (0.47 ± 0.07) and monsoon (0.41

± 0.04), with the minimum occurring in post-monsoon (0.25 ± 0.06) season. The observed Ångström exponent value varies from its minimum value (1.18 ± 0.05) in monsoon season to its maximum value (1.35 ± 0.09) in post-monsoon season. Considerable long-term annual increasing trends in AOD, Ångström exponent and tropospheric NO2 column has been observed over the study location. An increasing trend of total number of vehicles along with their emissions degrades the air quality and thereby contributing to the increasing trend of AOD over Guwahati. A significant correlation between long term averaged MODIS AOD and OMI NO2 tropospheric columns with same seasonality indicating their same source of origination. Long term increasing trend in Ångström exponents (0.008 per year) signify the contribution of smaller size aerosols attributed to urbanization and human activity over Guwahati. The monthly average visibility in Guwahati is highest (27.5 km) in October with a moderate reduction observed during the monsoon, reaching a minimum of 7.2 km in March. With increasing AOD values, horizontal visibility decreases over Guwahati.

A1.1-0075-18 FEASIBILITY STUDY OF THE PREDICTIONS ABOUT THE CROSS-BORDER TRANSPORT OF AEROSOLS/PM2.5 USING THE DATA ASSIMILATION WITH HIMAWARI 8 DATA AND NICAM-CHEM MODEL

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We are making a forecasting system of air quality for human health from the distributions of aerosols including PM2.5, oxidants (tropospheric ozone), NOx, SOx and so on. A report by WHO estimated that the air pollution due to those species caused the health damage such as lung trouble and cerebrovascular disease corresponding to kill 3.7 million people in the world during the year of 2012. In the case of Japan, about a half of the observed PM2.5 and tropospheric ozone originate outside of the country, and, especially in the western Japan, the cross-border transport of PM2.5 from the continent is significant. Therefore, in the prediction of air pollution there, the enough consideration of the global-scale transports of aerosols and oxidants is indispensable.

Himawari 8 observes the column distributions of aerosols covering the East Asia with very high resolutions for both time (10 minutes) and space (5 km), and provide the open observational data sets within a day. We have derived the column density of PM2.5 from the data sets assuming the bimodal size distribution of aerosols based on the algorithm by Higurashi and Nakajima (1999), and assimilated the density data into the NICAM-Chem general circulation model (Goto et al. 2015). The method of assimilation is based on the optimal interpolation to be adaptable for the fast predictions with small computational resources. In the presentation we show the preliminary results of the assimilated PM2.5 distributions on Japan, and discuss the connection with the km-scale regional simulations to predict the urban air quality.

A1.1-0077-18 LONG TERM TRENDS IN VARIABILITY OF AIR POLLUTANTS AND PARTICULATE MATTERS OVER VARANASI, INDIA

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Varanasi (25.31 N, 82.91 W), a densely populated city which lies in the mid of Indo-Gangetic Basin (IGB) has been chosen as site for monitoring the present study. This study is carried out in order to examine long term (2005-2016) trends of different Air pollutants viz. (AOD, BC, SO2, NO2, CO) and particulates over Varanasi.In this study data has been collected from MODIS of various meteorological parameters for a long period (2005-2016) and seasonal variability is analysed for these years. Further Seasonal variation is classified in four seasons viz. winter, pre monsoon, monsoon and post monsoon. January,February are considered as Winter season and similarly March, April, May as Pre-monsoon June, July, August, September as Monsoon and October, November, December as Post-Monsoon period consecutively. AOD was observed lowest for monsoon season for all the years and comparatively higher values for winter and post monsoon seasons. Pre monsoon also witnesses higher value compared to monsoon period due to increased wind speed which carries soil with it which gets suspended in the atmosphere. Black Carbon (BC) isa result of incomplete combustion of fossil fuels such as coal, diesel, petrol and biofuel and biomass burning. BC is observed highest during post monsoon season and winter and comparatively lower in pre monsoon and monsoon. Since monsoon season experiences regular rainfall these shoots get washed away with rain and hence lower BC concentrations is observed in this season. Higher BC during winters may be the result of burning of woods and shrubs which people do practice during this season in order to keep themselves warm.NO2 column was observed highest during pre-monsoon period and subsequently lower for winter and post monsoon period for all the years and lowest for monsoon period, attributing the fact that in monsoon period NO2 present in the atmosphere get wet with rain and comes down to the earth with the rain. SO2 is observed highest for most of the years during post monsoon season and is recorded higher in winter as well as a result of burning of fossil fuels in this seasonand it attains lower values for both the seasons viz. monsoon and pre monsoon. CO also shows increase in winter season due to burning of fossil fuels in this season and lowest value in monsoon period is observed due to its wet removal in this season.

A1.1-0078-18 FINE MODE AEROSOL CHEMISTRY OVER A RURAL ATMOSPHERE NEAR THE NORTH-EAST COAST OF BAY OF BENGAL IN INDIA

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A study was conducted on the chemical characterization of fine mode aerosol or PM2.5 over a rural atmosphere near the coast of Bay of Bengal in eastern India. Samples were collected and analyzed during March 2013 - February 2014. The concentration of PM2.5 was found to span over a wide range from as low as 3 g m-3 to as high as 180 g m-3. Maximum accumulation of fine mode aerosol was observed during winter whereas minimum was observed during monsoon. Water soluble ionic species of fine mode aerosol were characterized over this rural atmosphere. In spite of being situated near the coast of Bay of Bengal, we observed significantly higher concentrations for anthropogenic species like ammonium and sulphate. The concentrations of these two species were much higher than the sea-salt aerosols. Ammonium and sulphate contributed around 30 % to the total fine mode aerosols. Chloride to sodium ratio was found to be much less than that in standard sea-water indicating strong interaction between sea-salt and anthropogenic aerosols. Non-sea-sulphate and nitrate showed significant contributions in fine mode aerosols having both local and transported sources. Source apportionment shows prominent emission sources of anthropogenic aerosols from local anthropogenic activities and transported from nearby Kolkata metropolis as well.

A1.1-0079-18 AEROSOLS AND SMOKE PLUMES CHARACTERISTICS DURING HIMALAYAN FOREST FIRE EVENT, 2016

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The forest fires are common events seen over the Central Himalayan region during the premonsoon season (March - June). Some fire occurs naturally while some are reported as manmade. Forest fire plays a crucial role in governing the vegetation structure, ecosystem, climate change as well as in atmospheric chemistry. In regional and global scales, the combustion of forest and grassland vegetation releases large volumes of smoke, aerosols, and other chemically active species that significantly influence Earth's radiative budget and atmospheric chemistry, impacting air quality and risks to human health. Massive forest fires had recorded over the Central Himalayan region of Uttarakhand, Himachal, and Nepal during the year 2016, which continues for several weeks. To study this event we used the multi-satellite and ground-based observations of aerosols and pollutants during pre-fire, fire and post-fire period over the central Himalayan region. The data used in this study are active fire count and aerosol optical depth (AOD) from MODIS and ground-based AERONET, aerosol index and gases pollutants from OMI, along with vertical profiles of aerosols and smoke plume height information from Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO). The result shows that the mean fire counts were maximum in April. The daily average AOD value shows an increasing trend during the fire events. The mean value of AOD before the massive fire (25 April), during the fire (30 April) and postfire (5 May) periods are 0.3, 1.2 and 0.6 respectively. We find an increasing trend of total columnar NO2 over the region during the massive fire event. Space-born Lidar (CALIPSO) retrievals show the extent of smoke plume heights beyond the planetary boundary layer (free troposphere) up to 6 km during the peak burning day. The HYSPLIT air mass forward trajectory shows the long-range transportation of smoke plumes. The results of the present study provide valuable information for addressing smoke plume and aerosol transport in the Himalayan region.

Keywords: Forest-fire; Fire counts; AOD, Smoke plumes; CALIPSO

A1.1-0080-18 BIOMASS BURNING IMPACT ON AIR QUALITY IN NORTHERN SUB-SAHARAN AFRICA (NSSA)

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Emissions from biomass burning such as nitrogen oxides (NOx), carbon monoxides (CO), and primary aerosols do not only affect air quality locally, but also on continental to hemispheric scales through long-range transport. It is estimated that about 350 Million hectares of land burn globally every year of which 54 % are in Africa. The northern sub-Saharan African (NSSA) region (0 - 20N, 20W - 55E) is known to show one of the highest biomass burning rates (in terms of per unit land area) among all regions of the world. This is due to the high concentration and frequency of fires in this region. In 2016 a newly installed AERONET (Aerosol Robotic Network) sun photometer at All Nations University College (6.2N, 0.3W) within the NSSA region recorded enhanced aerosol optical depth presume to be triggered by smoke from fires. We will discuss sources of this enhancement as well results obtained from NASA's Global Modeling Initiative Chemistry and Transport Model (GMI-CTM), to quantify the impact on air quality by biomass burning.

A1.1-0081-18 A DECADAL (2007-2017) STUDY ON MERIDIONAL COUPLING BETWEEN POLAR AND TROPICAL REGIONS DUE TO SUDDEN STRATOSPHERIC WARMING (SSW) EVENTS

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The meridional coupling between polar and tropical stratospheric regions due to sudden stratospheric events is being investigated during all events occurred in the last decade (from 2007 to 2017). Using COSMIC RO data during two strong SSW events (2009, and 2013), It is observed that polar and tropical regions get coupled possibly through the rapid setup of strong meridional circulation within a period of one day, as a result significant temperature changes are observed in stratosphere and tropopause region from polar to tropical region. SSW event can strongly modify the polar and tropical stratospheric circulation pattern, which results a new pattern after termination of SSW. The newly emerged pattern usually dominates for 2-3 months. Stratospheric and tropospheric region have shown certain unique changes after the event such as a clear downward propagating cold phase at polar region, which located at similar heights as that of SSW phase. The magnitude of this cold phase was -80°C whereas the temperature prevailed of with 40°C in upper stratosphere (>30 km altitude) during SSW event. On the other hand, during cold phase at polar region that followed after the SSW event, a new warm motion emerged over tropical region. Strong implications of these unusually warm and cold phases are shown. Specifically it altered the cold point tropopause temperature and its height significantly for a period of 2-3 months from polar to tropical region. Cross equatorial response from northern to southern hemisphere of both cold and warm anomalies are also seen, such features are reported using COSMIC data which unprecedented.

A1.1-0082-18 SUDDEN STRATOSPHERIC WARMING (SSW) EVENTS AND RAPID SETUP OF DYNAMICAL CONNECTION FROM POLAR TO TROPICAL REGION: RESULTS FROM COSMIC OBSERVATIONS

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We have analyzed temperature changes in troposphere and stratosphere from polar to tropical region during major sudden stratospheric warming (SSW) using data derived from COSMIC over a period of 2007-2016. During peak period of SSW, a large variability noted in temperature structure, rise in temperature occurred down to the tropopause height (8 km height) in polar region. At around 40 km altitudes (as COSMIC data is available to this height), temperature increased by several tens of degrees within few days of SSW. After SSW termination, temperature decreased up to 80°C in strong SSW cases. After about a week of SSW event, descending cold anomalies emerged at polar region. These features are emerging normally known as polar night jet oscillations (PJO). The cooling phase was much longer along with large spatial coverage than the warm phase. Due to SSW, polar T-CPT and H-CPT alter significantly. As a consequence of SSW, bottom of stratospheric region expands and hence the tropospheric region shrunk by the same height. A rapid atmospheric response is identified between polar and tropical region possibly through set up of strong meridional circulation. During occurrence of SSW, at 40 km altitude in polar region, large increase in temperature noted, while in the tropics temperature dropped at similar heights. After termination of SSW, descending warm anomalies observed over the tropical region for a longer duration, while the long cold phase persisted at the polar region. These warm anomalies at tropical region are much longer and deeper in comparison to those of the cold anomalies. It is concluded that SSW event at polar region connects to the entire tropical tropopause region across the equator in SH up to 40°

S. Hence these processes need to be understood thoroughly to contribute to the temperature change.

A1.1-0083-18 RESIDUAL MEAN CIRCULATION DURING THE EVOLUTION OF SUDDEN STRATOSPHERIC WARMING

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Zonal mean flow changes during the evolution of sudden stratospheric warming are investigated by composite analyses of 76 warming events identified in the present day simulation from 299 winters. Their dynamical signatures are compared with the 17 SSW events using EraInterim data from 34 years (1979-2013). The main difference is that monthly distribution of the model SSW events are relatively less than reanalysis. The SSW events are classified as displacement or split events based on the geopotential field values at 10 hPa. The streographic projection of geopotential field values identifies 10 and 3 split events in model and observation respectively. The model quite accurately simulates some dynamical features associated with the major SSW. Residual mean circulation induced by EP-flux divergence, sum of advection and residual forcing are stronger in split events than displacement type SSW has been confirmed by both simulation and observation. Composite analysis of warming events from Era-Interim (1979-2013) record a cooling of the tropical lower stratosphere with corresponding changes in the mean meridional stratospheric circulation. A cooling of the upper troposphere induces enhanced convective activity near the equatorial region of the Southern Hemisphere and suppressed convective activity in the off-equatorial Northern Hemisphere. After selecting vortex splits, the sea-saw pattern of convective activity in the troposphere grows prominent and robust but the signal evolves somewhat earlier in model.

A1.1-0084-18 CHANGES IN MIDDLE ATMOSPHERIC CHEMICAL COMPOSITION OVER EQUATOR DURING SUDDEN STRATOSPHERIC WARMING EVENTS

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Microwave Limb Sounder (MLS) and Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) data are used to investigate the variation of ozone (O3), water vapour (H2O) and methane (CH4) volume mixing ratios (VMRs) in the equatorial stratosphere during 2009 and 2012 sudden stratospheric warmings, whose occurrence are identified using the ERA (European Center for Medium Range Weather Forecasting Reanalysis) Interim temperature and zonal wind. The Whole Atmosphere Community Climate Model (WACCM) reproduces the observed increase (decrease) of CH4 (H2O). It is suggested that short-term CH4 and H2O variations are due to tropical upwelling of air rich in CH4-rich and H2O-poor air.

A1.1-0085-18 MERGING DATASET OF STRATOSPHERIC OZONE PROFILES FROM OMPS, SCIAMACHY AND MLS LIMB OBSERVATIONS

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A constant monitoring over a global scale of the stratospheric ozone layer is carried on by means of several techniques. The limb geometry of observations from satellite platforms enables to obtain ozone profiles with a good vertical resolution, spatial and temporal coverage. SCIAMACHY and OMPS-LP are two satellite instruments able to collect shortwave scattered radiance in limb geometry. Ozone profiles from OMPS-LP and SCIAMACHY have been retrieved at the University of Bremen using the same radiative transfer model, a similar algorithm and spectral ranges. This study illustrates the merging of these two data sets, to obtain a consistent time series of ozone global distributions in the stratosphere. Since OMPS' scientific operations started at the beginning of 2012, the overlapping period of these 2 missions consists of only 3 months and a transfer function is needed to overcome issues related to the instrument calibration. To this aim, we used measurements performed by the MLS suite as a reference: this sensor has been operating from 2004 till present, collecting atmospheric emission in the microwave spectral region in limb geometry. Latitudeand longitude-resolved time series of ozone profiles retrieved from the three instruments have been calculated, thanks to the high spatial resolution of the merged data sets. After an inter-comparison of the three time series and their respective seasonal cycles, the merging has been performed minimizing the bias of both OMPS-LP and SCIAMACHY ozone number density profiles to MLS values, for each latitude, longitude and altitude independently. The seasonal cycle was not subtracted, because it was found to be consistent enough among the three instruments. Linear trends over the 2003-2017 merged time series were calculated considering QBO, ENSO and a solar forcing. Results are shown in this poster.

A1.1-0086-18 LONG-TERM VARIABILITIES AND TENDENCIES IN ZONAL MEAN TIMEDSABER OZONE AND TEMPERATURE IN THE MIDDLE ATMOSPHERE AT 10-15°N

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Long-term variabilities and trends of middle atmospheric (20–100 km) ozone volume mixing ratio (OVMR) and temperature and their responses towards quasi-biennial oscillation (QBO), solar cycle (SC) and El Niño-southern oscillation (ENSO) have been investigated using monthly averaged zonal mean Sounding of Atmosphere by Broadband Emission Radiometry (SABER) observations at 10–15°N for the years 2002–2012. Composite monthly mean of OVMR shows semi-annual oscillation (SAO) predominantly in the lower stratosphere (20–30 km) and in the upper mesosphere (above 90 km), whereas that of temperature shows SAO in the upper stratosphere (45–55 km) and lower mesosphere (60–75 km). Amplitudes of SAO and annual oscillation (AO) in OVMR show enhancement above 80 km and 90 km respectively in the mesosphere and both show maximum around 30 km in the stratosphere. The amplitudes of SAO and AO in temperature show maxima just below and above 80 km in the mesosphere, whereas in the stratosphere, they show maxima around 40 km and 20 km respectively. The phase profiles of SAO and AO in temperature show downward progressions below 80 km, whereas the phase profile of SAO in OVMR shows downward progression only below 40 km and the phase remains constant above 80 km. Regression analysis of OVMR shows increasing trend at 23 km, and small decreasing trend at 30 km, 34 km and above 80 km. Above 92 km, the trend sharply decreases. OVMR response to QBO winds at 30 hPa shows negative maxima at 30 km and 91 km, positive maximum at 26 km and is insignificant at other heights. The OVMR response to SC is positive in the middle stratosphere peaking at 31 km and in the upper mesosphere peaking at 95 km. The OVMR response to ENSO shows mixed behavior in stratosphere and positive in the upper mesosphere. It is positive in the lower height region 20–27 km with maximum at 25 km. The response to ENSO is insignificant up to 70 km and it is positive above 80 km with two maxima at 87 km and 97 km. Regression analysis of temperature shows cooling trends in most of the stratosphere and the mesosphere (40–90 km). The temperature response to SC is increasingly positive above 40 km. The temperature response to ENSO is negative in the middle stratosphere and positive in the lower and upper stratosphere. In mesosphere, it is largely negative in the height range 60–80 km and positive above 80 km.

A1.1-0087-18 PREDICTIONS OF THE ONSET OF MINI ICE AGE IN THE 25TH SOLAR CYCLE

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Predictions of the ir-regularity in the 11 year heartbeat of the Sun due to asynchronous of the two layered dynamo effect would result in mini ice-age as in the Maunder minimum. The onset of this event is expected in the beginning of 25th Solar cycle and would go to its maximum in the 26th Solar cycle. The minimum temperature is expected in 2028 due to the fall of solar activity by 60% termed as Solar Hybernation. The predictions are based on the observations obtained by the Royal Greenwich Observatory since 1874.

Keywords: Dynamo effect, Munder Minimum, Solar hybernation

A1.1-0088-18 THE ANGULAR CHARACTERISTICS AND POTENTIAL APPLICATION OF MOON-BASED EARTH OBSERVATION IN THE ELECTRO-OPTICAL REGION

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So far, space-borne, airborne, and ground-based remote sensing have provided us with a lot of valuable observation data. However, it is difficult or impossible for the existing remote sensing platforms to achieve the long-term consistent measurements. Thus, Moon, the only natural satellite of Earth seems to be a good platform for earth observation to solve the problem. However, the orbit and motion of Moon is completely different from other earth observation platforms, resulting in entirely different geometric characteristics.

Meanwhile, the angular information is an important and typical geometric characteristic of remote sensing with extensive applications, especially in the fields of atmosphere, radiation, oceanography and vegetation. Therefore, we focus on the angular characteristic of Moon-based earth observation in this paper. Considering equipment cost, energy demand and processing complexity, the optical remote sensing is mainly discussed in this research as the first step. As there is no long-term and stable Moon-based Earth observation data, a combination of simulation, numerical calculation and theoretical derivation were used.

Based on the Jet Propulsion Laboratory DE430 and Earth orientation parameters, together with related coordinate systems transformation, the position and attitudes of Sun, Earth and Moon were derived. At the same time, the direct illuminated region on the Earth is decided. Then, an angular geometrical model of Moon-based Earth observation was constructed and the angular algorithm was designed. The angular results were analyzed and it turned out that the solar and viewing zenith and azimuth angles of Moon-based Earth observation showed a good performance with the potential for global energy budget monitoring. Compared with space-borne remote sensing, the lunar observatory is able to observe the whole disk of Earth with various angular range, showing the potential for monitoring the large-scale geoscientific phenomena, especially energy budget.

A1.1-0089-18 A STUDY OF TROPICAL CYCLONES OVER INDIA (BAY OF BENGAL AND ARABIAN SEA) AND SOLAR INFLUENCE ON IT

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A prominent example of extreme weather event in India is Cyclonic Storm. In this paper annual variation of tropical Cyclonic Storm (CS), Severe Cyclonic Storm (SCS), Very Severe Cyclonic Storm (VSCS) and Super Cyclonic Storm (SuCS) over Bay Of Bengal (BOB) and Arabian Sea (ARS) during last 20 years (1990-2009) have been analyzed .The analysis revels that the total number of cyclone (TNC) has increased with high rate(gradient being +1.67 per year) and although C.S. is more over BOB than that over ARS.The rate of increase of

C.S. over Arabian Sea is more than that over Bay of Bengal. Furthermore, two interesting features have been noted: (i) Monsoon tends to prohibit the formation of C.S (ii) Cyclonic Storm(C.S.) increases with the increase of Global Sea Surface Temperature (GSST) during said period. Attempt has also been made to find out the influence of solar activity on these extreme weather events. Keeping in mind that the Sun Spot Number (SSN) is an indicator of the strength of solar effects, it has been found that in most of the times the high value of SSN is associated with small number of total cyclone (C.S.). Specifically, when only the years of high Sun's Spot Number (approximately greater than 90) are taken into consideration then Correlation Coefficient (C.C.) between SSN and number of cyclones comes out to be quite high (-0.78) significance at 99.99. The wavelet analysis also has been done to get a significant periodicity of the tropical cyclone.

A1.1-0090-18 THE TROPICAL CYCLONES OVER INDIA (BAY OF BENGAL AND ARABIAN SEA) AND THE IMPACT OF THIS HAZARD IN TO THE SOCIOECONOMIC STRUCTURE OF THE MEGA CITIES AND THE COASTAL AREA OF INDIA

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A prominent example of extreme weather event in coastal area of India is Cyclonic Storm. In this paper annual variation of different types of tropical Cyclonic Storm (CS) over Bay Of Bengal (BOB) and Arabian Sea (ARS) during last 40 years (1970-2010) have been analyzed .The analysis revels that the total number of cyclone (TNC) has increased with high rate (gradient being +1.67 per year) but the rate of increase of C.S. over Arabian Sea is more than that over Bay Of Bengal. Furthermore, two interesting features have been noted: (i) Monsoon tend to prohibit the formation of CS (ii) Global Sea Surface Temperature (GSST) increases with the increase of CS (if not facilitate) the Cyclonic Storm to form during said period. Attempt has also been made to find out the impact of such hazard into the vast coastal area of 7516.6 km long and the population of 14.2% with respect to whole nation. From last 4 decades the no. of cyclone become increases but the life causalities has been decreases. On the other hand the damage on the aspect of property and economy it increased. The increase of population and construction in coastal area also enhance the property damage and economic losses. Here in this study we have found some significant result to understand this impact of cyclonic storm in the coastal area and some megacities of there of India over Bay of Bengal and Arabian Sea.

A2.1-0001-18 THE PROGRESS OF SATELLITE ALTIMETRY IN OCEAN CIRCULATION LEADING TO THE SWOT MISSION

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The Surface Water and Ocean Topography (SWOT) is a satellite mission to map the elevation of water on Earth over both the ocean and land surface water for applications to oceanography and hydrology (https://swot.jpl.nasa.gov/). This presentation will address the progress from conventional altimetry leading to the oceanographic objectives and plans of the mission. Over the ocean, this new measurement will extend the two-dimensional resolution of ocean surface topography estimated from conventional radar altimetry from 150 km wavelength to possibly 15 km, offering opportunities to study the oceanic dynamic processes at these scales over the global oceans.

The dynamic processes at the scales of 15-150 km have typical temporal scales of days to weeks and act as one of the main gateways that connect the interior of the ocean to the upper layer. These processes provide both sink and source for the kinetic energy at larger scales, involving both low-frequency geostrophically balanced motions and high-frequency internal tides and gravity waves. The active vertical exchanges linked to these scales are a key aspect of the role of the ocean in the climate system. These vertical exchanges have impacts on the local and global budgets of heat, carbon and nutrients for biogeochemical cycles.

It is currently a major observational challenge to measure the ocean fine scales over domains large enough to quantify their global effects. For this reason our knowledge on the fine scales is largely based on simulations performed by high-resolution circulation models. SWOT will address this observational gap, and provide an unprecedented opportunity to study these motions and their interactions, which is key to understanding the energy budget of the global ocean dynamics. Model simulations have been conducted to illustrate the impact of the mission on the study of the oceanic mesoscales and submesoscales.

In terms of applications, the high-resolution SWOT data will allow a more accurate observation of fine-scale ocean currents, sea level and tides, in the coastal regions. These joint geostrophic and tidal currents feeding into operational models will help improve maritime operations, ship- ping routes, pollution and debris monitoring.

A2.1-0002-18 SENTINEL-3 SAR ALTIMETRY OVER COASTAL AND OPEN OCEAN: PERFORMANCE ASSESSMENT AND IMPROVED RETRIEVAL METHODS IN THE ESA SCOOP PROJECT.

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The European Sentinel-3 satellite, launched by ESA in February 2016 as a part of the Copernicus programme, is the second satellite to operate a SAR mode altimeter. The Sentinel 3 Synthetic Aperture Radar Altimeter (SRAL) is based on the heritage from CryoSat-2, but this time complemented by a Microwave Radiometer (MWR) to provide a wet troposphere correction, and operating at Ku and C-Bands to provide an accurate along-track ionospheric correction.

SRAL is operated in SAR mode over the whole ocean and promises increased performance w.r.t. conventional altimetry. SCOOP (SAR Altimetry Coastal Open Ocean Performance) is a project funded under the ESA SEOM (Scientific Exploitation of Operational Missions) Programme Element, started in September 2015, to characterise the expected performance of Sentinel-3 SRAL SAR mode altimeter products, in the coastal zone and open ocean, and then to develop and evaluate enhancements to the baseline processing scheme in terms of improvements to ocean measurements. Another objective is to develop and evaluate an improved Wet Troposphere correction for Sentinel-3, based on the measurements from the on-board MWR, further enhanced mostly in the coastal and polar regions using third party data, and provide recommendations for use.

In this presentation we present results from the SCOOP project that demonstrate the excellent performance of SRAL in terms of measurement precision, and we illustrate the development and testing of new processing approaches designed specifically to improve performance close to the coast.

The SCOOP test data sets and relevant documentation are available to external researchers on application to the project team. At the end of the project recommendations for further developments and implementations will be provided through a scientific roadmap.

A2.1-0003-18 OVERVIEW OF LONG-TERM OBSERVATIONS OF AIR-SEA INTERACTIONS AND POLAR OCEANS BY THE ADVANCED MICROWAVE SCANNING RADIOMETER (AMSR) SERIES

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The Global Change Observation Mission-Water (GCOM-W) satellite was launched by the Japan Aerospace Exploration Agency (JAXA) on 17 May 2012, as a member of the A-Train satellite constellation. The GCOM-W satellite carries the Advanced Microwave Scanning Radiometer 2 (AMSR2), which is a 6-band multi-frequency (6.9/7.3, 10.6, 18.7, 23.8, 36.5, and 89.0 GHz), dual-polarization (V and H) microwave radiometer and is a successor of the AMSR on the Advanced Earth Observing Satellite-II (ADEOS-II) satellite launched in December 2002 and the AMSR for NASA's Earth Observing System (AMSR-E) onboard the Aqua satellite launched in May 2002. The AMSR2 measures microwave brightness temperature over a 1600-km-wide swath with spatial resolutions of 5-50 km depending on the frequency. The conical scan mechanism of the AMSR2 covers more than 99% of the Earth's surface every 2 days. From the multi-frequency and dual-polarized measurements, several parameters of the ocean, atmosphere, land, and cryosphere were retrieved through theoretical and empirical algorithms. The JAXA's standard AMSR2 data product contains the sea surface wind speed, vertically-integrated water vapor, cloud liquid water, precipitation, sea surface temperature (SST), sea ice concentration, snow depths, and soil moisture. AMSR2 has completed its 5-year designed mission life in May 2017, and has transferred to extended-mission. Besides the 10-month gaps between AMSR-E and AMSR2, the AMSR series provide long-term global observation data for studies of air-sea interactions and polar oceans. Currently, JAXA is studying possible payload capability of the AMSR-2 follow-on instrument onto the Greenhouse Gases Observation Satellite-3 (GOSAT-3).

A2.1-0004-18 THE IMPORTANCE TO CONTINUE AND ENHANCE SPACEBORNE SALINITY OBSERVING CAPABILITY TO STUDY OCEAN-WATER CYCLE-CLIMATE LINKAGES

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In-situ observing system has provided the capability to monitor multi-decadal changes of salinity in the open ocean and on large scales. However, in-situ platforms are inadequate to monitor salinity changes in marginal seas and coastal oceans as well as salinity variations on mesoscales. Monitoring longer-term changes of salinity in these regions and scales are important to the studies of terrestrial-ocean water cycle linkage, cross-shelf exchanges, coastal-open ocean connection, energy transfer, and biogeochemistry. Satellite measurements of sea surface salinity (SSS) have demonstrated their values to enhance salinity observing capability in these regions and scales. This presentation highlights the accomplishments of satellite SSS, especially in studying salinity variations for regions and scales not well resolved by in-situ platforms. Examples will be provided to emphasize the synergy of satellite and in-situ salinity observing systems to investigate the linkage of open-ocean and marginal sea salinity in relation to longer-term changes in the climate and water cycle. Recognizing this need, the Global Climate Observing System (GCOS) Implementation Needs (Belward et al.2016) suggested Action 032: Ensure the continuity of space-based SSS measurements. Sustaining satellite SSS observing capability, enhancing spatial resolution, and improving accuracy (especially in high-latitude oceans) are important to studying the linkages of the ocean with the water cycle and climate variability.

A2.1-0005-18 MEASURING OCEAN SURFACE WINDS AND CURRENTS FROM SPACE

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Ocean surface vector winds and currents are tightly coupled Essential Climate Variables (ECVs) that play a critical role in ocean-atmosphere interactions. Although ocean surface vector winds have been observed for close to two decades, only the long-wavelength geostrophic component of ocean currents derived from sea surface height (SSH) have been available from nadir altimetry. The recent US National Academy Decadal Review, Thriving on Our Changing Planet A Decadal Strategy for Earth Observation from Space, (2018), has identified “coincident highaccuracy currents and vector winds” as a high priority Targeted Observable for the next decade exploration. Collecting these measurements would be the goal of a potential candidate for the new class of NASA competed Earth System Explorer missions.

In our presentation, we review the scientific, operational, and applications benefits of such a potential Winds and Currents Mission (WaCM). Simultaneous measurements of winds and currents will allow a direct assessment of momentum transfer between the ocean and the atmosphere. They will also improve our understanding of the fluxes of heat, gas, and momentum across the air-sea interface. We expect these measurements to be useful inputs for weather, ocean circulation and climate models, and to impact the science, applications and operational communities. We also expect that they will have societal benefits by informing coastal circulation and weather warnings, routing of shipping, and disaster management from current current-borne pollutants as well as marine debris. A system capable of making these measurements is also expected to be of benefit for arctic applications, such as determining sea ice motion.

In the second part of the presentation, we show how a Ka-band Doppler scatterometer instrument using existing technology could make these measurements from space in the next decade. The WaCM scatterometer would provide daily global coverage, similar to NASA’s QuikSCAT, by using rotating pencil-beam scanning covering a 1,400 km swath. The azimuth spatial resolution is expected to be on the order of 5 km, or a factor of 5-times better than QuikSCAT, enabling better coastal coverage and better resolution of fronts. To show the viability of the measurement concept and measurement physics, NASA has funded the DopplerScatt instrument (PI, D. Perkovic-Martin), which has collected substantial amounts of data in 2016 and 2017. We use these data to demonstrate the measurement capabilities of the potential WaCM mission concept, including the predicted error budgets for the space-borne scatterometer instrument.

A2.1-0006-18 DEVELOPMENT, VALIDATION, AND APPLICATIONS OF A NEW OCEAN OSE-OSSE SYSTEM FOR QUANTITATIVE ASSESSMENTS OF SATELLITE AND IN-SITU OBSERVING SYSTEMS

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A new ocean OSE-OSSE system has been developed by the Joint AOML/CIMAS/RSMAS Ocean Modeling and OSSE Center (OMOC). It is the first ocean system that follows best practices for design and rigorous validation that were established for atmospheric OSSE systems to ensure credible observing system impact assessments. It is a fraternal twin system that uses two substantially different configurations of the HYbrid Coordinate Ocean Model (HYCOM) as the unconstrained Nature Run (NR) and the data-assimilative Forecast Model (FM). The system was initially developed in the Gulf of Mexico, and it has since been extended to a North Atlantic domain. Validation of the North Atlantic system was conducted in three steps: First, the NR was evaluated based on the realism with which it reproduced climatological mean conditions and mesoscale variability. It was judged to be sufficiently realistic to represent the truth with respect to these ocean properties. Second, errors (differences) between unconstrained simulations of the FM and NR were analyzed to establish that the two models were neither too similar nor too different. Finally, OSE and OSSE pairs were conducted where data denial experiments assimilated the same sets of real (OSE) and simulated (OSSE) observations. These experiments demonstrated that OSSEs produced consistently similar impact assessments.

System capabilities are illustrated by performing OSSEs to quantitatively assess the impact of assimilating satellite altimetry. Given that the NR provides a high-resolution, three-dimensional representation of the truth, the ability of satellite altimetry to improve analyses of ocean mesoscale features is quantitatively assessed using horizontal wavenumber power spectrum analysis, an approach that is not possible in the OSE framework. Correction of mesoscale structure extends to smaller wavelengths in the meridional (predominantly along-track) direction compared to the zonal (predominantly across-track) direction. By assimilating zero through four altimeters in addition to all other ocean observations, assimilation of two altimeters provides over 90% of the correction provided by four altimeters. In particular, the fourth altimeter only provides redundancy with respect improving mesoscale ocean analyses. Future plans include extending the OSE-OSSE system to global and to develop the capability of performing OSSEs in the coastal ocean.

A2.1-0007-18 ACCURATE ESTIMATION OF REGIONAL SEA LEVEL CHANGES WITH THE ESA CCI SEA LEVEL ESSENTIAL CLIMATE VARIABLE

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Accurate monitoring of the sea level is required to better understand its variability and changes. In particular, this is of crucial importance in coastal zones regarding the societal impact of climate change in these regions. Sea level is one of the Essential Climate Variables (ECV) selected in the frame of the ESA Climate Change Initiative (CCI) program. It aims at providing a longterm homogeneous and accurate sea level record at global and regional scales. The needs and feedback of the climate research community have been collected so that the development of the products is adapted to the users. The range of applications of the dataset covers the analysis of the global and regional sea level changes, from the periodic and inter-annual signals to the longterm evolution. A fully reprocessed time series of monthly sea level maps has been produced in 2016 and is now available for the users (see http://www.esa-sealevel-cci.org/products). About 70 cumulated years of satellite altimetry data from 9 different missions (TOPEX/Poseidon, Jason-1/2, ERS-1/2, Envisat, Geosat-FO, CryoSat-2 and SARAL/AltiKa) have been reprocessed and the dataset covers the period 1993-2015. Within the project, the 15-partner consortium has focused on the development, validation and selection of the best algorithms that contribute to increase the ECV homogeneity and reduce the errors. Among the selected algorithms, some have led to improved sea level estimation in coastal regions. These are the GPD+ wet troposphere correction (based on radiometer and GNSS measurements including inter calibration with respect to external sensors) and the new ocean tide model FES14. Other global algorithms also contribute to the improved quality of the time series such as the orbit solutions (POE-E and GFZ15), the ERA-Interim based atmospheric corrections and the Mean Sea Surface (MSS DTU15). In addition, a dedicated study has led to improved retracking of the altimeter radar echoes in coastal areas

(2D waveform retracker) and specific validation activities have been carried out in these regions with in-situ and geodetic data, partly focusing on the estimation of the total relative sea level. The presentation will focus on the description of the new Sea Level record and the impacts of the different altimeter standards. The associated uncertainties have been characterized at different spatial scales (global, regional, mesoscale) and temporal scales (long-term, inter-annual, periodic signals). The perspectives on improvement of the sea level estimation in coastal zones will be also highlighted.

A2.1-0008-18 USING SATELLITE ALTIMETRY TO ENHANCE MONITORING AND SIMULATION OF STORM SURGES

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Storm surges are the major factor causing coastal flooding, resulting in catastrophic damage to properties and loss of life in coastal communities. In this presentation, I will show how satellite altimetry can be used to enhance observation and simulation of storm surges, by overcoming challenges associated with individual events. These events include storm surges during Hurricane Sandy off New York, Hurricane Isaac off Florida York, Typhoon Seth off East China, and an extratropical storm off Newfoundland. Satellite results are evaluated against tide-gauge data and dynamic mechanisms for storm surges are explained. Finally, I discuss the potential of a wide-swath altimetry mission, the Surface Water and Ocean Topography (SWOT), for observing storm surges.

A2.1-0009-18 INTERANNUAL FORCING OF MESOSCALE EDDY KINETIC ENERGY IN THE SUBTROPICAL SOUTHERN INDIAN OCEAN

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A region of elevated mesoscale eddy activity spans the subtropical southern Indian Ocean (SSIO) between Madagascar and Australia. Interannual and decadal changes in eddy activity in the SSIO eddy band have implications for the shallow overturning circulation, meridional heat transport, and biological productivity in the Indian Ocean basin. The sea level anomalies (SLA) from merged satellite altimeter data are decomposed into large-scale and mesoscale components. Near Australia, where eddies are generated in the Leeuwin Current hugging the coast, the spatial distribution and temporal variability of eddy kinetic energy (EKE) derived from the mesoscale SLA field is positively correlated with the total SLA. This correlation is attributed to remote forcing from the Pacific: a higher sea level in the western tropical Pacific (e.g., during La Niña or negative PDO conditions) drives downwelling coastal Kelvin waves and a stronger Leeuwin Current, increasing the generation of mesoscale eddies that radiate towards the west.

In the central SSIO, interannual and decadal variability of mesoscale eddy activity is not well explained by large-scale climate mode forcing. However, EKE variations propagating northwestward from the mid-latitudes southwest of Australia are associated with central SSIO mesoscale EKE variability, with a lag of 2-3 years. The zonal and meridional propagation of eddy energy is consistent with the advection of the mean flow towards the northwest at depths below 150 meters. When elevated mesoscale activity south of Australia propagates into the usually quiescent region just south of the SSIO eddy band, instability promotes further eddy development in the central SSIO. The identification of these boundary and interior mechanisms for EKE variability facilitates predictions of SSIO eddy activity levels with lead times of several months to several years, and provides a basis for assessment of model simulations of eddy activity in the region.

A2.1-0010-18 THE POTENTIAL USE OF SARAL ALTIKA TOWARDS COASTAL REGIONS

- A CASE STUDY ON EAST COAST OF INDIA.

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The Indian coastline has been subjected to several geomorphological changes due to natural processes and manmade activities. There are areas of severe erosion and accretion, which lead to loss of several acres of coastal land and accretion of river mouths/inlet preventing the waste water entering into the sea. The most important factor which governs the coastal erosion is wind waves. Attempts were made to predict the waves in deep and intermediate waters but no attempts are made to obtain waves nearer to the coast as the conventional altimeters provide wave measurements as close as maximum up to 6-10 km only but SARAL being new in its kind having such a high frequency and smaller foot print enables measurements of wave data as close as three km from the coast. Also Higher pulse repetition frequency enables more sampling rate. The Bay of Bengal is influenced by three different conditions during a year. They are Southwest monsoon SW (June to September), Northeast monsoon NE (December to February) and a transition period between these two seasons. The wave data obtained from the conventional altimeters during the calm season are are not reliable because of wave heights are so small that will fall within the accuracy of the instrument and provides better correlation of higher wavelengths. The eight-millimetre wavelength of SARAL enables more accurate measurement of the backscatter coefficient over calm or moderate seas. Hence, SARAL data provides better measurements of wind and wave data as close as 3km away from the coast and thus helps us to measure shallow water wave characteristics.

A2.1-0011-18 DIRECT RETRIEVAL OF STRESS AND EVAPORATION FROM SPACE OBSERVATIONS

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Momentum flux (stress) and latent heat flux (evaporation) at ocean surface are transported by turbulence, which is small scale random process generated/subdued by wind shear and buoyancy (vertical wind and density gradients). Turbulence is difficult to measure and, traditionally, transfer coefficients (bulk parameterization formula) are used to related them the mean parameter measured on ships, such as, wind and humidity in air, and temperature and current at ocean surface. Satellite sensors measure radiance and backscatter at the ocean surface and there is no critical reason to reproduce measurements of meteorological and oceanic sensors on ships. We show that direct retrieval of latent heat flux from the radiance measured by microwave radiometers mitigate errors caused by the multiplication of retrieval uncertainties of wind to those of temperature or humidity while facing the uncertainty of the transfer coefficient. We will address the uncertainty of retrieving strong wind caused by backscatter saturation and the change behavior of the transfer coefficient under tropical cyclone by direct stress retrieval. We will show that scatterometers measurements represent the vector difference between wind and current, the characteristic of stress rather than wind. As different from the prevailing winds, stress spins down the mesoscale eddies and reduce the kinetic energy into the ocean.

A2.1-0012-18 DATA VISUALIZATION FOR CITIZEN ENGAGEMENT IN OCEAN ENVIRONMENTAL CHALLENGES

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One of the most critically overlooked aspects of climate change is the declining health of Earth's oceans. The oceans have absorbed 25-30% of all human produced carbon emissions since the Industrial Revolution and 93% of the excess heat generated by anthropogenic global warming. As a result, oceans have shielded us from more severe surface warming effects, but at a high cost. This paper will take steps to connect individuals to tools including data visualizations and satellite imagery to learn about and understand challenges to Earth's oceans including warming, acidification, sea level rise, hypoxia, pollution, and overfishing. Exabytes of data exist on all of the Earth's subsystems, but such information is often disparate and expertoriented. People are too overwhelmed to take action to change our harmful relationships with the Earth. Starting with the North Atlantic region, this paper connects ocean challenges to local climate, ecosystem, and human development issues, making these topics more personal to stakeholders. Next, these problems are mapped to specific, adoptable actions and behavior changes ranging from consumer choices and diet, to more sustainable daily habits, to local policy activism. With this framing, people can be motivated rather than defeated and start making a positive difference. A catalogue of available data visualization resources-including from NASA, ESA, and nonprofit organizations-was assembled and curated for interactivity and user-friendly design. As a part of the larger MIT Earth Speaks initiative to develop a digital interface for engagement with earth conservation and sustainability, this paper will lay out a roadmap for more widespread understanding of ocean challenges and practical individual actions to take to heal endangered marine ecosystems and prepare for inevitable changes in ocean climate systems. User interface and user experience (UI/UX) concepts for the oceans section of Earth Speaks platform will also be presented.

A2.1-0013-18 INSIGHTS ON TSUNAMI GENESIS FROM SATELLITE GRAVITY CHANGES OF LARGE EARTHQUAKES

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Large earthquakes at subduction zones usually generate tsunamis and coseismic gravity changes. These two independent oceanic and geodetic signatures of earthquakes can be observed individually by modern geophysical observational networks. The Gravity Recovery and Climate Experiment (GRACE) twin-satellites can detect gravity changes induced by large earthquakes, while altimetry satellites and Deep-Ocean Assessment and Reporting of Tsunamis (DART) buoys can observe resultant tsunamis. In this study, we introduce a method to connect the oceanic tsunami measurements with the geodetic gravity observations, and apply it to the 2004 Sumatra Mw 9.2 earthquake, the 2010 Maule Mw 8.8 earthquake and the 2011 Tohoku Mw 9.0 Earthquake. Our results indicate consistent agreement between these two independent measurements. Since seafloor displacement is still the largest puzzle in assessing tsunami hazards and its formation mechanism, our study demonstrates a new approach to utilizing these two kinds of measurements for better understanding of large earthquakes and tsunamis.

A2.1-0014-18 SEA SURFACE SALINITY VARIATIONS IN THE MARITIME CONTINENT REGION AND THE RELATIONSHIPS WITH CLIMATE VARIABILITY AND OCEAN CURRENTS

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Variations of sea surface salinity (SSS) in the Maritime Continent (MC) region have important implications to ocean circulation and climate variability. Systematic monitoring of salinity changes in the MC region has been extremely challenging due to the complicated geometry and other factors. This has hindered our understanding of freshwater changes in the MC region, the relationships with climate variability (e.g., monsoon, El Nino-Southern Oscillation, and Indian Ocean Dipole), and the potential implications to climate predictions. NASA's Soil Moisture Active Passive (SMAP) satellite has been providing sea surface salinity (SSS) measurements at 40-km spatial resolution and 8-day repeat cycle since April 2015. Here we examine seasonal-tointerannual variations of SSS in the MC region using SMAP SSS in relation to other satellite observations, including precipitation, sea surface height, ocean surface currents, ocean color, and soil moisture. The analysis results illustrated the relationships of SSS variations with monsoonal forcing in the northern and southern parts of the MC region, the effects of the 2015 positive Indian Ocean Dipole, the 2015-16 El Nino, and the exchange between the MC and the Pacific Ocean. In particular, we identified the source of freshwater in the MC region that modifies the structure and transports of the Indonesian throughflow, a climatically important element of the global ocean circulation that connects the Pacific and Indian Oceans.

A2.1-0015-18 USE OF REMOTELY SENSED SEA SURFACE TEMPERATURE (SST) VALUES TO ASSESS THE BLEACHING EVENTS IN THE NORTHERN PERSIAN GULF

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The bleaching events have become more repeated worldwide and may affect the health of coral communities permanently and irreversible. The most important reason of this phenomenon is high amounts of sea temperature, where it is more efficient if it remains high for a long period of time. Continuous measuring of sea temperature may help us to assess the effects of fluctuation of this value on health coral reefs. Remotely sensed data have provided us a proper source of sea surface temperature (SST) data from early 70s. This research employed historical remotely sensed SST values from the northern Persian Gulf (spatial resolution= 1°×1°) to assess the relationship between variations of this value and coral bleaching events happened in this area. In this regard, degree heating weeks (DHWs) was selected as main indicator, because it considers the persistence of positive water temperature anomalies which is most effective parameter on coral bleaching. Normal values of SST for each cell were extracted from a remotely sensed data source between 1971 and 2000 and the mean weekly SST values were compared with it form 1981 to 2017. Pierce skill score (PSS) was selected to quantify the capability of selected threshold for DHW. The final results demonstrated that the DHW value more than 5.3 may cause bleaching in coral reefs, where it happens on 1998, 2007, 2015, and 2017 in the studied area.

A2.1-0016-18 HIGH FREQUENCY BISTATIC RADAR OBSERVATIONS OF THE OCEAN SURFACE WITH GROUND-IONOSPHERE-OCEAN-SPACE (GIOS) SCATTER

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Knowledge of the sea is of primary importance for both ship transportation and HF radar clutter prediction. A new concept has been developed called HF Ground-Ionosphere-OceanSpace (GIOS) which can view vast regions of the Earth's surface. Ground HF transmissions are reflected by the ionosphere to illuminate the ocean over a few thousand kilometers. HF receivers on low-earth-orbit satellites detect the radio waves scattered by the sea and land surface. Using the theory of radio wave scatter from ocean surfaces, the GIOS data is then processed to yield the directional wave-height spectrum of the ocean. The GIOS technique has several advantages over existing remote sensing methods. First, a large area of the ocean can be sampled to yield the wave-height characteristics with high, km-scale resolution. This measurement scale matches the grid size used in physics-based oceanographic models. The wave height spectrum can be directly compared with temporal frequency spectrum obtained with buoys at specific points in the ocean volume. Furthermore, the GIOS technique uses HF waves which penetrate the dense rain found in hurricanes. Microwave attenuation inside strong sea storms blocks mapping of the sea surface.

The GIOS program at NRL is being developed using both experimental and theoretical methods. To test the GIOS concept, ground HF transmissions from over-the-horizon radars were employed to scatter sky wave signals from the ocean to radio receivers in low-earth-orbit. The HF receiver (RRI) on the Canadian ePOP/CASSIOPE satellite has collected radio signals scat- tered from the ocean illuminated by ground transmitters in the US, Australia and Northern Europe. This satellite has two dipole antennas in a crossed configuration to measure HF waves below 18 MHz. Right and left hand circular polarization is synthesized from the data from the in phase (I) and quadrature (Q) data provided by the RRI digital instrument. For the ground HF transmission source, the Relocatable Over the Horizon Radar (ROTHR) system in

Chesapeake Virginia was used to illuminate the ocean extending from coast of Florida to south of Jamaica. Range and Doppler processing of the radar waveforms yields an ocean scatter map at each time in the ePOP orbit.

Tests of the GIOS technique were conducted with the NRL Surface Wave Radar located at Cape May, New Jersey scatter up from the ocean to the ePOP satellite and the NRL Airborne HF Sensors. The Twin Otter will be flown east and south of Wallops Island Virginia while the ePOP is passing overhead. The airplane component provides a calibration point over the ocean to aid in the range-Doppler analysis of the HF data from the satellite receiver. All of these experiments are analyzed using both ocean scatter data and ray trace simulations.

A2.1-0017-18 ON THE SPATIAL SCALE OF THE SWOT KARIN MEASUREMENT OVER THE OCEAN

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The Surface Water and Ocean Topography (SWOT) mission aims to measure the sea surface height (SSH) at a high spatial resolution using Ka-band Radar Interferometer (KaRIN). The primary oceanographic objective is to characterize the ocean eddies at a spatial resolution of 15 km for 68% of the ocean. This resolution is derived from the ratio between the wavenumber spectrum of the conventional altimeter (projected to submesoscale) and the SWOT SSH errors. While the 15km threshold is useful as a global approximation of the spatial scales resolved by SWOT (SWOT-scale), it can be misleading for regional studies. Here we revisit the problem using a high-resolution (2km) tide-resolving global ocean simulation and map the SWOTscale as a function of latitude-longitude and season. The results show that the SWOT-scale has a strong geographic and seasonal dependence. In general, it is smaller (<15km) in low latitudes, increases to 30km in mid-latitudes and 40km in high latitudes especially over the Southern Ocean. It also shows a seasonality with a maximum during the local winter and minimum during the local summer. Both balanced motions and internal gravity waves/tides have a significant contribution to the scale variation. These characteristics provide a guideline for interpreting the satellite fidelity with ocean physics in consideration and shed light on the development of the future SWOT data assimilation system.

A2.1-0018-18 OBSERVATION OF SATELLITE DERIVED MONTHLY SCALE VARIABILITY OF SURFACE WATER CHLOROPHYLL, TEMPERATURE, SALINITY AND NITRATE IN THE BASINS BAY OF BENGAL AND ARABIAN SEA

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The analysis has been carried out to study the monthly scale variability of sea surface chlorophyll, temperature (SST) and nitrate using Modis-Aqua and ocean salinity using SMAP satellite datasets during 2016 and 2017. The chlorophyll, SST and derived nitrate products are of 4 kilometre resolution data and the SMAP salinity data is of 25 kilometre resolution. The nitrate images have been generated using the in situ data based model using chlorophyll and SST datasets. The model has been developed for the southwest Bay of Bengal and has been applied for the Bay of Bengal (BoB) and Arabian Sea (AS). There has been observation of high salinity trend (34-36 psu) in AS during most of the months, but the BoB salinity range is broader, 22-36psu. The variability of salinity is well observed in the BoB, depicting the river water flux and dilution of the BoB water. The chlorophyll observed to be higher (0.4-5.0 mg/m3) in northern Arabian Sea as compared to other regions. The BoB productivity has shown lesser chlorophyll biomass as compared to AS, except few months during northeast monsoon (November-December) and southwest monsoon (June-August). During southwest monsoon months (July-September), the low saline water (22-26 psu) has been observed to be linked to high chlorophyll water with chlorophyll concentration 0.3-4.5 mg/m3 in the coastal BoB water. This is due to the riverine fluxes with high nutrients inducing to have more productivity in the coastal water. The winter cooling like in AS and has been observed in the BoB and well depicted with the decrease in SST (range 24-26°C) during December to February in the northern BoB coastal water. The BoB region SST has shown linkage to salinity but in Arabian Sea the relationship is different as the salinity is higher and uniform almost round the year. The nitrate image has shown more resemblance to chlorophyll images. Only few coastal region has shown match trend to SST. The nitrate on monthly scale ranged 0.01-6.0 µM. The observed high productivity zones with effect of southwest and northeast monsoons in the coastal BoB and AS has been suitable for fishing resources exploration. The phytoplankton distribution and the habitat suitability and biogeography of zooplankton and fishes can be understood referring different physicochemical parameters variability in synoptic scale using different satellite datasets irrespective resolutions and different platforms.

A2.1-0019-18 CHLOROPHYLL VARIABILITY IN THE BAY OF BENGAL AND ITS RELATION WITH ENSO AND IOD

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The present study focuses on the variability of the biological parameter (chlorophyll) and physical, dynamical parameters like sea surface temperature, sea surface wind and sea surface height over the Bay of Bengal during 1998 - 2017. Satellite observations chlorophyll and sea surface temperature clearly shows the seasonal and inter-annual variability along the central east coast of India which is associated with upwelling process. The upwelling index varies from 9 to 135 m3/s/100m of coastline and the corresponding chlorophyll concentration is 2 to 8 mg/m3. The lack of upwelling favorable conditions results in the majority of the southern side of the central east coast of India waters being insufficient, which is reflected in low or moderate productivity. Drastic decrease in chlorophyll concentration is observed during ENSO and as well as in IOD periods.

A2.1-0020-18 INVESTIGATION OF THE INTRA-ANNUAL VARIABILITY OF THE NORTH EQUATORIAL COUNTERCURRENT/NORTH BRAZIL CURRENT EDDIES AND OF THE INSTABILITY WAVES OF THE NORTH TROPICAL ATLANTIC OCEAN USING SATELLITE ALTIMETRY AND EMPIRICAL MODE DECOMPOSITION

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The intra-annual variability of the tropical Atlantic Ocean north of the equator is investigated with satellite altimetry mean sea level anomaly data and with an algorithm based on empirical mode decomposition (EMD) methods. Two regions of high variability are identified. The first region, between 3° and 12°N, is characterized by the presence of westward-propagating eddies linked to the North Brazil Current retroflection in the vicinity of the Brazilian coast. They show a strong annual cycle. In this paper the EMD algorithm points out that this signal is frequency modulated shifting from large length-scale structures in October to smaller ones in March. Consequently, the number of "eddies" per year can be aliased, according to the time and location of sampling, and can impact the percentage they explain of the interhemispheric exchange of mass and heat associated with the meridional overturning circulation's upper limb. A scenario concerning this dynamics is proposed. The second region reveals the presence of westward-propagating instability waves centered north of the equator (3°-7°N) between 50° and 10°W. These instability waves are also frequency modulated and show a strong seasonal cycle with maximum amplitude around August.

A2.1-0021-18 GLOBAL SEA LEVEL BUDGET AND OCEAN MASS BUDGET ASSESSMENT: PRELIMINARY RESULTS FROM ESA'S CCI SEA LEVEL BUDGET PROJECT

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Studies of the sea level budget are a means of assessing and understanding how sea level is changing and what are the causes. Closure of the total sea level budget implies that the observed changes of global mean sea level equal the sum of observed (or otherwise assessed) contributions, namely changes in ocean mass and ocean thermal expansion. Closure of the ocean mass budget implies that the observed ocean mass change equals assessed changes in mass from glaciers, ice sheets, land water storage, snow pack and atmospheric water content. Misclosure of these balances indicates errors in some of the components or contributions from missing or unassessed elements in the budget.

ESA's Climate Change Initiative (CCI) has conducted a number of projects related to sea level, namely the Sea Level CCI project, the Greenland and Antarctic Ice Sheet CCI projects, the Glaciers CCI project and the Sea Surface Temperature CCI project.

The aim of the ongoing CCI Sea Level Budget Closure project is to use the CCI data products, together with further data products provided by the project partners to re-assess the sea level budget and ocean mass budget. Specifically, the project further develops and analyzes products based on the CCI projects mentioned above in conjunction with data products from ocean profilers (e.g., Argo), GRACE-based ocean mass change assessments, and model-based data for glaciers and land hydrology. The work benefits from directly involving the expertise on the product generation for all the involved sea level contributions. The presentation will report on preliminary assessments of global sea level budget and global ocean mass budget closure. We focus on two periods: 1993-

2015 (the altimetry period) and 2003-2015 (the GRACE / ARGO period). We consider the budget of the long-term trends as well as the budget of the overlaid interannual variations. A special focus is on the account for uncertainties of the individual contributions, building on the expertise of all project partners.

A2.1-0022-18 IMPROVEMENT OF THE ARCTIC OCEAN BATHYMETRY AND REGIONAL TIDAL ATLAS (CP4O-CRYOSAT PLUS 4 OCEANS)

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Cryosat Plus for Oceans (CP4O) is a project under the European Space Agency's "Support to Science Element" programme which aims to develop and evaluate new ocean products from the Cryosat cryosphere earth observation mission. The main focus of CP4O has been on the additional measurement capabilities that are offered by the Synthetic Aperture Radar mode offered by the innovative SIRAL altimeter, with further work in developing improved geophysical corrections

The Arctic Ocean is a challenging region, because of its complex and not well-documented bathymetry, together combined with the intermittent presence of sea ice and the fact that the in situ tidal observations are scarce at such high latitudes. This initiative initially addresses the bathymetry in the Arctic in attempting to improve altimetric bathymetry using the near 7 years of Cryosat-2 high quality and high resolution "geodetic" SAR altimetry all the way up to 88°N. Subsequently the project progresses to use Cryosat-2 in TWO ways for improved ocean tide modelling in the Arctic Ocean. One is to use Cryosat-2 improved bathymetry the second is to use Cryosat-2 derived harmonic tidal constituents for assimilation into a regional tide model.

The project runs during 2017 and includes the following activities: • Evaluate existing bathymetries available for the Arctic (R-TOPO2, IBCAO etc). • Generate an improved Arctic bathymetry by inverting the high resolution DTU15 gravity field derived from Cryosat-2 data, and combining with the bathymetry selected in the previous task. • Evaluate this new bathymetry through comparisons against available reference data, and assessments with the TUGO hydrodynamic model. • Using tidal constituents (with associated error estimates) derived from Cryosat-2 data, together with the TUGO hydrodynamic model, develop and evaluate a new regional Arctic Tidal model for the Arctic Ocean.

A2.1-0023-18 A STUDY ON THE COMPATIBILITY OF THE SEA SURFACE TEMPERATURES BETWEEN HIMAWARI-8/AHI AND LANDSAT-8/TIRS

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Japanese geostationary meteorological satellite Himawari-8 was launched on October 7, 2014. The Himawari-8 is equipped with an Advanced Himawari Imager (AHI). The AHI has total of 16 observation bands (3 for visible, 3 for near-infrared and 10 for infrared). The Himawari-8 observes the whole of Japan with 2.5 minutes intervals. The spatial resolutions of the Himawari8 are 0.5 - 1 km for visible bands and 1 - 2 km for near-infrared and infrared bands. On the other hand, American earth observation satellite Landsat-8 was launched on February 11, 2013. The Landsat-8 is equipped with the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). The OLI has total of 8 observation bands (4 for visible, 3 for near-infrared and 1 for infrared) and the TIRS has 2 observation bands (2 for infrared). The Landsat-8 observes the same area with 16 days intervals. The spatial resolutions of the OLI are 30 m and those of the TIRS are 100 m. Utilizing the data of bands 13 and 14 of the Himawari-8/AHI which observed the whole of Japan, and the data of bands 10 and 11 of the Landsat-8/TIRS which observed over the Uwa Sea of Japan, we compared the Brightness temperatures (BTs) and the Sea Surface Temperatures (SSTs) obtained from the synchronous observation by both satellites. From the analysis of correlation of the BTs of the Himawari-8/AHI and those of the Landsat8/TIRS in the thermal infrared bands of similar wavelength, we found that the correlation coefficient was the highest between the band 13 (10.194-10.612 μm) of the Himawari-8/AHI and the band 10 (10.780-11.280 μm) of the Landsat-8/TIRS. Finally an atmospheric correction and an emissivity correction were applied to the BTs, we compared the measurement SSTs of in situ survey and the computed SSTs obtained from satellites over the Uwa Sea of Japan. From the analysis, we confirmed that the error between the measured SSTs and the computed SSTs of both satellites were within approximately 1 Kelvins.

A2.1-0024-18 BROADVIEW RADAR ALTIMETRY TOOLBOX

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The universal altimetry toolbox BRAT (Broadview Radar Altimetry Toolbox) is a collection of tools and tutorial documents designed to facilitate the processing of radar altimetry data. It can read all previous and current altimetry missions' data. It incorporates the capability to read the upcoming Sentinel-3 L1 and L2 products. ESA endeavoured to develop and supply this new capability to support the users of the Sentinel-3 mission.

The toolbox is freely available at http://earth.esa.int/brat. The BRAT suite is mostly made of command line tools, of which the BratGUI is the front-end. BRAT can be used in conjunction with MATLAB/IDL (via reading routines) or C/C++/Python/Fortran via a programming API, allowing users to obtain the desired data, bypassing the data-formatting hassle. BRAT can also be used to simply visualise data quickly or to translate the data into other formats such as NetCDF, ASCII text files, KML (Google Earth) and raster images from the data (JPEG, PNG, etc.).

Several kinds of computations can be done within BRAT, involving both user-defined combinations of data fields that can be saved for posterior use and the BRAT's predefined formulas from oceanographic altimetry. BRAT also includes the Radar Altimeter Tutorial, which contains an extensive introduction to altimetry,

showing its applications in different fields. Use cases are also available, with step-by-step examples, covering the toolbox usage in the different contexts.

A2.1-0025-18 SATELLITE DERIVED SEA SURFACE TEMPERATURE FRONTS IN RELATION WITH TUNA CATCH IN THE EEZ OF PAKISTAN

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Sea surface temperature (SST) is an important parameter in marine ecosystem studies as its relations of Fishery and other marine resources. In this study SST fronts have also been studied with relate to tuna fish catch data of April and August 2014 was acquired. Satellite derived MODIS daily products have been used to derive thermal fronts in the exclusive economic zone (EEZ) of Pakistan. Research results indicated that the Sea surface temperature gradually changed from 22C to 24C where Tuna catch is high and By Catch is low in frontal region. The further Relationship between these two data are discussed in this study and also made recommendations for in what way these two datasets should be handled. Remote sensing data and GIS tools are efficient and less time consuming for mapping and classifying sea surface temperature in a broader way. Survey of fishing resources is really time consumed and costly, Satellite Remote sensing data shows a promising tool to monitor fishery resources in a cost effective manner. Satellite data play an important role to identify fish aggregation zones and these techniques could also be used to forecast potential fishing zones by measuring oceanic parameters which influence on fish distribution on a broader scale and these techniques can help to local fisherman and fishery organizations to observe fishery resources.

A2.1-0026-18 SALINIFICATION IN THE SOUTH CHINA SEA SINCE LATE 2012: A REVERSAL OF THE FRESHENING SINCE 1990S

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Salinification has occurred in the South China Sea (SCS) from late 2012 to the present, as shown by satellite Aquarius/SMAP data and Argo float data. This salinification follows a 20-year freshening trend that started in 1993. The salinification signal is strongest near the surface and extends downward under the seasonal thermocline to a depth of 150 m. The salinification occurs when the phase of the Pacific Decadal Oscillation switches from negative to positive. Diagnosis of the salinity budget suggests that an increasing net surface freshwater loss and the horizontal salt advection through the Luzon Strait driven by the South China Sea throughflow contributed to this ongoing salinification. In particular, a decrease in precipitation and enhanced Luzon Strait transport dominated the current intense salinification. Of particular interest is whether this salinification will continue until it reaches the previous maximum recorded in 1992.

A2.1-0027-18 SAR ALTIMETRY PROCESSING ON DEMAND SERVICE FOR CRYOSAT-2 AND SENTINEL-3 AT ESA G-POD

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The scope of this presentation is to feature the G-POD SARvatore service to users for the exploitation of CryoSat-2 and Sentinel-3 data, which was designed and developed by the Altimetry Team at ESA-ESRIN EOP-SER. The G-POD service coined SARvatore (SAR Versatile Altimetric Toolkit for Ocean Research Exploitation) is a web platform that allows any scientist to process on-line, on-demand and with user-selectable configuration CryoSat-2 SAR/SARIN and Sentinel-3 SAR data, from L1a (FBR) data products up to SAR/SARin Level-2 geophysical data products.

The G-POD graphical interface allows users to select a geographical area of interest within the time-frame related to the Cryosat-2 SAR/SARin FBR and Sentinel-3 L1A data products availability in the service catalogue. The processor prototype is versatile, allowing users to customize and to adapt the processing according to their specific requirements by setting a list of configurable options. Pre-defined processing configurations (Ocean, Inland Water, Ice and Sea-Ice) are available for the Sentinel-3 service. After the task submission, users can follow, in real time, the status of the processing. The output data products are generated in standard NetCDF format (using CF Convention), therefore being compatible with the Multi-Mission Radar Altimetry Toolbox (BRAT, http://www.altimetry.info/toolbox/) and typical tools. The following upgrades have been recently introduced: 1) Inclusion of SAR echo and SAR RIP (Range Integrated Power) waveforms in the NetCDF files; 2) Inclusion of STACK Data in the NetCDF files.

Initially, the processing was designed and uniquely optimized for open ocean studies. It was based on the SAMOSA model developed for the Sentinel-3 Ground Segment using CryoSat data (Cotton et al., 2008; Ray et al., 2014). However, since June 2015, a new retracker (SAMOSA+) is offered as a dedicated retracker for coastal zone, inland water and sea-ice/ice-sheet. Following the launch of Sentinel-3, a new flavour of the service has been initiated, exclusively dedicated to the processing of Sentinel-3 mission data products. The scope of this new service is to maximize the exploitation of the Sentinel-3 Surface Topography Mission's data over all surfaces providing user with specific processing options

not available in the default processing chain. The service is open, free of charge (supported by the ESA SEOM Programme Element) for worldwide scientific applications and available at https://gpod.eo.esa.int/services/CRYOSATSAR/.

A2.1-0028-18 SPICE: SENTINEL-3 PERFORMANCE IMPROVEMENT FOR ICE SHEETS

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For the past 25 years, polar-orbiting satellite radar altimeters have provided a valuable record of ice sheet elevation change and mass balance. One of the principle challenges associated with radar altimetry comes from the relatively large ground footprint of conventional pulse-limited radars, which reduces their capacity to make measurements in areas of complex topographic terrain. In recent years, progress has been made towards improving ground resolution, through the implementation of Synthetic Aperture Radar (SAR), or Delay-Doppler, techniques. In 2010, the launch of CryoSat-2 heralded the start of a new era of SAR Interferometric (SARIn) altimetry. However, because the satellite operated in SARIn and LRM mode over the ice sheets, many of the non-interferometric SAR altimeter processing techniques have been optimized for water and sea ice surfaces only. The launch of Sentinel-3, which provides full non-interferometric SAR coverage of the ice sheets, therefore presents the opportunity to further develop these SAR processing methodologies over ice sheets. Here we present results from SPICE (Sentinel-3 Performance Improvement for Ice Sheets), a 2 year study that focuses on (1) developing and evaluating Sentinel-3 SAR altimetry processing methodologies over the Polar ice sheets, and (2) investigating radar wave penetration through comparisons of Kuand Ka-band satellite measurements. The project, which is funded by ESA's SEOM (Scientific Exploitation of Operational Missions) programme, has worked in advance of the operational phase of Sentinel-3, to emulate Sentinel-3 SAR and pseudo-LRM data from dedicated CryoSat-2 SAR acquisitions made at the Lake Vostok, Dome C and Spirit sites in East Antarctica, and from reprocessed SARIn data in Greenland. In Phase 1 of the project we have evaluated existing processing methodologies, and in Phase 2 we are investigating new

evolutions to the Delay-Doppler Processing (DDP) and retracking chains. In this presentation we (1) evaluate the existing Sentinel-3 processing chain by comparing our emulated Sentinel3 elevations to reference airborne datasets, (2) describe new developments to the DDP and retracking algorithms that are aimed at improving the certainty of retrievals over ice sheets, and (3) investigate radar wave penetration by comparing our SAR data to waveforms and elevations acquired by AltiKa at Ka-band.

A2.1-0029-18 GOCE USER TOOLBOX AND TUTORIAL

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The GOCE User Toolbox GUT is a compilation of tools for the utilisation and analysis of GOCE Level 2 products.GUT support applications in Geodesy, Oceanography and Solid Earth Physics. The GUT Tutorial provides informationand guidance in how to use the toolbox for a variety of applications. GUT consists of a series of advancedcomputer routines that carry out the required computations. It may be used on Windows PCs, UNIX/Linux Workstations,and Mac. The toolbox is supported by The GUT Algorithm Description and User Guide and The GUTInstall Guide. A set of a-priori data and models are made available as well. Without any doubt the developmentof the GOCE user toolbox have played a major role in paving the way to successful use of the GOCE data foroceanography. The GUT version 2.2 was released in April 2014 and beside some bug-fixes it adds the capability for the computation of Simple Bouguer Anomaly (Solid-Earth). During this fall a new GUT version 3 has been released. GUTv3 was further developed through a collaborative effort where the scientific communities participate aimingon an implementation of remaining functionalities facilitating a wider span of research in the fields of Geodesy,Oceanography and Solid earth studies. Accordingly, the GUT version 3 has: - An attractive and easy to use Graphic User Interface (GUI) for the toolbox, - Enhance the toolbox with some further software functionalities such as to facilitate the use of gradients,anisotropic diffusive filtering and computation of Bouguer and isostatic gravity anomalies. - An associated GUT VCM tool for analysing the GOCE variance covariance matrices.

A2.1-0030-18 THE FORMATION AND "MULTI-HAZARD" EFFECT OF TROPICAL CYCLONES

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A tropical cyclone (TC) is one of the strongest atmospheric hazards. The tropical cyclone creates a "multi-hazard" effect. It is accompanied with very strong winds, heavy rain, high ocean waves and damaging storm surge which can produce extensive coastal flooding. The appearance of a tropical cyclone is also accompanied by multi-hazard conditions. Several centuries ago it was noticed that the appearance of a tropical cyclone is associated with such primary hazard as earthquakes and volcanoes. So, we can say that the tropical cyclone is not only the cause of other hazards (secondary hazards), but can itself be created "at list in part" by those very same hazards (primary hazards). This is the "multi-hazard" effect. The formation of tropical cyclones is the topic of extensive ongoing research and is still not fully understood. While some factors (for example, the water temperature, a rapid cooling with height, etc.) appear to be generally necessary, TCs may occasionally form without meeting all of the following conditions. In this paper, the author analyzes the reasons for the TC's appearance which based on the available international common results. For example, it is a well-known fact that in the Southern hemisphere around South America TCs are absent. Why? The author makes an attempt to find the answer. How the salinity of the ocean can affect it? How it can be connected to the geomagnetic field. This analysis based on many years ongoing research of the author.

A2.1-0031-18 SMALL PARAMETRIC MODEL FOR NONLINEAR DYNAMICS OF TROPICAL CYCLONES WITH OCEAN TEMPERATURE VARIATIONS

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A numerical investigation of a self consistent small parametric model (SPM) of tropical cyclones is performed by usage of connected nonlinear equations for mean wind speed in the atmosphere and the ocean surface temperature, taking into account small variations of ocean temperature in the cyclone background. Previously it was shown that these equations describe a different scenario of temporal dynamics of a powerful atmospheric vortex (tropical cyclone - TC) during its full life cycle. Our numerical calculations have shown that the choice of the SPM's initial parameters allows us to obtain the seasonal behavior of a regional large scale cyclogenesis dynamics for a given number of TC during the active season in a particular region, which allows a plausible explanation of the observation data. The SPM allows us to obtain the essential variable wind speed variations (created by nonstationary background) inside the TC and their influence on the TC temporal dynamics. It is shown, on the basis of numerical calculations, that such an influence may create an essential variation in the TCs dynamics. Such a conclusion is important for the correct interpretation of observations data on TC. Thus by usage of the nonlinear SPM, with motivated choice of background characteristics, it is possible to study the features of TC temporal behavior during the active season in a specific area. The correlation between regional cyclogenesis parameters and different external factors as the space weather, including solar activity level and cosmic rays variations is also possible to analyze. It is important to note, as it is known, that the cosmic rays variations may provoke essential changes in the Earth atmosphere dynamics. The cosmic rays may have an essential influence on sediments through the atmosphere ionization. A particle of cosmic rays, due to its very large energy, may produce million and more ionization events in the atmosphere. The numerical analysis results are graphically presented in figures and conclusions about SPM range applicability are made.

A3.1-0001-18 AN ALGORITHM OF GROSS PRIMARY PRODUCTION CAPACITY ESTIMATION FROM GLOBAL OBSERVING SATELLITE AND THE DIFFERENCE BETWEEN GPP CAPACITY AND GPP.

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An algorithm to estimate gross primary production (GPP) capacity from global satellite data was developed. The characteristic of this method corresponds to photosynthesis process. The photosynthesis velocity depends on it's capacity and its' depression because of weather conditions. The capacity part depends on one of plant physiological parameters of chlorophyll contents of a leaf. In the previous study (J. Thanyapraneedkul et al., 2013), the framework of estimation method using light-response curve was developed. The two parameters of lightresponse curve of the maximum of GPP capacity in the light saturation and relating on the initial slope were determined. The parameter relating on an initial slope was used as fixed values for each plant functional types. The maximum of GPP capacity at the light saturation was determined from the linear relationship between GPP capacity at 2000 (μmolm−2s−1) and

Chlorophyll index (CIgreen) using green band developed by Gitelson et al. (1996). The relationship determined for plant functional types of needleleaf deciduous trees, broadleaf deciduous trees, needleleaf evergreen trees, broadleaf evergreen trees, C3 grass, open and closed shrubs, and crops were determined. In this study, the difference between GPP capacity and GPP was studied using several years Flux data. From this study, GPP was more than 90 % of GPP capacity of paddy field and other vegetation types when vegetation was under less stress for the dry condition. This result means that GPP capacity was the first approximation of GPP when vegetation was under less stress. And the differences were discussed when vegetation was under high stress.

A3.1-0002-18 VALIDATION OF OGVI (OLCI GLOBAL VEGETATION INDEX) AND OTCI (OLCI TERRESTRIAL CHLOROPHYLL INDEX) PROVIDED BY THE OLCI (OCEAN AND LAND COLOR INSTRUMENT) SENSOR AT THE VALENCIA ANCHOR STATION

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Vegetation plays a key role in the global energy balance, carbon cycle, and water budget of the Earth by controlling the exchanges between the lower atmosphere and the continental biosphere. The Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) is a primary variable controlling the photosynthetic activity of plants, and therefore it constitutes an indicator of the presence and productivity of live vegetation, as well as of the intensity of the terrestrial carbon sink. It is the fraction of incoming solar radiation in the spectral range from 400 - 700 nm that is absorbed by plants and one of the 50 Essential Climate Variables (ECVs) recognized by the WMO Global Climate Observing System.

The Sentinel-3A (Copernicus Programme) satellite launched in February 2016, has onboard the Ocean and Land Colour Instrument (OLCI) with the primary objective of screening the ocean and land surface to harvest information related to biology, the atmosphere and climate. OLCI's spectral definition permits a fine characterisation of the vegetation with three parameters: FAPAR, LAI and Chlorophyll.

For the validation of FAPAR and chlorophyll, 3 full-balance PAR (Photosynthetically Active Radiation) stations were installed over an OLCI pixel (300 m x 300 m) in a vineyard field at the Valencia Anchor Station, Earth Observation validation site in Spain. Continuous comparisons have been made with the processed field data and the data obtained from the satellite. Each station has four sensors for calculating the energy balance, collecting the incident PAR, the reflectance of the vegetation cover, the transmittance of the foliar mass and the reflectance of the soil, taking into account the lambertian character of the reflectivity. Manual measurements of chlorophyll content were also performed.

In order to obtain a better representativity of the satellite estimations, a transect was defined manually measuring the PAR fluxes and chlorophyll content over the 8 pixels surrounding the main one above mentioned.

A3.1-0003-18 COMPARISON OF SUPERVISED CLASSIFICATION METHODS ACCURACIES USING SENTINEL-2 DATA

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The understanding and sustainability of the earth we live in is one of the important research topics, and the quality of the data held in such research is of importance. Land use and land cover (LULC) analyzes are frequently used in research. Today there are remote sensing satellites that are shared with all the world's users and enable the environmental analysis to be done temporally. As a result of analysis using remote sensing, meaningful outputs can be produced and interpretations can be made for study areas. One of the most important of the used satellites is Landsat. In order to carry out analyzes with Landsat satellites, the data for Sentinel-2 satellite, which are among the aims, are shared with researchers free of charge. The most important steps taken in the analysis of LULC are the classification of one of the steps. The comparison of the accuracy of supervised classification methods with Sentinel-2 satellite data, which is used today and intensively in the future, has been carried out. The image at the 1C level of the Sentinel-2 was upgraded to 2A level by the transformations performed. The study area is located in the province of Istanbul in Turkey. Analyzes of Binary Encoding, Mahalanobis Distance, Maximum Likelihood, Minimum Distance, Neural Net, Parallelepiped and Support Vector Machine supervised classification methods were obtained separately from the commonly used methods in the literature and the accuracy percentages of each method were obtained.

A3.1-0004-18 MONITORING LAND USE/LAND COVER CHANGE USING REMOTE SENSING AND GIS TECHNIQUE: A CASE STUDY OF BARANI AREAS PUNJAB, PAKISTAN

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Small dams have traditionally been the permanent source of water in the arid province of punjab in Pakistan. A check dam is used to delay the floodwater runoff to make it available for domestic and agriculture purposes or to recharge aquifers. The aim of this study is to present and illustrate different techniques for evaluating the performance of small dams. The data were collected based on studies of published research papers and reports of international organizations containing key characteristics of performance evaluation techniques. This review will help to evaluate techniques, policy, and governance interventions in Punjab by comparing them with the best practices being employed in other regions of the world. In this paper, performance evaluation of check dams for specific cases is presented. The knowledge acquired will be utilized to highlight state-of-the-art practices and to identify the need for further research in this field.

A3.1-0005-18 GEOSPATIAL APPROACH FOR LAND USE/LAND COVER CHANGE PREDICTION: A CASE STUDY OF BHAGIRATHI BASIN, UTTARAKHAND, INDIA

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Changes in land use and land cover (LULC) in mountainous areas have been less studied with remote sensing due to obvious difficulties in observations and interpretation. These regions are often hard to access and are also poorly instrumented and documented by conventional methods. As a result, there is a gap in our knowledge concerning the extent and impacts of land use change in high elevations. These regions are also where we are likely to see the early impacts of climate change. The main objective of this paper is to evaluate the land use change in Bhagirathi basin based on the need and purpose to predict future scenario of the region. Bhagirathi Basin being a hilly terrain has been challenged by numerous difficulties like deforestation, dam construction, expanding urbanization, tourism activities, land degradation etc. Land use classification and analysis is performed using Geographic Information System (GIS) and Remote sensing technique, and GIS aided 'Markov Cellular Automata' technique is used to model the land use change. Based on the past trend (1979 to 2010) of land use changes, the future land use map of Bhagirathi Basin for the year of 2020 has been generated. Landsat TM image of 1979 and 2010 were employed in this study to produce land use classification based on Anderson modified version method. Land change Modeler (LCM) was used to analyze the land use / cover changes between various classes and prediction of 2020 scenario of the region. The result of LULC analysis in the reference period depict that major changes includes increase in built-up area beside the increment in agriculture land in lower basin region. In upper basin region snow cover area has shown positive growth. Area under dense forest cover has increased marginally, whereas area under open forest cover has decline over all. There has been a remarkable increase in area of water bodies showing fivefold increment which can be attributed to Tehri Dam Project and area surrounded by it. According to LCM Modeling, Land use change projection in 2020 highest growth would be seen in agriculture land. Further, this study may contribute in land use planning and development of mountainous region. Keywords: LULC, Remote Sensing, GIS, Climate Change, Land Change Modeler.

A3.1-0006-18 THE CLASSIFICATION OF THE RICE FIELDS BY THE SEASONAL VARIATION TENDENCY OF THE NDVI IN THE LANDSAT-8/OLI

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In order to estimate the quantity of yield from a rice crop or to manage water resources, it is necessary to classify land surface into the rice fields from satellite images. However, it is difficult to classify agricultural fields into the rice and another fields. The aim of this study is to classify the agricultural fields from the difference in the tendencies of the seasonal change by using Normalized Difference Vegetation Index (NDVI). The NDVI seasonal variation tendency in the grassland, the rice field and another field in Chiba prefecture of Japan had been analyzed by using Landsat-8/OLI data observed several years. As the results, the NDVI of the three kind of area had been different tendencies. The NDVI of rice fields from growing to harvest seasons had been increased, and drastically decreased in the season after harvest. The NDVI of another fields had been similar to rice field, but the peak of it had been different season depending on the growth period of farm products. In the grassland, the peak of it had spread out for several months.

A3.1-0007-18 APPLICATION OF HYTES DATA FOR HYSPIRI OPTIMAL BAND POSITIONING TO MAP VEGETATION AND URBAN ENVIRONMENT

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A new space-borne sensor HyspIRI (Hyperspectral and Infrared Imager) is soon to be launched by NASA Jet Propulsion Laboratory (JPL). Out of the two instruments on board HyspIRI is the Thermal Infrared (TIR) multispectral scanner, while the other being hyperspectral imaging spectrometer sensing from the Visible to Short Wave Infrared (VSWIR: 0.38 - 2.5 µm). The TIR scanner will comprise of eight spectral bands operating between 3 and 12 m, one of these is present in the MIR (3-5 µm) while the remaining are located in TIR (7-12 m) region of EMR spectrum. However, the exact spectral location of these bands is not yet assigned and will be defined in a way to assist in various applications such as mapping GHG emissions (i.e., SO2, CH4 and NH3), minerals, vegetation health and urban materials. This study explored the possibility of using Genetic Algorithms coupled with Spectral Angle Mapper (SAM) for the selection of optimal bands from the TIR emissivity spectra to map four vegetation species and five land use land cover (LULC) classes. In this research the precursor dataset over the region of Santa Barbara was provided by Hyperspectral Thermal Emission Spectrometer (HyTES). HyTES is an airborne hyperspectral sensor, having a high spectral resolution (256 spectral channels in TIR). The GA-SAM was trained for nine classes and the algorithms were made to run repeatedly for 40 iterations. Genetic Algorithm (GA) even coped with spectral similarity at the species level and efficiently selected a meaningful subset of bands with high training (> 85 %) and testing (> 70 %) accuracies. Information on significant spectral band locations in TIR will help scientists of HyspIRI group in positioning spectral bands at best suited locations.

A3.1-0008-18 URBAN LANDUSE SPATIAL ANALYSIS: A CASE STUDY OF NORTH-NAZIMABAD BLOCK-D, E, F, G, H

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Process of urbanization is on peak in Karachi for last fifty years. It's considered as a mega polis in Pakistan with population of approx. 20 million. Therefore planners and administrative unit's need spatial and socio economic data for analysis at multiple places specially in urban planning for unplanned physical environment. The most planed housing sector after independence is North Nazimabad located at northern suburbs of Nazimabad region. It was developed to manage the residential needs of federal employee because Karachi at that time served as the capital of Pakistan. For that purpose town is alphabetically located blocks with well-planned structure. It's considered as the modern planed town of Karachi. For this GIS technology having effective use to study and analysis the comprehensive planning, site suitability, zoning, temporal variation and specially for all mapping purpose. To study and analysis purpose data is acquire in the form of satellite imageries and ground surveys. Absolute position of land cover mark through GPS. GPS points converted into ground control points in GIS. GCP's are plot on satellite imageries for absolute position of places. Satellite imageries are acquired from Google Earth for high spatial resolution. Also Landsat images are acquired due to their high spectral resolution. This helps to determine change through different indices. North Nazimabad is a well-planned and modernized town of Karachi city based on the concept of Clarence Perry. It started out as a planned town with residential development as the main focus with well-defined areas assigned for commercial and residential uses. However from our survey it has become apparent that most of the residential areas along the roads have been converted for commercial use, also the growing need for residency has led to vertical growth resulting in the construction of apartment buildings.

A3.1-0009-18 URBANISATION AND ITS IMPACT ON ECOSYSTEM SERVICES IN THE NATIONAL CAPITAL REGION, INDIA

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Urbanisation and land change are interrelated however it's difficult to interpret different processes on ground regarding immediate consequences. Change in land use and land cover are emerging as central to a range to development-linked sustainability challenges, leading to loss of ecosystem services in urban and peri-urban regions. It has impacted the productivity capacity (via intensification and land degradation) of ecosystem and polluted the environment, impacting socio-ecological sustainability and livelihood security and thus exacerbating existing social and economic vulnerability. This study is an attempt to assess the impacts of urbanisation on ecosystem services in the National Capital Region (NCR).To assess spatial and temporal trends of land use land cover change (1991, 2001 and 2011) for National Capital Region, satellite images have been taken from the Landsat 5 (TM) and Landsat 7 (ETM). Further, the coefficients published by Costanza et al. (Global Environmental Change, 26:152-158, 2014) were used to quantify changes in ecosystem services for each land use land cover category. Results showing the rate of decline in ecosystem services value from 1991 to 2011 is $ 0.03 million per year. The influence of land use change on individual ecosystem functions indicated the decline in the contribution of food production services, genetic resources, soil formation, water supply, waste treatment, raw materials, habitat/refugia, erosion control, biological control, and gas regulation while contribution of recreation, climate regulation, disturbance regulation, water regulation and nutrient cycling functions has increased substantially over the 20 years' time period. For the sustainable development of ecosystems in NCR, it is significantly important to understand the factors that facilitate urban sprawl and associated loss in ecosystem service and further policy intervention is required in urban and peri-urban regions for protecting and enhancing ecosystems at local as well as regional level. Keywords: Ecosystem Services; Peri-urban; Urban Sprawl; Sustainable Development; Land use land cover change.

A3.1-0010-18 THERMAL INERTIA AND URBAN HEAT ISLAND IMPACT ON CLIMATOLOGY OF DELHI

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This study attempts to examine the role of thermal inertia in the variable behaviour of day-time Urban Heat Island over Delhi. LISS-III data of Resourcesat-I, MODIS (Moderate Resolution Imaging Spectroradiometer) combined Aqua and Terra, 16-day, Level 3 Albedo Product (Black Sky Albedo and White Sky Albedo) and 8-day Land Surface Temperature Product have been used to investigate the spatial variations in land cover, albedo, land surface temperature and thermal inertia for the month of March, 2015. The LISS-III image shows the predominance of built-up area over Delhi, which is surrounded by agricultural land covered by crop vegetation at this time of the year. The albedo map shows that albedo over Delhi is significantly less (0.08 to 0.13) over major part of Delhi, while albedo in its surrounding regions ranges from 0.15 to 0.2. This suggests that a significantly greater fraction of the incoming solar radiation is utilized for heating up of land surface over Delhi as compared to its surrounding regions. The Enhanced Vegetation Index (EVI) Map of Delhi for March 2015 reveals that EVI over Delhi varies from 0.06 to 0.29 whereas EVI over the surrounding regions reaches up to 0.66, which confirms the prevalence of crop vegetation in the surrounding regions. The day and night-time land surface temperature maps reveal that temperatures over Delhi are significantly higher (8°C

-10°C) than those over the surrounding regions. The day and night time temperature maps are then used to obtain the diurnal temperature range and together with albedo maps of the study region, are used to estimate the thermal inertia over the region. The study reveals that the dense built-up urban area of Delhi has higher thermal inertia than that of the surrounding rural areas during the March.

A3.1-0011-18 ESTIMATION OF HEAVY METALS CONCENTRATION IN CROPS USING SENTINEL-2 DATA

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Excess of heavy metals concentration in crops exert negative impact on crops, animals and human health. Information about the level of contamination in crops is of critical importance for understanding the problem and formulating its possible solutions. Remote sensing provides fast, efficient, cost effective alternative to quantify and map the distribution of heavy metal contamination in crops. Sentinel 2 is relatively new addition to the constellation of optical remote sensing satellites and the bands are positioned for studying vegetation health and status. In this research, the potential of Sentinel-2 data was investigated for the retrieval of heavy metals contents in crops in Kusur district, Pakistan. The study area is part of Upper Indus basin and is densely vegetated due to the availability of water for irrigation from Sutlej and Ravi rivers. A total of sixty six samples were collected in the field and heavy metal concentration of Zinc (Zn), Copper (Cu), Nickel (Ni), Lead (Pb) and Chromium (Cr) was measured using Atomic Absorption spectroscopy. The values of the field data were regressed against Sentinel

-2 derived vegetation indices (NDVI, SAVI, TSAVI, MTCI, REP and band depth parameters). Using NDVI, the highest R2 was obtained for Zn (R2 = 0.60) followed by Cu in NDVI (R2 = 0.26) and Cr in (R2 = 0.18). The relationship of Lead (Pb) and Nickel (Ni) with vegetation indices was found very low (0.05). The multiband index (band depth parameters: CR, BD, NDBI, BDR, BNA) yielded R2 of (0.53, Zn vs. BDR), (0.20, Cu vs. BDR) and (0.18, Cr vs. CR). This study concludes that Sentinel 2 data is quite effective for quantifying heavy metal concentration in crops and for monitoring spatial distribution of heavy metals and its effects on crops health.

A3.1-0012-18 EARTH OBSERVATION IN SUPPORT OF SUSTAINABLE WATER RESOURCES MANAGEMENT IN THE FRAMEWORK OF EIT CLIMATE KIC COPERNICUS CLIMATHON 2017

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The it University of Valencia Climatology from Satellites Group developed the it Copernicus Climathon 2017 Burjassot City Challenge basically consisting of the ideation of adaptation to climate change projects using Copernicus Earth Observation data and products in support of water management solutions. The goal was to encourage participants to study water-related negative climate change impacts and low-efficiency usage to tackle them and generate incomes.

This paper explains the development of the it Copernicus Climathon 2017 Burjassot activity and the ideas developed on it Smart Water for Cities (SAT WATERS), it Make Available Water Visible (MAWV) and it Irrigation optimization software (CROPSENSING)

A3.1-0013-18 CLIMATE RESILIENT WATER SECURITY PLANNING USING SPACE

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In the Backdrop of Paris agreement on climate Change and the adoption of the Sustainable development goals(SDGs), when the environments degrade either locally or globally, it is the poorest countries, communities and the people that bear the brunt of the damage(Rebecca Grynspan, IIED). It is also a fact that the occurrence of natural disasters about 50 in 1900 have reached 200 per year by 2000(UN reports). Shockingly, during 1875 and 1975 the population has increased three fold while the primary energy consumption has been a shocking 32 times. Global warming and related climate changes are likely to significantly increase the weatherrelated risks facing human settlements, including floods, water and power supply failures and associated economic collapse into failed cities.(David S, 2018). IMSD-1995,Integrated Mission on Sustainable Development under ISRO is a pioneering watershed management in 195 districts of India focusing on the decentralised community governance using the space technology. In continuation World Bank Supported SUJALA Watershed is one of the space best practices. In the recent past, river restoration projects and water resources aiming community empowerment with Corporate Social Responsibility are a reality (Art of Living, 2017). Water Resources Information System WRIS under NRSC ISRO is pioneering platform hub for application of Space Technology for Water Resources Management in India. In this presentation with the backdrop of a unique self-reliant space technology heritage for water resources management in India, water security issues for Irrigation in the state of Karnataka and Bangalore Urban settlement are reported. Case Studies of a new trend of community cantered water security governance by monitoring using simple techniques and remote sensing data are reported.

A3.1-0014-18 FUTURE SPACEBORNE MEASUREMENTS NEEDED TO CHARACTERIZE THE WATER CYCLE IN SNOW-DOMINATED WATERSHEDS

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Measurements of snow-covered area have been a staple of remotely sensed operations for more than fifty years, and passive microwave estimates of snow water equivalent provide information in areas with shallow, spatially homogeneous snow cover. In the mountains especially, where the snow is often deep and always heterogeneous at the scale of the topography, improved knowledge of the snow water equivalent (SWE) and snow albedo () will help us manage water resources, understand anthropogenic effects on snow and glaciers, and validate models of precipitation and snowmelt.

Snow water equivalent: SWE = depth × density, but most of the spatiotemporal variability owes to depth, with variation in density a secondary contributor. Shortcomings of directly retrieving SWE from passive microwave sensors include its low saturation threshold of about 200 mm, its large pixel size causing substantial subpixel heterogeneity, and its lack of any ability to estimate SWE when snow is wet. Snowpack resources computed from numerical weather models, such as SNODAS, show discouraging results with significant underand over-estimates. Directly measuring SWE from synthetic aperture radar (SAR) has been investigated, but wet snow and snowpack stratigraphy complicate the results. An alternative approach, which we describe in detail, is to measure depth instead with a high-frequency (Wor Ka-band) altimeter or interferometer, and to either model density or measure it less frequently with SAR or a scatterometer. The advantage of measuring snow depth and inferring SWE through density is a feasible, economical implementation, and the measurement of snow depth is insensitive to liquid water in the snowpack.

Snow albedo: As with any process driven partly by absorbed solar radiation, variability in snow albedo causes variability in the rate of melt. For surfaces with high albedo, an error in the measurement of albedo leads to a greater proportional error in absorption of the solar radiation (absorption = 1-α, so for values of α closer to 1.0, a small error in causes a greater proportional error in 1-). Changes in snow albedo are tied to changes in snow microstructure and contamination by absorbing particulates like dust and soot. Over homogeneous snow covered areas like Antarctica or Greenland, measurement of albedo with multispectral sensors is feasible, but in pixels that also contain vegetation and soils along with snow, the science of imaging spectroscopy must be brought to bear.

A3.1-0015-18 CALIBRATING SNOW AND GLACIER MELT RUNOFF MODEL BY EMPLOYING IN-SITU MEASUREMENTS AND SATELLITE DATA TO PREDICT FUTURE MELT-WATER FLOWS IN HIGH-ALTITUDE BASIN OF NORTH PAKISTAN

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The river basins having significant contribution of snow and glacier melt water are highly susceptible by falling future flows owing to climate change. The high altitude cryospheric

/ hydrological observations are still remains scarce particularly in the Karakoram-Himalayan region of Pakistan due to remoteness and limited accessibility. Notwithstanding, the future behavior of their water resources is still unclear, although for the sustainable management of water resources, better assessment and quantification of snow and glacier melt contributions in the river runoff is crucial. In order to quantify the daily contributions of melt-water yield from snow and glaciers in the basin, the degree day melt runoff model was calibrated for Astore stream-flow by employing daily snow cover products of MODIS satellites to estimate spatiotemporal snow cover extents. Similarly, the

high resolution SPOT and Landsat imagery to map the areas of exposed ice separately from the snow covered area towards the end of the snowmelt season were also employed in combination with in-situ hydro-meteorological observational data. Most of the parameters used in the calibration process were measured directly from the field or either measured from satellite data. The simulated stream-flow shows good agreement with the measured stream-flow during the calibration as well as validation period, since the NashSutcliffe model efficiency coefficient was never become <0.8. The simulation results suggested that although the glacier ablation started in May in the basin, but the volumetric contribution in the stream-flow was very little, however, in the month of June the glacier melt contribution is stared to increase and after July almost all the flows were dependent on glacier melt produced water. Although there is also some contribution from the summer rain but its volumetric contribution is almost negligible as compare to glacier melt. The overall contribution from snow and glacier melt was calculated as 76% of the basin runoff. The results revealed that the simulated glacier melt runoff during 1960-2013 displayed a marked decreasing trend from the early 1960s to the late 1980s, afterwards it began to increase from the early 1990s. However, there has been a general decrease of glacier melt contribution in the basin runoff, since the early 1990s this trend has become more pronounced. The decreasing trend of glacier melt runoff was in contrast of the increasing trend of Astore River runoff during this period. This implies that the increase in the river runoff of the Astore river basin was very likely to be because of the influence of increase in winter precipitation but not due to the increase in the glacier melt runoff. The calibrated model was used to simulate future melt-flows of Astore basin under different climatic warming scenarios. The future runoff simulations under projected climatic warming trends suggested that it would significantly influence the contribution of glacier melt yield in the Astore basin stream-flow. Due to persistent warming initially the glacier melt runoff would be increased significantly (+14%) by 2050, however afterwards it would start to decline abruptly due to the continuous mass shedding of glaciers and by the end of this century the contribution from the glacier melt would be declined by more than 30% of current glacier melt runoff contribution in the main stem of Astore river, which would significantly influence the summer and autumn stream-flows of Astore river basin which may adversely affect the ecological environment and water resources in the region.

A3.1-0016-18 GLACIER DYNAMICS STUDY USING C-AND L-BAND SAR DATASETS IN HIMALAYAN REGION

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The Himalayan region contains third largest amount of fresh water in form of seasonal snow and permanent glacier ice, outside the Polar Regions. This regions is home to world's largest rivers and glaciers, and water from these rivers feeds the billions of people in its downstream locations. Remote sensing plays an important role in mapping and monitoring of snow and glacier of this region, which otherwise is very difficult using traditional survey methods. The present work have utilized freely available C-band Synthetic Aperture Radar (SAR) data from Sentinel-1 and 1A satellites and ALOS-PALSAR-2 PolInSAR data for glacier dynamics study of major Himalayan glaciers such as Siachen, Bara Shigri, Samudra Tapu, Gangotri, Milam, Zemu etc. PALSAR-2 data was provided by JAXA under announcement of opportunity science project and Sentinel data was taken from Alaska SAR facility. Earlier studies using Interferometric SAR (InSAR) data has suffered from loss of coherence due to high temporal resolution of SAR images and high glacier velocity. Glacier velocity was derived using InSAR based method using 6 day temporal interval (During winter of 2016-2017) images from SENTINEL-1A and 1B satellites and at 14 day interval for PALSAR-2 data. High coherence was obtained for all main glaciers in both the data sets, which resulted accurate line of site (LOS) glacier velocity estimates for glacier. In both cases, SRTM-x band 30 m DEM was used to remove topographic phase due to its better vertical accuracy. ALOS-PALSAR-2 during shows the mean velocity of 3.2 to 5.2 cm day-1 during 14 day time interval for full glacier and main trunk glacier respectively. This is after gap of 19 to 21 years that InSAR data has given suitable data for glacier velocity estimation. In addition, TANDEM-x data of year 2012 and 2013 was also used to derive temporal elevation changes due to dynamic snow/ice in condition of Gangotri glacier. The time series of SAR data from SENTINEL-1A and 1B and Indian RISAT-1 MRS satellites was also used for glacier in Chenab and Gangotri basins, for creating SAR image time series composites, and to identify and map radar glacier zones such as debris ice, bare ice zone, percolation-refreeze zone at different elevations, wet snow and dry snow zones. All these maps were verified by extensive ground done at these sites during 2014-2017 time. In September 2017, Gepang glacier differential GPS and hyperspectral survey was conducted to quantify the glacier and glacier lake dynamics. The lake growth, moraine survey and GLOF modelling was also done to quantify vulnerability of Gepang glacier lake. This study highlights use and applicability of InSAR data sets for glacier dynamics study, supported by ground truth. This study will help in refining algorithms to be used for such studies using upcoming NASA-ISRO SAR (NISAR) InSAR data sets.

A3.1-0017-18 THE PRODUCTION OF HR WATER MASKS WITH SENTINEL-1, THEIR VERIFICATION WITH SENTINEL-2 IMAGES AND THEIR USE IN SENTINEL3 ALTI-HYDROLOGY

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This work tests and refines some pixel-based water mapping algorithms for Sentinel-1 SAR images. Updated High Resolution water masks are needed to produce a water fraction field as an auxiliary data to Sentinel-3 SRAL products. The objective is to 1. help better characterise Sentinel-3 SAR waveforms, 2. help analyse SAR retrackers performances, 3. help alti-hydrology processing chain in many aspects among which the rejection of spurious signals during the production of water levels over rivers and lakes (low water fraction associated to an outlier measurement).

The Sentinel-1 water extraction algorithms are described. Sensitive aspects like shadowing in mountainous regions are addressed (shadow in radar images could easily be classified as water). To validate the results, the outputs of these algorithms are then compared with a 10m resolution water index derived from Sentinel-2 images. The best water mask is finally used to produce Water Fractions within the Sentinel-3 footprints of collocated and tightly codated Sentinel-3 SRAL acquisitions. The results are illustrated on difficult cases such as those found along the Brahmaputra River.

This work, performed under ESA/SEOM SHAPE contract 4000115205/15/I-BG, highlights the great synergy potential of the Sentinel-1, 2 and 3 missions to improve the inland water SAR altimetry processing. It could be replicated to LRM altimetry missions and the concomitant imagers as well. Improving Water Level time series will permit assimilation into models such as HYPE to produce improved Water Discharge. This is one of the main objectives of the SHAPE project.

A3.1-0018-18 IMPROVING STREAMFLOW ESTIMATES OF THE RAPID RIVER ROUTING MODEL WITH DATA ASSIMILATION

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The increasing availability of remotely-sensed observations of surface water enables regional or global monitoring of rivers. However, the current (and expected) measurements still have a sparse spatiotemporal coverage. Hydrological models are able to predict river streamflows at finer scales but those estimates suffer from non-negligible uncertainties. This motivates the merging of space-based observations with computer models of rivers through data assimilation. The use of data assimilation allows to produce consistent, and hopefully improved, estimates of terrestrial hydrology variables that fill the spatiotemporal gaps in observations. The river routing model RAPID (Routing Application for Parallel Computation of Discharge) is based on the Muskingum method and estimates river streamflow over large scale with high computational efficiency. The relatively simple model physics implies that RAPID simulations could be significantly improved by including a data assimilation capability. Here we present the developments of such data assimilation approach where the simulated streamflows are improved through the assimilation of streamflow observations. Given the linear and matrix-based structure of the model, we chose to apply a classical Kalman filter, hence allowing for the preservation of high computational speed. In this study, we develop and test the assimilation framework using in situ measurements at continental scales. The preliminary results demonstrate the feasibility of the approach which is designed to ultimately leverage altimetry measurements from existing (e.g. EnviSat, Jason 2) and upcoming satellite missions (e.g. SWOT), and be applied globally.

A3.1-0019-18 ENHANCING FLOOD FORECASTING AND RIVER BASIN PLANNING IN THE LOWER MEKONG USING SATELLITE-BASED LAND USE AND PRECIPITATION INFORMATION

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The Lower Mekong countries suffer from devastating and frequent flooding. Agencies exist at regional and national level who are mandated to provide flood forecast and warning information to the public, typically through utilizing flood models. The flood models require a range of input data at different temporal and spatial resolution, but those are hardly available in the region. Both rural and urban populations rely on weather forecast and flood early warning to take preemptive action and to quickly respond to flood events. Hydro-meteorological data such as precipitation and stream gauge are critical elements in flood forecasting as well. Countries such as Cambodia are hampered in their ability to produce reliable and accurate flood forecasts due to the sparse hydro-meteorological observation network in the country. An important input to river basin models at a regional level is land use data from countries. Challenges often arise when different classifications of crop-types and land cover typologies are defined by national agencies, while gaps in data frequency and accuracy also existed. Currently, the regional flood model in the Lower Mekong by the Mekong River Commission is using a compiled dataset from 2010, which no longer reflects the rapid land use change that has occurred in the region till now, leading to inaccuracy in flood modeling outputs. This study addresses the regional needs to improve flood forecasting capability significantly through the SERVIR-Mekong's Land Cover Mapping System (LCMS) providing custom and harmonized land use datasets and map products, and the Virtual Rain and Stream Gauge Information System (VRSGIS) addressing data sparsity through the addition of near-real time gridded rainfall datasets from the Global Precipitation Mission as well as stream water levels from available satellite altimetry missions including recently launched Sentinel-3 mission. Use of these additional data will increase accuracy of the existing hydrological, hydrodynamic and basin simulation models in the Lower Mekong.

A3.1-0020-18 EVALUATING TERRAIN STABILITY IN STEEP TERRAINS USING DOWNSCALED SMAP DATA

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Soil moisture in the vadose zone, typically in the top layer is a key variable in terrestrial cycle. Its temporal and spatial variability over steep terrains affect partitioning of precipitation into infiltration and runoff, hence the terrain stability. This work aims at studying soil moisture - atmosphere - terrain stability associations along the steep terrains of Himalayas by considering the static (Slope, soil type, and land cover) and dynamic (precipitation and root soil moisture) factors. Though rainfall induced slope failures are common in the study area, shallow landslides are not less in number and are predominantly influenced by antecedent soil moisture content. Soil Moisture Active Passive (SMAP) using passive microwave techniques, L-band frequency, which minimizes the impact of vegetation on the soil parameter retrievals, have shown good promise for global mapping of near-surface (top 5cm of the soil profile) soil moisture at a spatial resolution of 25 to 40 km and a revisiting period of 2 to 3 days. With the help of process-based models and data assimilation schemes this top soil moisture is further extended to the root zone (top 1 m). Recent studies have suggested that the performance of available Radiative Transfer Models (RTMs) used for satellite soil moisture algorithms are not optimum under highly heterogeneous landscape conditions and vary with hydro-climate. The available models and algorithms available globally for terrain stability analysis are at coarser level. Since the landslides are local phenomena which are chiefly controlled by in situ parameters, SMAP based soil moisture data is downscaled to an appropriate level. In order to downscale the SMAP soil moisture product, MODIS-derived Normalized Difference Vegetation Index (NDVI) and surface temperature (Ts) are used as conditioning attributes. These two variables are derived for each 1km sub-pixel in the 36km SMAP footprint soil moisture data. Fang et al. (2013) constructed lookup curves between daily surface temperature difference and daily average soil moisture from the Global Land Data Assimilation System (GLDAS) for different NDVI values (derived from the Advanced Very High Resolution Radiometer [AVHRR]) for a 30year period (1979-2008). Based on the collocated MODIS based NDVI and Ts, and the established lookup curves, the SMAP soil moisture data is downscaled to 1km sub-pixels. With downscaled SMAP data along with static and dynamic factors, a threshold of soil moisture content, at which slopes fail, is determined and the vulnerable zones are demarcated spatially and temporally.

A3.1-0021-18 EVALUATION OF HIGH RESOLUTION GRIDDED PRECIPITATION PRODUCTS AND COMPARISON WITH THE SIMULATED PRECIPITATION OBTAINED FROM WRF MODEL IN REGIONS OF NORTH WESTERN HIMALAYA

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Water is the essence of life in all forms in earth. The hydrological cycle is defined as the process of storage and movement of all available amount of water on earth. A main component of water cycle is precipitation. Extreme precipitation events are responsible for flood like situations, on the contrary, deficiency in rainfall results in droughts in the regions. In recent years, simulations and projection of weather conditions to future, with Numerical Weather Prediction (NWP) models like Weather Research and Forecast (WRF), has become an imperative component of research in the field of atmospheric science and hydrology. The validation of modelled forecast from WRF model configuration and estimating bias of the modelled output is of utmost importance in case of generating weather prediction. This study presents an all-inclusive assessment of 5 high spatial resolution gridded precipitation products including satellite data products and also climate reanalysis product as compared to WRF precipitation product. The study was performed in river basins of North Western Himalaya in India extending from latitudinal extent of 29° to 36.5° N and longitudinal extent of 72.5° to 83.5° E. The basins in North Western Himalayan region like catchment areas of Indus, Beas, Sutlej, Chenab, Jhelum, Ravi, Yamuna and Upper Ganga, experience frequent floods and rainfall extreme conditions. Accordingly, performance of WRF model is evaluated through an extensive comparison of the produced forecast with the other datasets and also comparing with observational gridded (0.25°×0.25°) precipitation data from Indian Meteorological Department (IMD). Other products include version 7 TRMM (Tropical Rainfall Measuring Mission) Multi Satellite Precipitation Analysis (TMPA) 3B42 product (0.25°×0.25°), Global Precipitation Measurement (GPM) product (0.1°×0.1°) and Climate Hazards Group Infrared Precipitation with Station data (CHIRPS) product having a finer spatial resolution of 0.05°. Moreover, climate reanalysis rainfall product at 0.50° and 0.25° resolution from ERA Interim is also used. Analyses were carried out on a daily scale. Evaluations were based on watershed based zones and also on topography based zones in NWH. Forecast evaluation parameters like Bias, Mean Absolute Error, Root Mean Square Error, False Alarm Ratio, Probability of False Detection, and Probability of Detection are estimated for the zones classified as mentioned before. Threshold of rainfall amount were considered as 10mm and 30mm on different group of analyses, and the results found to be similar. TMPA and CHIRPS products were found to be most resembling with the observations. All products showed better performance in the higher latitudes i.e. in planes of Upper Ganga and Yamuna basin and also in parts of Indus basin. Discrepancies found to be increasing with topographical variation i.e. in hilly regions of Beas basin and western part of Sutlej and Chenab basins. GPM product shows greater deviation from the actual precipitation by underestimating the values of precipitation. ERA Interim product is very much identical to the modelled precipitation values of WRF. This study can be used for identifying suitability of WRF simulated data and assessing performance of other rainfall datasets as well.

A3.1-0022-18 INTERCOMPARISON BETWEEN AQUARIUS AND SMOS BRIGHTNESS TEMPERATURES FOR HETEROGENEOUS LAND AREAS

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This paper shows a comparison between ESA SMOS (Soil Moisture Ocean Salinity) and NASA Aquarius brightness temperatures during the time in which both missions coincided observing in space.

Intercomparison between Aquarius and SMOS brightness temperatures (TBs) over land surfaces is more challenging than over oceans because land footprints are more heterogeneous. The different spatial resolutions make the comparison difficult and this has motivated the application of different approaches (purely geometrical, geophysical and more purely physical) which have been evaluated over nine different continental and marine areas with different degree of homogeneity or heterogeneity. The metrics used have been (i) the method of the areas where the SMOS pixels TBs are weighted averaged within the Aquarius footprint (ii) the method of land uses where the averaging weights are obtained from the different land uses within the respective instruments (iii) the TVDI (Temperature Vegetation Dryness Index) method where the weights are obtained from the different degrees of dryness/wetness of the respective surfaces and (iv) the method of the gain matrix where the weighting factors are obtained from the antenna pattern of both radiometers. Other significant differences between both instruments have naturally been considered such as the fact of SMOS consisting of an interferometric aperture synthesis radiometer and Aquarius a real aperture one, the different overpassing times over the areas observed, etc.

Significant and innovative results have been obtained when using the antenna pattern of both instruments. The SMOS data used correspond to CATDS (Centre Aval de Traitement des Données SMOS) level-3 brightness temperatures with the incident angle of 27,5º and Aquarius data correspond to brightness temperatures acquired by its inner beam. Horizontal and vertical polarisations are considered in both configurations.

As expected, the gain matrix method achieves better results, with considerably reduced errors in all experimental areas and for both polarisations. The TVDI method utilizes complementary data (LST and NDVI) from MODIS and it has the advantage that it considers the dynamical aspects of the evolution of the surface, naturally over continental surfaces, and this represents a significant advantage in front of the static methods of the areas and of the land uses.

A3.1-0023-18 SURFACE BIOLOGY AND GEOLOGY WITH IMAGING SPECTROSCOPY

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On the 5th of January 2018, the 2017 Earth science Decadal Survey was released titled, “Thriving on Our Changing Planet A Decadal Strategy for Earth Observation from Space.” This 700 page document was developed over more than two years with broad input from the Earth science and applications communities. Five targeted observables are indicated as observing system priorities. One of these is designated surface biology and geology. In this category, a set of science and applications targets are identified including: ground/water temperature, snow reflectivity, active geologic processes, vegetation traits and algal biomass. The candidate measurement approach is described as, “Hyperspectral imagery in the visible and shortwave infrared, multior hyperspectral imagery in the thermal IR.” This paper reviews some of the key new science and applications objectives, and outlines some measurement approaches that could be used to address this guidance in the area of global visible to short wavelength infrared imaging spectroscopy.

A3.1-0024-18 COMBINING REMOTE SENSING, ECOPHYSIOLOGY, AND MULTI-SCALE MODELING TO MANAGE RESOURCES IN AQUATIC ECOSYSTEMS IMPACTED BY ENVIRONMENTAL VARIABILITY

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The California Sacramento-San Joaquin River Delta is the hub for California's water supply and supports important ecosystem services, agriculture, and communities in Northern to Southern California. Expansion of invasive aquatic plants in the Delta coupled with impacts of changing climate, long-term drought, shifting land use, and variations in water flow and water quality are detrimental to water management, commerce, and the ecosystem complex in the San Francisco Bay/California Delta. NASA Ames Research Center and the USDA-Agricultural Research Service partnered with the State of California to develop science-based, adaptive-management strategies to understand the relative response for invasive aquatic plants to these environmental variations and balance resource management in the Sacramento-San Joaquin Delta. The project combines remote sensing, watershed land use models, newly defined environmental response of invasive aquatic plants to climate, and spatial distribution/biomass density mapping and water quality to study ecosystem response to climate and aquatic plant management practices. Specific mapping tools developed utilize satellite and airborne platforms to provide regular assessments of population dynamics on a landscape scale and support both strategic planning and operational decision making for resource managers. Spectral analysis is targeted to determine composition and relative proportions of individual species spatially across plant communities. Water flows to the Delta primarily through the San Joaquin and Sacramento River watersheds; quality of that inflow water is modeled using the Soil-Water Assessment Tool (SWAT). A modified SWAT tool customized to account for unique landscape and management of agricultural water supply and drainage within the Delta addresses quality changes within the Delta. Localized plant distribution and environmental parameters couple with plant response to provide assessment of aquatic plant ecosystem function as a result of variation in factors in and around the Delta. On-the-water validation and operational utilization of these tools by management agencies are improving decision making, management effectiveness and efficiency in the region and provide insight regarding the merging of remote sensing, ecosystem modeling, and functional component assessment tools to aide land and water resource managers make science-informed decisions regarding management and outcomes.

A3.1-0025-18 CLASSIFICATION OF MICRO-TOPOGRAPHICAL DISTRIBUTION IN THE ILI DELTA OF BALKHASH LAKE BY ALOS MULTI-SENSOR DATA

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Authors are investigating wide-range environmental change in Central Asia by the analysis of multi satellite data with the field survey information. Particularly, based on the water area fluctuation analysis result of the closed lakes in Central Asia by satellite data, authors are investigating environmental change situation for a long period. In Balkhash Lake which is one of the typical closed lakes in Central Asia, it was suggested that anthropogenic impact is stronger and natural factor is also added to it in recent years. However, the remains of the lake water level thousands of years ago being wetness compared with the present are left as micro-topography along a lake shore line and in the delta of the Ili River as a main inflow river. If the age of this micro-topography is obtained, the history of geomorphological formation accompanying the climate change during the last thousands to tens of thousands of years will be grasped. In this study, several micro-topographies of different formation year reflecting the past environmental change situation were classified in Ili Delta spreading in the middle and the lower streams of the Ili River as the maximum inflow river of Balkhash Lake by using the multi observational data of PALSAR, PRISM, and AVNIR2 of ALOS. Specifically, landcover classification depending on sediment, and distribution of vegetation and sand dune was firstly carried out by ALOS/PALSAR data. Next, classification of the micro-topography reflecting sand hill or terrace distribution was performed by the high spatial resolution and highly precise DEM which were mainly generated from ALOS/PRISM stereo pair data. In this process, comparison and verification with the public opened existing DEM data such as SRTM or GDEM, and field topographical survey result were also carried out. Finally, the subdivided classification of the micro-topography in the Ili Delta was also tried by using the pansharpened image data derived from ALOS/AVNIR-2 and PRISM data. As a result of this study, the extraction and classification of several kinds of micro-topographies for past different age were carried out by the comparative analysis of the seasonal ALOS/PALSAR data and the high spatial resolution DSM generated from the ALOS/PRISM stereo pair data. Furthermore, restoration of the history of geomorphological formation of the Ili Delta during the last several hundred to thousands of years was tried based on reference of the pansharpened image and field survey results to the geomorphological classification image.

A3.1-0027-18 FULL POLARIMETRIC ALOS-2/ PALSAR-2 ANALYSIS FOR SHORELINE DETECTION

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Shoreline erosion results from any number of factors, including a decrease in sand supply from rivers, storms, simple inundation of the land by rising sea levels, or ground deformation. To evaluate the actual erosion conditions, we need current shoreline data. Advanced Land Observing Satellite 2 / Phased Array type L-band Synthetic Aperture Radar 2 (ALOS-2/PALSAR-2) data is expected to continue updating the data archives related to national land and infrastructure information. Full polarimetric ALOS-2/PALSAR-2 data observed with below-30°off-nadir angle and with the synthetic aperture radar (SAR) beam facing the opposite direction of landward waves produced appropriate images to detect the shoreline of a sandy coast in our previous study. In this study, we aimed to evaluate full polarimetric ALOS-2/PALSAR-2 data observed on January 12th, 2016 for sandy coast and rocky coast shoreline detection. We applied the Canny edge detection algorithm to detect the boundary between sandy or rocky coast and sea area with surface scattering power images (Ps), double-bounce scattering power images (Pd), volume scattering power images (Pv), and helix scattering power images (Ph) derived from the full polarimetric ALOS-2/PALSAR-2 data. The Ps, Pd, Pv, and Ph images are calculated by the four-component scattering model. Through comparative verification of shoreline data from medium-resolution optical satellite imagery (Terra/ASTER observed on March 2nd, 2016), we determined that full polarimetric ALOS-2/PALSAR-2 data could be used to detect the approximate shorelines of both a sandy coast and a rocky coast.

A3.1-0028-18 GRAVITY AS A MEASURE OF CLIMATE CHANGE

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The interactions of the Earth System components are a significant contributor to current weather and longer climate trends. The interactions involve mass change that involve both energy and momentum. Water movement at diurnal, monthly, annual and decadal periods is a significant part of this exchange. Phenomena associated with these interactions involve mass change related to continental surface and sub-surface water storage (rivers, lakes, ground water), snow cover and polar and mountain ice sheets) as well as change in the ocean and atmospheric mass. Understanding these interactions and their consequences is essential to forecasting future states of the Earth System.

The mass change events involved in these phenomena have an associated gravity change signal which can be measured as a means of both understanding and monitoring these interactions. To fully understand the signal, repeated global and near synoptic measurements of the mass variations are necessary and a satellite-based observation capability is the only feasible approach for satisfying this requirement. The Gravity Recovery and Climate Experiment (GRACE) mission was conceived as a response to the need for such satellite-based measurements. The objective of the GRACE mission is to improve our understanding of the Earth by making pioneering measurements of the gravity signals associated with mass exchange within and between the Earth System components.

Launched on March 17, 2002 with a proposed mission life of 5 years, the GRACE mission ended on October 12, 2017 after providing paradigm shifting measurements for over 15 years. This presentation will describe the mission data set and its contributions to climate change investigations involving change in global sea level, terrestrial water storage, continental aquifers, surface and deep ocean currents, polar ice mass and the mass redistribution associated with large earthquakes and post glacial rebound. The totality of the contributions to studies of Earth system dynamics under-score both the role of the mass change as an essential climate variable and the importance of continuing the measurement record initiated by the GRACE mission. This critical role will be fulfilled by the GRACE Follow On mission, which is scheduled for launch in the late spring 2018.

A3.1-0029-18 REMOTE SENSING TECTONIC AND GROUNDWATER PROCESSES IN CENTRAL CALIFORNIA USING ALOS-1/2 AND SENTINEL-1 INSAR

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The improved spatiotemporal resolution of surface deformation from recent satellite sensors provides a great opportunity to better constrain and understand both tectonic and non-tectonic processes. In central California the primary plate boundary fault system (San Andreas fault) lies adjacent to the San Joaquin Valley (SJV), a vast structural trough that accounts for about onesixth of the United Sates' irrigated land and one-fifth of its extracted groundwater. The central San Andreas fault (CSAF) displays a range of fault slip behavior with creeping in its central segment that decreases towards its northwest and southeast ends, where it transitions to being fully locked. Despite much progress, many questions regarding fault and groundwater processes in the region still remain. In this study, we combine satellite InSAR and in-situ GPS to image fault and anthropogenic deformation. We performed a synoptic InSAR time series analysis using Sentinel-1, ALOS-1/2 interferometry. We estimate azimuth mis-registration between single look complex (SLC) images of Sentinel-1 in a stack sense to achieve accurate azimuth coregistration between SLC images for low coherence and/or long interval interferometric pairs. We show that it is important to correct large-scale ionosphere features in ALOS-2 ScanSAR data for accurate deformation measurements. In addition to fault creep, the L-band ALOS, and especially ALOS-2 ScanSAR interferometry, show large-scale ground subsidence in the SJV due to over-exploitation of groundwater. Groundwater related deformation is spatially and temporally variable and is composed of both recoverable elastic and non-recoverable inelastic components. InSAR time series are compared to GPS and well-water hydraulic head in-situ time series to understand water storage processes and mass loading changes. We present model results to assess the influence of hydrological processes on surface deformation, fault mechanics and implication for regional earthquake hazard.

A3.1-0030-18 THE GFZ GRACE RL06 LEVEL-2 AND ASSOCIATED LEVEL-3 DATA PRODUCTS

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The GFZ German Research Centre for Geosciences as part of the GRACE Science Data System (SDS) is currently reprocessing the complete GRACE mission data. This new Level-2 data release (RL06 in the SDS nomenclature) will incorporate updated standards and background models as well as an updated processing strategy in order to take care of limitations known from the current GFZ RL05a time series.

Amongst others changes from RL05a to RL06 comprise: (1) a reprocessed GPS constellation consistent with ITRF2014/IGS14; (2) reprocessed RL03 Level-1B products for K-band and star camera instrument data; (3) updated models for ocean tides (FES2014) and Atmosphere and Ocean Dealiasing (AOD1B RL06); (4) modified parameterization of orbit and instruments.

The resulting 15+ year RL06 time series of monthly GRACE Level-2 spherical harmonics with its underlying processing standards will then serve for the continuation with GRACE-FO (Follow-on) data expected for late spring 2018. It will also be the basis for the Gravity Information Service (GravIS) jointly developed by a team of GFZ, the Alfred-Wegener-Institute Bremerhaven and TU Dresden where users can download dedicated Level-3 products for hydrological, oceanic and polar research activities.

The presentation will report on the reprocessing status and show examples of the new GRACE RL06 gravity field products and (if already available) first results of GRACE-FO. In addition, an overview of the GravIS web portal will be given and examples of the latest Level-3 products will be shown.

A3.1-0031-18 SEISMICITY AND GPS OBSERVATIONS FOR STUDYING CRUSTAL DEFORMATION AND GEODYNAMICS IN AND AROUND EGYPT

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Egypt has suffered from a numerous of destructive earthquakes such as Kalabsha earthquake (1981, Mag 5.4) near Aswan city and the High dam, Dahshour earthquake (1992, Mag 5.9) near Cairo city and Aqaba earthquake (1995, Mag 7.2). As the category of earthquake damage includes all the phenomena related to the direct and indirect damages, the Egyptian authorities do a great effort to mitigate the earthquake disasters. The seismicity especially at the zones of high activity is investigated in details in order to obtain the active source zones. Since the year of 1994 till now, the geodetic observations by means of Global Positioning System (GPS) were applied instead of the terrestrial ones to cover some other regions of the country. These regions include Sinai, Gulf of Suez, Greater Cairo, Aswan and the Middle part on the River Nile. Data adjustment and analysis of the repeated GPS campaigns from the different networks using Bernese Software prevailed significant movements which may help in more understanding the geodynamics of these regions. In the meantime, GPS measurements of crustal motions for 189 sites extending east-west from the Caucasus Mountains to the Adriatic Sea and northsouth from the southern edge of the Eurasian plate to the northern edge of the African plate were carried out and Estimate of plate motions at stations located at different plates were determined. From the previous results, we could find there are some correlations between the computed surface deformation and the earthquake occurrences in Local and regional scales. In the regional scales, the Hellenic arc is the region which shows very well this correlation. While in the Local scales, there are some regions in Egypt such as Sinai, Aswan, Greater Cairo and Middle part of the Egypt around the River Nile. We also use the results of computing crustal deformation by means of GPS in studying the stabilities of any area for the purpose of establishing new strategic project and in planning for the constructions of new cities.

A3.1-0032-18 KINEMATICS OF THE SUEZ-SINAI AREA FROM COMBINED GPS VELOCITY FIELD

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A combined GPS velocity solution covering a wide area from Egypt to Middle East allowed us to infer the current rates across the main, already well known, tectonic features. We have estimated 126 velocities from time series of 90 permanent and 36 non-permanent GPS sites located in Africa (Egypt), Eurasia and Arabia plates in the time span 1996-2015, the largest available for the Egyptian sites. We have combined our velocity solution in a least-squares sense with two other recent velocity solutions of networks located around the eastern Mediterranean, obtaining a nal IGb08 velocity eld of about 450 sites. Then, we have estimated the IGb08 Euler poles of Africa, Sinai and Arabia, analyzing the kinematics of the Sinai area, particular velocity proles, and estimating the 2D strain rate eld. We show that it is possible to reliably model the rigid motion of Sinai block only including some GPS sites located south of the Carmel Fault. The estimated relative motion with respect to Africa is of the order of 2-3 mm/yr, however there is a clear mismatch between the modeled and the observed velocities in the southern Sinai sites. We have also assessed the NNE left shear motion along the Dead Sea Transform Fault, estimating a relative motion between Arabia and Africa of about 6 mm/yr in the direction of the Red Sea opening.

A3.1-0033-18 ASSESSMENT OF TEMPERATURE VEGETATION DRYNESS INDEX (TVDI) AND REGIONAL WATER STRESS INDEX (RWSI) FOR DROUGHT MONITORING IN SINDH

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Drought is one of the most complex and least understood phenomena in all-natural hazards. Intense drought periods impacted the livelihoods, crop destruction, human deaths, killed thousands of livestock and pushed peoples to migrate other areas. The drought has hit Indus basin historically from 19th to first half of the 20th century. It ranked 3rd in the frequency of significant hazards of Pakistan according to United Nation Disaster Risk Management. Historical data indicate that the province of Balochistan and Sindh frequently suffered from drought as compared to Punjab and KPK. Since the evaluation of satellite land observation data, numerous investigations have been done to monitor the occurrence and severity of drought using numerous satellite remote sensing based indices. Of these indices, Temperature Vegetation Dryness/Drought Index (TVDI) has been extensively used because of its easiness and accurate monitoring. But recently the application of TVDI has been questioned due to many limitations as it is based on the theoretical concept of the direct correlation between Land surface temperature (LST) and Normalized difference vegetation index (NDVI). Therefore, the selection of suitable index or model for drought monitoring has great importance in order to achieve effective drought monitoring management which results in increased agricultural production and economic development. In this study, the potency of TVDI was investigated, that calculated with modified methodology unlike the many studies using five different vegetation indices (VIs) i.e., NDVI, ANDVI, EVI, SAVI, MSAVI, by comparing it with Regional Water Stress Index (RWSI), an evapotranspiration based index having relatively clear physical meaning and high precision measurement. The northwest portion of Sindh which include Larkana, Qambar Shahdadkot, and some portions of Jacobabad, Dadu, Naushahro Feroze, Khairpur, and Shikarpur was selected as the study area to cover up all land cover types from no vegetated land (bare) to fully vegetated land. Landsat scenes of four different years (1998, 2000, 2014 2017) of the same month (February) were used for all the processing to derive vegetation indices, LST, TVDI, and RWSI. The relationship among TVDI, RWSI, soil moisture and Standard precipitation index (SPI) were also examined. Results indicate that: (1) LST and VIs showed negative relationship in most of the cases except in the case of dense vegetation in 2000 due to the prevailing of severe drought episode at that particular year; (2) The relationship between TVDIs and RWSI were found to be weakened when RWSI > 0.85, which deduces that TVDIs are appropriate for assessing and monitoring light drought, normal, and wet conditions, but not for severe drought conditions; (3) SPI and soil moisture had better significant relationship with RWSI than TVDIs, indicating that RWSI is more reliable and appropriate index for monitoring and assessing drought in this region. This study helps to enhance the drought monitoring capabilities which allows decision makers to make more knowledge-based decisions to reduce the impacts of drought.

A3.1-0034-18 RIVERINE FEATURE EXTRACTION AND VULNERABILITY ASSESSMENT TOWARDS ECO-FRIENDLY TOURISM SITES DEVELOPMENT

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Texture plays a very vital role in feature extraction from remote sensing satellite images. Texture is an important visual property that is used to characterize the natural and artificial images which make it a very useful feature for image analysis. High resolution satellite images contains abundant textural information which is very helpful for making distinction between the objects with similar spectral reflectance. The main objective of the proposed research is twofold (i) automatic identification of riverine features (island, water and sand) based on their textural information from high resolution remotely sensed data using object based image classification.

(ii) To assess the vulnerability of each river island towards flooding using 2D hydrodynamic model and SAR data. The GLCM based textural features are extracted to be used with image classification. The implementation and execution of flood mapping, monitoring and management applications has become easier with the availability of SAR data with all weather, day and night capabilities. In this study, the exploitation of the SAR dataset for hydraulic modelling and disaster management has been highlighted using feature extraction techniques for water area identification and water level extraction within the floodplain. The availability of high precision digital elevation model generated from the Cartosat-1 stereo pairs has enhanced the capability of retrieving the water depth maps by incorporating the SAR derived flood extent maps. This paper illustrates the flood event on June 2013 in Ganga River, Uttarakhand, India. Water levels that were computed by carrying out the modelling using hydraulic model in HECRAS also suggest that the water surface profiles provided by the combined use of topographic data and SAR accurately reflect the true water line. The outcome of the research can further be utilized in various application including river morphology, flood mapping, tourism infrastructure planning etc.

A3.1-0035-18 APPLICATION OF MULTIPLE REMOTE SENSING TECHNIQUES FOR DELINEATING GLACIER LAKE BOUNDARIES IN NORTHERN PAKISTAN

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Glaciers are the best indicators of climate change in any region. In view of the facts that glaciers are being depleted in south Asian region, application of an accurate remote sensing (RS) technique to map a glacier lake is the needed when many researchers claim to have better results using a particular RS method. We report here the mapping of one of lakes at the bottom of Hisper Glacier using satellite. The Landsat 8 data obtained from USGS were used for Sept.1990, March 2000, June 2010, May 2016 and march 2017 alongwith SRTM DEM. A number of lakes were demarcated using band ratios, NDWI and pan sharpening techniques. A number of lakes were demarcated using band ratios, NDWI and pan sharpening techniques. By comparing all these techniques, Panchromatic Sharpening Enhancement Technique provided the best result in visual interpretation. Then Unsupervised Classification since each water class was spectrally differentiated though it was hard to reclassify the polygons but results which were obtained were all satisfactory. In the last, NDWI and Band Ratio, the results obtained by using NDI were better than Band Ratio separating water from other classes. Coversely, Band Ratio mixed all the classes making harder for the user to interpret the differences and distinguish among water related classes.

A3.1-0036-18 INTERGRATING GIS AND SCS-CURVE NUMBER FOR ESTIMATING RUNOFF COEFFICIENT

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ABSTRACT: This study is an attempt to integrate Geographical Information System and SCSCurve Number for estimating runoff coefficient. Basic element in estimation of rainfall runoff depth is watershed management, which is determined by runoff coefficients. It is one of the most important factor for hydrologic designs such as dams and small ponds. Factors affecting the runoff coefficient value for a watershed are the land use, the soil type and the slope of the watershed and rainfall data. Soil Maps generated using Soil Map obtained by Geological Survey of Pakistan and then digitized using Arc GIS. The slope is another essential factor for runoff Index which had been calculated using 30m ASTER Dem. Land Use Land Cover (LULC) data is obtained by Open Street Map as shape file. CN-Grid HSG (Hydrologic Soil Group) developed to further integrate LULCs and the CN Lookup table for HSG. Intersection performed with each soil group (A, B, C and D) against all LULC. Study area only comprises of soil group 'B', therefore, the CN numbers were only assigned to group B, and for other soil groups the value was set at zero. Rainfall data was acquired from Pakistan Meteorological Department (PMD). SCS curve number method developed USA Soil Conservation service "SCS" (now called Natural Resources Conservation Service-NRCS) a division of US Department of Agriculture. The major objective of the study is to determine the potential runoff coefficient and runoff depth for Karachi.

INTRODUCTION or planning and management of land and water resources, watersheds are the fundamental units to be considered [1]. In urban centers like Karachi city, these watershed supports agricultural activities in its sub-urban areas. Karachi is the biggest city of Pakistan, facing a continuous population growth and urban expansion in its northern, northeastern and northwestern regions [2]. Within Karachi jurisdiction, three major river basins of Malir, Hub, and Lyari Rivers play their role in draining the storm water from the city and recharge ground water. In spite of having extensive network of natural streams, these streams do not have any flow gauges that's why the runoff data is not available. Karachi receives its maximum rainfall during monsoon and average rainfall range from 10mm to 150mm according to the Normal (1985 -2014) data provided by the Pakistan Meteorological Department (PMD). Karachi also receives little rainfall from western disturbances during winter. These natural streams are nonperennial and only active during the rainfall. That is why the agricultural activities in suburban areas of Karachi is mainly dependent on the ground water (recharged during the rainfall). The heavy rainfall of monsoon period is mostly converted into runoff and a huge part of this just gone to the Arabian Sea. But with the harvesting of this rainwater, it is possible to sustain the water resources in suburban areas of Karachi, so the water for agricultural activities would be available for a longer time period. Estimation of rainfall runoff depth is one of the basic elements in watershed management, which is determined by runoff coefficients [3]. Rainfall depth is also important for hydrologic designs such as dams and small ponds. Runoff coefficient is the portion of rainfall which converted into direct runoff during a rainfall event [4]. It can be defined as the ratio of the runoff depth to rainfall depth or as the ration of peak runoff rate to rainfall intensity for the time of concentration [5] These runoff coefficients are also used understand the recurrent interval of floods in an hydrologic or climatic regime [6]. The runoff coefficients varies with the change in topography, landuse/landcover, soil type and it moisture content. The Natural Resource Conservation Service (NRCS)'s curve numbers (CN) represent the runoff potential of a basin based on hydrologic soil group, landuse, and hydrologic conditions of the study area. To calculate CN for a specific area, the information regarding its land use/cover, soil type, and antecedent soil moisture condition (AMC) are to be known [7]. In NRCS curve number method (popular with its previous name SCS-CN), it is assumed that rainfall occurred uniformly during the storm. The SCS-CN method is a rainfall-runoff method based on the basic concept that when rain falls in a basin, it converts into surface runoff after initial losses or initial abstractions. These losses include interception due to vegetation and pavements that restrict the rainwater to penetrate into the ground immediately after the rainfall, surface water storage (lakes, ponds, and depressions), and water infiltrated into the ground [1]. The range of CN values is from 30 -100. The lesser values show high infiltration and low surface runoffs. On the other hand, a higher CN value indicates lower infiltration rate producing higher surface runoffs. The major objective of the study is to determine the potential runoff coefficient and runoff depth for Karachi BACKGROUND

STUDY AREA AND MATERIALS Karachi district of sindh-Pakistan was selected for this study. Karachi is the major city of Pakistan and provincial capital of Sindh. To estimate the runoff coefficient of Karachi a number of data-set were used, including Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM), Soil map, Rainfall Data and, Land-use/Land-cover (LULC) data from Open Street Map (OSM).

METHODOLOGY A. Data preparation 1) Soil map Soil map of the study area was obtained from Geological Survey of Pakistan (GSP) and then converted to shapefile. Soil data provided by GSP have detailed information of soil physical and chemical properties of topsoil (0-30 cm). There are four Hydrologic Soil Groups (HSGs), A, B, C, and D. According to USDA-SCS (1988) HSG A has the minimum runoff potential and D has the maximum. In Karachi major soil texture is loam which belongs to 'Group B' of the HSG, having moderate runoff potential [78].

2) Landuse/Landcover (LULC) For this study we need a detailed LULC data, that's why this data is obtained by OSM as shapefile.

3) Digital Elevation Model (DEM) SRTM DEM acquired from USGS website to calculate the slope of the study area. Slope is one of major parameters which determine the runoff coefficient of the study area. B. CN-Grid Generation To calculate the curve number for each LULCC, a CNGrid was generated. For the CNGrid generation HSG (Hydrologic Soil Group), LULCs and the CN Lookup table for HSG were used [8]. To calculate the percentage of each soil group (A, B, C and D) against all LULC, Soil groups were intersected with LULCs. The CN Lookup table consist all the values of CN for each LULC according to the soil group. In the study area only 'B' soil group was present, therefore, the CN numbers were only assigned to group B, and for other soil groups the value was set at zero. C. Rainfall runoff Rainfall data was acquired from Pakistan Meteorological Department (PMD). SCS curve number method developed USA Soil Conservation service "SCS" (now called Natural Resources Conservation Service-NRCS) a division of US Department of Agriculture. This is one of the common method used to compute peak runoff rates and volumes of small and ungauged streams [9][10]. The SCS Runoff Curve Number used to simulate rainfall-runoff response in Karachi due to 24-hr storm events. According to SCS curve number, the runoff from a rainfall event starts after initial losses. Initial losses include evaporation, absorption, transpiration and surface storage, called 'initial abstractions (Ia). The variable 'Ia' also includes interception losses due to vegetation and paved surfaces which restrict the rainfall from reaching the ground instantly after it occurs. The surface storages losses are water bodies such as ponds, lakes, depressions and infiltration of rainwater to the ground [11]. In SCS method Ia is assumed to be about 20 percent of the potential maximum retention (Eq. 01), whereas, the potential maximum retention (S) is calculated using Eq. 02 ???????? = 0.2 ???? Eq. 01 ???? = ???? (100/???????? 1) Eq. 02 Where: Z = 10 for English measurement units or 254 for metric units CN = Runoff Curve Number CN value depends on soil type, landcover, and Antecedent Moisture Condition (AMC) of the study area. Equation 03 represents a relationship between the accumulated rainfall and the accumulated runoff.

???? = (???? ????????)2/(???? ????????) + ????) Eq. 03 Where: Q = directly accumulated runoff (inch or mm) P = accumulated rainfall or maximum potential runoff in inches or mm (24- hr storm depth versus rainfall frequency) Ia = initial abstraction (includes surface storage, evaporation, interception, and infiltration before the occurrence of runoff (in or mm) S = maximum potential soil moisture retention after runoff begins (inch or mm) D. Runoff coefficient Annual runoff coefficient per pixel derived using Equation 04, K= yearly (seasonal) total runoff (mm) / yearly (seasonal) total rainfall (mm) IV. RESULTS AND CONCLUSION Remote sensing data along with ground information helps a lot in SCS-CN model. Products like drainage pattern, catchment, land use/land cover of Remote Sensing can have integrated with GIS for watershed management. Estimation of Runoff coefficient in this process is very important as it is one of the most important parameters in hydrologic design. This study can also help in identification of runoff coefficient of areas whose observed runoff records are not available.

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A3.1-0037-18 IMPACT OF NEW URBAN SCHEMES ON NATURAL STREAMS OF KARACHI

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Pakistani social activist, director of the Orangi Pilot Project Research and Training Institute Ms Parveen Rehman said that "Development doesn't come from concrete! It comes from human development." Landuse planning and development is one of the key feature of urban centers. This landuse planning has a direct impact on landuse patterns and eco-environmental quality of the area. Landuse planning is a systematic analysis of land suitability and its alternative use. For landuse planning the best choice of land is that which fulfills the present social need but without disturbing the environment of area. Residential development processes in the urban-rural fringe of mega cities has major environmental consequences. Karachi, Pakistan is one of fastest growing urban centers of the world, but this fast-growing population has also been associated with increasing pressure on ecosystems and their individual components. In 1993 only 08% of the city area was developed which is now 21% of the total city area. These development processes have influence on socio-economic, political and environmental situation of the city. The conversion of fertile agricultural land and natural ecosystems into built-up area bring negative ecological impacts. One recent study shows that the urbanization is also going to cause recurrent flash floods in Karachi city which will cause damages in terms of livelihood and assets. The damages by these floods is just not due to heavy rainfalls but because urban development acts as barriers to natural major stream networks and hamper the flow of rainwater to the riverbeds. This study also aims to analyze the impact of one of the well-known real state scheme "Bahria Town Karachi" on natural landcovers. Bahria town is located in the northern part of Karachi almost covering an area of 44,000 Acres. In a newspaper article urban development expert and town planner Mr. Arif Hasan reveals that according to the first master plan of Karachi (1953) the rural area around Karachi were previously reserved for agriculture and the status was unchanged in the revised plans of 1958, 1989 plan for 2000. Bahria town Karachi also responsible for displacement of villages located in the area of prior to the development of the project. About 45 goths (villages) residents were displaced. Figure 01 shows the map and list of the villages which were affected due to Bahria town. In spite of having all the controversies the new town is also responsible for deteriorating the natural landcover and natural streams bed in the area. A previous study related to blockage of stream networks in Karachi reveals that the town is encroaching the riverbeds which in turn will affect the river flow and also ground water recharge. This research aims to study the detailed impacts of Bahria town development on the natural and semi natural environment of the city. For this study Landsat ETM+ and Landsat data for the year of 2000 and 2017 were collected. Landsat is one of the satellite program providing extensive remote sensing data free of cost. Landsat data have been proved valuable for many urban related studies.

A3.1-0038-18 DROUGHT ASSESSMENT USING SATELLITE DERIVED METEOROLOGICAL PARAMETERS AND NDVI IN POTOHAR REGION

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Pakistan faces a number of severe meteorological droughts due to various meteorological variations such as rainfall, air quality and related climate changes. The study area namely as and due to its unique topography, it lacks the network of canals system. Multi-temporal MODIS NDVI product 16-days composite for year 2000-2013 was used to identify any drought period in study area i-e, Potohar Plateau in the north of Pakistan. There was an unexpected decrease in NDVI value in 2009-2010, which caused a short term drought. The minimum mean value for NDVI observed was 0.268 for the whole decade, where mean departure from minimum NDVI value was 0.063 reducing it to a value of 0.20. Meteorological parameters derived from NCEP satellite data such as Precipitation, Max. Temperature, Min. Temperature, Humidity and Solar Radiation were assessed for drought sensitivity for the past drought period 2009-2010. Further precipitation based drought index, known as the Standardized Precipitation Index (SPI) was also derived for 6 months. Maps for each parameter showing its intensity trend were generated for the drought period. For further investigation, the relationships between meteorological parameters were examined. A negative relationship between NDVI and SPI, in month of October was observed that triggered the condition of drought. A decreasing trend was also observed in relationship between NDVI and humidity. Further, Fuzzy Overlay analysis was performed after generation of Fuzzy membership function of these meteorological parameters. VCI was derived from NDVI that estimates the vegetation health. Finally, overall drought severity map was generated by combining VCI and Fuzzy overlay of meteorological parameters. This map gives a significant understanding about the areas under various degrees of drought stress.

A3.1-0042-18 TOWARDS CHARACTERIZING INUNDATION DEPTH UNDER DIFFERENT LAND COVER TYPES WITH L-BAND SAR IMAGERY

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Information derived from imagery acquired with instruments onboard satellites, aircrafts or drones can be used in many applications and help advance our understanding of environmental processes. This has been demonstrated in many research studies to date, however, in many cases, remote sensing cannot measure directly the variable that is of greatest interest. In the case of flooding for instance this would be clearly flow velocities along with floodplain inundation depths since those two parameters actually constitute hazard during an event. Yet, it is not possible to measure either one of those parameters from satellites (at least not until now). Therefore, it is necessary to derive the best possible proxy or try to characterize the "unmeasurable" parameters in the best possible way. In an attempt to add to the current advances in remote sensing of floods, we demonstrate that it is possible to characterize inundation depth under different land cover types with ALOS-2 PALSAR L-band SAR images acquired during the 2015 January flooding season in the Lower Zambezi Basin. We believe that the results are robust enough for extrapolation and generalization but acknowledge that more studies of this type are needed to reach a consensus on the value of the findings.

A3.1-0043-18 SEA WATER INTRUSION AND INUNDATION MAPPING ALONG COAST OF KARACHI USING SPATIAL TECHNIQUES; AN IMPLICATION FOR RECENT ADVANCES AND FUTURE CHALLENGES.

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Karachi Metropolitan, which is not only the most populous and biggest industrial base but also the largest coastal abode of Pakistan. The groundwater conditions in the coastal area of Karachi has experienced rapidly changing trends surrounded with the intensity of extreme events in the region due to global warming, the imbalance between fluvial and marine hydrodynamics which in turn provoke to seawater intrusion towards coastal groundwater aquifers.This project is developed with aims to delineate the effected invaded areas of Karachi by sea water and portrays it through inundation mapping using spatial techniques. The aim of the study is to investigate the mapping of seawater intrusion in Karachi area and adjoining coastal aquifers. Physiochemical analysis has been performed for different samples collected from coastal and adjacent areas of Karachi. Existing hydrogeology and resistivity data have been integrated with physiochemical to spatially analyze the distribution of intruded saline water within aquifers. For mapping vulnerability of aquifers, GALDIT model has been used by incorporating different parameters. Generally, there are three aquifers has been reported from the resistivity field curves within a depth of about 120 meters in consolidated aquifer material. The depth of first confined aquifer in sandstone of Gaj formation ranges between 6-40 meters, second confined aquifer 25 and 90 meters while third one may encounter at a depth between 45- 110 meters. These confined aquifers are found in sandstone and siltstone of lower Mancher or upper member of Gaj formation. Karachi can be divided hydro-geologically into Lower Malir Basin, lower Gadap and some part of the eastern lower Hub basin. These basin exhibits an average gradient of 3m/ km from NE to SW direction. Based on hydro-chemical data, deep groundwater has a higher value of electrical conductivity (range: 5.1 - 19.1 ms/cm), salinity (range: 2.7 - 7.4 ppt) as well as Chloride concentration (range: 1480 - 6034 ppm) and SO (range: 144 -2221 ppm). In Malir basin, South-Eastern part of Karachi, the confined aquifer reported to hosts a mixture of rainwater as well as trapped sea water, through intrusion under natural infiltration conditions, while aquifers of upstream regions indicates that the source of water might be saline water, which significantly arises from nearby industrial unit having High concentrations of Cl (6034 ppm) and SO (221 ppm), coupled with slightly alkaline pH values. Hence, in the light of all physio-chemical data integrated with hydrogeological assessment and the result of GALDIT model, it can be concluded that immediate South and South-Western part of Karachi has much more vulnerable aquifers for saline sea water intrusion as compared to the upstream region.

A3.1-0044-18 REMOTE SENSING OF CRYOSPHERE: ESTIMATION OF GLACIER MASS BALANCE IN THE ANDES AND IN THE US

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Glaciers are the key components in understanding rapid changes in climate. A continuous measurement of glacial extent, mass and velocity is therefore a key to the understating of the climate change. The main purpose of this paper is to analyze the glacier mass balance in the Andes and in the US using various remotely sensed data. Specifically, we analyzed the mass balance of glaciers in the Southern Andes (Chile and Argentina) using Shuttle Radar Topographic Mission (SRTM) with the elevation footprints from the Geoscience Laser Altimeter System (GLAS-ICESat) campaign. Further, we analyzed a multi-decadal analysis of glacial mass balance, glacier retreat and glacial lake expansion in the Northern Patagonia using Landsat (TM, ETM+ and 8) and ASTER satellite. Finally, we studied melting patterns of snow cover in the Sierra Nevada and Mt. Shasta regions in California using ASTER DEM and Landsat ETM+ satellite images. In the Southern Andes, our analysis showed a negative mass balance of glaciers in the Cordillera Darwin Icefield and North Wet regions with very low uncertainty in the estimation. In the South Patagonian Icefields and Dry Central regions, mass balance was also negative, but with higher uncertainties in the estimation. In the North Patagonian Ice Fields, San Quintin glacier experienced the highest retreat. Glacial lake area increased and additional glacial lakes were formed during the study period. Some glaciers such as Nef glacier recorded mass gain, but glaciers such as HPN-4 lost mass. In California, a remarkable reduction in snow cover extent of about 80% between 2000 and 2015 was observed in the studied watersheds.

A3.1-0045-18 SYNERGESTIC UTILIZATION OF EARTH OBSERVATIONS BY INTEGRATIVE USE OF VARIABLE INFILTRATE CAPACITY MODEL AND RUNOFF ROUTING MODEL FOR FLOOD MONITORING AND FORECASTING

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India is one of the worst flood-affected countries in the world and accounts for 20 % of global death count due to floods. Floods occur mostly during southwest monsoon starting from June to September. About 40 million hectares of land in the country is prone to floods as per National Flood Commission, 2007. The annual average of land area and crop area affected due to flood is about 18.6 million hectares and 3.7 million hectares respectively. The most floodprone areas in India are the Brahmaputra and Ganga River basins in the North and Northeast India. The impact of flood in India is high due to lack of reliable flood monitoring, forecasting and insufficient resources. A reliable flood monitoring and forecasting system is of paramount importance for hazard mitigation and management. Hydrologically oriented Land Surface Models, such as Variable Infiltration Capacity model (VIC), are coupled with runoff routing models for better monitoring and forecasting. VIC model can use any combination of daily or sub-daily meteorogolical forcings, from point observations, gridded observations, or reanalysis fields. At minimum, VIC requires daily (precipitation, max/min air temperature, and wind speed). The VIC model has been successfully applied for many hydrological simulations and water resource management studies, including flooding (Hamlet and Lettenmair, 2007; Hamlet et al., 2010; Elsner et al., 2010; Voisin et al., 2011). The meteorological input parameters for flood monitoring and forecasting are the most critical for the model and can be obtained through satellite remote sensing with relatively high spatio-temporal resolution. The model can give good results for lower latitude basins with few dams (Wu et. al., 2014). The present study focuses on the flood monitoring and forecasting using integrated LSMs and runoff routing model for the downstream areas of the Brahmaputra and Ganga River Basin by using the current state of meteorological and hydrological modelling capabilities and try to fill the knowledge gaps within the scope of study.

A3.1-0046-18 FLOOD EARLY WARNING AND VULNERABILITY ASSESSMENT USING INTEGRATION OF WEATHER FORECASTING, HYDROLOGICAL AND GEOSPATIAL MODELLING IN NORTH WESTERN HIMALAYA RIVER BASINS

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Globally floods are one of the most frequent and most damaging disasters in terms of loss of property and human life. India is one of most affected country in the world affected by flood disaster on annual scale, second only to Bangladesh. In India, North Western part of country is dominated by Himalayan Mountains and flooding in these areas is different as compared to other low relief and plains areas of India in terms of source of floods, travel time and volume of floods. In North Western Himalaya (NWH) most of the floods are flash floods caused by high intensity precipitation or more popularly known as cloud burst. The presence of moraine dammed glacier lake also possess high threat of Glacier Lake Outbursts Floods (GLOF) in this area, as demonstrated by 2013 Kedarnath floods. The other source of floods can be breaching of landslide dammed artificial river lakes. In all these cases, the time of travel of flood water from source to outlet or human habitation located along these river valleys is only few minutes to few hours. Hence, any flood warning activity in NWH should be done by taking into consideration all these unique factors. Current study has used 3-day advance weather forecast in NWH using double nested domain of Weather Research and Forecasting (WRF) model (9 km for outer domain and 3 km for inner domain) for entire monsoon of 2015, 2016 and 2017. The model is run using National Centre for Environmental Prediction (NCEP) Global Forecasting System (GFS) 0.25 degree data as initialization state. The WRF outputs were at 3hourly time scale. Based on historical and current data of Indian Meteorological Department (IMD) 0.5 degree daily rainfall grids, validation of few events of 2013-2017 monsoon has been done, giving simulation accuracy of WRF in rainfall prediction above 100 mm of 60%, but overall pixel wise correlation coefficient R2, is low at 0.2-0.3. Accuracy assessment of WRF simulations of 2017 is under progress. The forecasted precipitation of every three hours is used hydrological modelling system (HMS) and variable infiltration capacity (VIC) model for flood hydrograph generation at various outlets of study area. Currently, part of Beas river basin, Upper Ganga basin upto Haridwar and Yamuna basin upto Poanta Sahib are tested for near real time flood forecasting. Limited validation of simulated river flow hydrograph for Uttarkashi and Joshimath sites are done using historical data of 2005-2007 monsoon using Central Water Commission (CWC) discharge data with R2 of 0.6-0.7 for two stations. The output of hydrological models in terms of flood hydrograph is used for flood inundation scenarios along river reaches using 1-D HydroDynamic (HD) modelling to see the probable areas which can come under flood inundation. In 2015 monsoon, the flood event of 05 to 08 August 2015 in part of Beas river basin in Mandi District of H.P. near Dharampur has caused very high damages. Similarly in Late June and Early July 2016, an extreme rainfall event caused flash floods in Pithoragarh region of Uttarakhand, UK. These events were also forecasted well in advance of three days by WRFARW model. During the non-flood season the cloud free cartosat-1 images of upper Ganga basin has been acquired before and after 2013 flood disaster to map the flood affected areas of this area. The Majors Rivers of NWH are also selected to make buffer of 100m, 200m and 500m on both sides to identify and map the flood vulnerable areas. Flood frequency analysis considering 25, 50, and 100 years floods also being done along with DAM break and GLOF modelling of vulnerable lakes of study area to identify the flood vulnerable areas using geospatial modelling approach. In this method, flood inundation scenarios (actual or frequency based) is overlaid with Land Use Land Cover (LULC), roads, settlements etc. to identify probable flood hazards areas. Next, based on class and present conditions of buildings, roads or crop/forest type, the overall vulnerability of area to flooding is assessed. The test sites of this detailed flood vulnerability study are few sites in NWH such as critical river stretches of Mandakini river basin, upper Ganga and Yamuna basin and parts of Beas river basin and later all areas of NWH will be covered. This study shows how an integrated approach can be used for flood early warning and vulnerability assessment in mountainous areas.

A3.1-0048-18 APPLICATION OF SATELLITE DATA COLLABORATING WITH VIC MODEL FOR IDENTIFICATION OF WATER SCARCE REGIONS OF INDIA

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Drought is a complex, slow onset phenomenon of ecological challenges that affect people more than any other natural hazard. Drought cause serious economic, social and environmental losses. Drought in India is a regular event occurring almost every year in some Indian states. Because droughts are a normal part of virtually any climate, it is important to develop plans to reduce their impact. In order to identify and classify drought-prone and drought-affected regions, variables such as evapotranspiration, runoff, and soil moisture storage have been retrieved through Variable Infiltration Capacity (VIC) land surface hydrological model and hydrological drought index is calculated from simulated soil moisture. Soil moisture data is analyzed from a retrospective simulation from 2005 to 2018 are used to develop probability distributions of monthly average soil moisture, and the relative position of soil moisture fields. Meteorological data such as precipitations and temperature are based on Central Forecast System (CFS), Indian Institute of Tropical Meteorology (IITM). Other meteorological forcing parameters such as wind direction, specific humidity, shortwave and longwave radiation have been extracted from the Extended Range Prediction System, IITM. Further, modeled data is validated with available in situ soil moisture observations for Varanasi during the period Sep 2017-April 2018. Temporal variation of drought in affected regions have been identified with high spatial resolution to ensure that drought index is able to allow for the effects of short-term changes in meteorology as well as longer-term climate variations and resolve the high spatial variability in soil moisture and drought occurrence.

A3.1-0049-18 FLOOD SIMULATION AND INUNDATION MODELLING USING HYDROLOGICAL MODEL AND HAND TOOL FOR JHELUM RIVER BASIN

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Flood is one of the most destructive natural hazards that cause damage to human settlements and natural environment. In the past years, India has been largely affected from the flood during monsoon season such as 2008 and 2014 devastating flood in Bihar and Jammu and Kashmir etc. A study has been done to simulate the flood discharge and flood inundation in the Jhelum River Basin of geographical area 9,472.14 Sq. Kms. Since, several flooding events have been occurred in the Jhelum River basin in the past years such as 1948, 1950, 1957, 1959, 1969, 1976, 1988, 1992,2002,2004,2010 and 2014 etc. According to report of 11th planning working group of planning commission, India, total 45.640 million hectares area of the country is flood prone and out of which 0.514 million hectares lie in the Jammu and Kashmir that is 2.3 % of total geographical area. In the Lawrence Report (1895), it has been stated that there was a major flood occurred in July 1893 in this basin due to 52 hour continuous rainfall that had caused damage to 25,426 acres of crop land and 2,225 houses in Jammu and Kashmir. The Jhelum River basin is the sub-basin of the Indus River Basin originates from the spring called Chashma Verinag. The total geographical area of this river basin 34,775 Sq. Kms. according to India WRIS (Water Resources Information System). ALOS PALSAR Digital Elevation Model (DEM) of 12.5 m resolution has been used to delineate the river basin. The outlet chosen for the delineation of this basin in the downstream of this river at Asham gauging station lie in the Bandipora district of Jammu and Kashmir. Apart from this, there are two other gauging stations have been chosen for the validation and calibration of the results, one at RamMunshibagh in the Srinagar district and other at Sangam in

the Anantnag district which lie in the middle stream and upstream of the Jhelum River. The vertical accuracy of ALOS PALSAR DEM and Cartosat-1 DEM have been also compared using ground truth data to obtain the suitable DEM for this area. The Geospatial Hydrologic Modelling Extension (HEC-GeoHMS) extension in ARC-GIS software has been used to delineate the basin and the HEC-HMS software has been used to simulate the flood discharge. The threshold value has been used to delineate stream is 100 Sq. Kms. The Tropical Rainfall Measuring Mission (TRMM) 3B42RT rainfall data and the (European Reanalysis) ERA-INTERIM temperature data of from 15th August 2014 to 30th September 2014 has been used for the simulation. The simulation has been run from 15th August 2014 to 30th September 2014 as Hydrologic Engineering Center's-Hydrologic Modelling System (HEC-HMS) software is storm specific. The Soil Conservation Service (SCS) curve number has been used for simulation of run-off and the Muskingam-Cunge method has been used for the routing. The Value of Curve Number (CN) varies from 0-100. Higher the CN value, higher will be the run-off. The Gumble's method has been used to calculate the 2 years 24 hour rainfall that has been used as an input in the TR-55 excel sheet generated by HEC-GeoHMS. The temperature index method has been used in the HEC-HMS to simulate the snow melt. The Height Above Nearest Drainage (HAND) tool has used to generate the inundation map at various threshold value such as 2m, 3m, 4m and 5m respectively. The RISAT-1 images of date 08th Sep 2014, 10th Sep 2014, 20th Sep 2014 and 21st Sep 2014 has been processed for Flood mapping and to obtain the duration of flood. The 10th Sep 2014 RISAT-1 image show more flood than others. The Outflow obtained from hydrological simulation shows maximum discharge of 11,529.10 Cumec at Asham gauging station on 04th Sep 2014 and maximum discharge of 8,252.70 Cumec and 4,988.20 Cumec at RamMunshibagh and Sangam on 5th Sep 2014. The Observed discharge data of these gauging stations obtained Irrigation and Flood Control Department, Kashmir has used for calibration and validation. The outflow obtained can be used for hydrodynamic modelling to obtain flood hazard, vulnerability and risk analysis that can be further used to generate the evacuation plan during flood.

Keyword: Hydrological Modelling, HEC-HMS, TRMM, HAND Tool, RISAT-1

A3.1-0050-18 AFRICAN GEODETIC REFERENCE FRAME AND FIRST RESULTS FROM GNSS NETWORKS IN AFRICA

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The African Geodetic Reference Frame (AFREF) is conceived as a unified geodetic reference frame for Africa. It will be the fundamental basis for the national three-dimensional reference networks fully consistent and homogeneous with the International Terrestrial Reference Frame (ITRF). When fully implemented, its backbone will consist of a network of continuous, permanent GPS stations such that a user anywhere in Africa would have free access to, and would be at most 1000km from, such stations. Full implementation will include a unified vertical datum and support for efforts to establish a precise African geoid, in concert with the African Geoid project activities. The realization of AFREF has vast potentials for geodynamics, geodesy, mapping, surveying, geoinformation, earthquakes, natural hazards mitigation, earth sciences, etc. Its implementation will provide a major springboard for the transfer and enhancement of skills in surveying and geodesy and especially GPS technology and applications. AFREF is, therefore, an African initiative to unify the geodetic reference frames of Africa based on the ITRF through a network of Global Navigation Satellite System (GNSS) base stations at a spacing such users will be at most within 1000 km of a base station. First Reference Frame Solution of about 80 geodetic GPS stations in Africa has been started in February 2014 at some processing centers in Europe and Africa. Results of independent solutions being developed by various African scientific teams: Hart RAO, South Africa, Ardhi University, Tanzania and SEGAL, University of Beria Interior, Portugal, show an accuracy of aligned ITRF 2008 using 42 IGS stations in E and N components with 3.0 mm and in U component 7.5 mm.

A3.1-0051-18 ESTABLISHMENT OF VLBI FOR THE MEXICAN ASTRONOMICAL GEODESICAL NETWORK (RAGN)

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The RAGN serves as a unique analytical reference framework that coordinates all the scientific and technical measuremens of the mexican country. It determines its dimensions and combined with other countries networks provides the basis to define the reference ellipsoid parameters as well as to study the Earth as a planet. The RAGN helps in the control of artificial satellites (SAT);furthermore, it provides the basis to study the deformation of the Earth's crust in the country.

The RAGN in México was developed in roughly three periods. In the first, from1915 to 1965, it was dependent on optomechanical methods of triangulation and polygonation. In the second, at the end of the 1970's, the RAGN was adjusted to the "Transit Satellite System". In the third epoch which started at the beginning of the 1990's, with the help of the "Navigation Global Positional System" (NAVSTAR), the current "National Satellital Geodesic Network" (RGNS) was implemented.

The Mexican territory sits on a very active sismic zone in which several tragical earthquakes have ocurred in the last 80 years. After an earthquake technoscientific studies have to be made to determine the deformation of the vertices of the RGNS. This work proposes a way to quickly determine the changes of coordinates of the vertices via an intercalated VLBI to the RGNS. One of the radiotelescopes could be the Large Millimeter Telescope Alfonso Serrano (LMT), located in Sierra La Negra, Puebla, while the second could be located in Mexicali, Baja California, on a point of the RGNS. The method to be used compares the two RGNS coordinates referenced to te VLBI in a time when the Earth's surface is stable in México. After an earthquake the adjustment of the coordinates is calculated. The observational methodology for the VLBI and the RGNS, how they are linked as well as the least squares method to adjust over the reference ellipsoid are presented.

A3.1-0052-18 THE 2017-2027 NATIONAL ACADEMIES DECADAL SURVEY FOR EARTH SCIENCE AND APPLICATIONS FROM SPACE: AN OVERVIEW OF THE REPORT

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A pre-publication version of the final report of the 2017-2027 National Academies' decadal survey for Earth Science and Applications from Space ("ESAS 2017") was delivered to its agency sponsors on December 31, 2017; publication of the edited version is expected in Spring 2018. Like the inaugural survey, which published its final report in 2007, ESAS 2017 was requested by NASA, NOAA, and the USGS. The survey's overarching objective was to develop consensus recommendations from the environmental monitoring and Earth science and applications communities for an integrated and sustainable approach to the conduct of the U.S. government's civilian space-based Earth observation programs. The survey co-chairs will review the report's findings and recommendations and discuss its implementation. A PDF of the report is posted at www.nas.edu/esas2017 where details about the survey may also be found.

A3.1-0053-18 TEMPORAL REGULARISATION FOR MERGING OPTICAL, THERMAL AND SAR DATA

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Changes of Earth surface can have different nature and can influence different domains of electromagnetic spectrum. Using different domains as an input to an advanced machine learning methods can help in detection of comprehensive changes of earth surface. One of main complications in combining different Earth Observation (EO) data streams is a requirement of common time and space resolution. This can be archived by merging observations that were made by different EO sensors. Merging is typically involves some kind of spatio-temporal interpolation. However, applying interpolation can increase uncertainties due to different spectral properties of adjacent pixels. This in turn can dramatically influence further processing of data streams such as classification or change detection. This issue can be solved by propagation of uncertainties through whole processing chain. Therefore one of the requirement for this study is using a method which permits estimation of EO uncertainties. So we need to provide gap free time series of Earth Observation (EO) data with their associated uncertainties. In order to normalise reflectance, fill gaps due to cloudiness and calculate uncertainties we use temporal regularisation which is based on Bayesian inference. We exploit temporal regularisation which allows filing gaps in the time series of parameters and explicitly characterise the output uncertainties. So we combine data across wavelengths, including optical and microwave (with different spatial and temporal properties), into a common observation vector. We use these data to generate optimally smoothed and filtered time series of reflectance, albedo and backscatter, as the core SSV output, with consistent uncertainties (key for use in further quantitative modelling and change detection chain, particularly attribution). We use MODIS daily reflectance, Sentinel 1 observations, thermal (MODIS LST) and historical microwave (ENVISAT ASAR).

A3.1-0054-18 GPS REFLECTOMETRY MONITORING OF THE UNDULATING SEA SURFACE LEVEL: NUMERICAL SIMULATIONS AND ERROR MITIGATION APPROACHES

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Dramatic changes in the natural environment, observed in the present epoch, are threatening and can be dangerous for the future of the whole world human population. Systematic monitoring of these global changes is now critical for detection of log periodic variations and long term trends such as global warming, polar ice melting, raising of the ocean level etc. Extensively developing technologies of observation of the Earth from space provide excellent possibilities for remote measurements of key physical parameters of the atmosphere, ocean and land surface. GPS reflectometry [1] is a relatively cheap technique for in situ measurements of the sea level surface, which can be implemented both at coastal stations of geodetic GPS-networks and specially organized observatories of global environmental monitoring. This technique, however, suffers from errors caused by rapid sea level perturbations, e.g. wind generated waves which can introduce not only random but also systematic biases in the measured data.

In this study, numerical simuilation of reflections of navigational space-borne radio beacons from undulating sea surface is performed at the main frequency of the Global Positioning System (GPS) L1 (1575.42 MHz). Electromagnetic field has been simulated with the Finite Difference in Time Domain (FDTD) technique [2] for different model spectra of the sea waves. Impact of the surface waves on the mean sea level estimate at the monitoring station location is investigated. Random and systematic errors, in particular related to partial shadowing of the undulating surface at low grazing alngles of the sounding wave coming from a GPS beacon, are evaluated and estimated.

Approaches to mitigation of the observational errors using auxiliary support data, including local sea waves spectra recorded in situ, context images/footage video of the surrounding aquatory, local weather conditions (wind speed and so on) are discussed.

The research is carried out using the equipment of the shared research facilities of HPC computing resources at Lomonosov Moscow State University [3]. Support from Russian Science Foundation with the grant 17-77-20087 is kindly acknowledged.
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A3.1-0055-18 GIS AND REMOTE SENSING BASED FEATURE EXTRACTION FOR TOPOGRAPHIC MAP UPDATING IN SYLHET CITY, BANGLADESH

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Regular and timely updating works of Topographic map is a major concern for the Mapping Organizations around the World. The usual operations for updating such maps include, acquiring High resolution satellite data that is faster in acquisition but costlier and Aerial photography that demands both longer time and higher cost. Both are acquired and processed in Survey of Bangladesh (The National Mapping Agency of Bangladesh) for generating and updating topographic maps. But, they are done in irregular basis, as the financial aspects for acquiring Satellite data or Aerial Photo, often, do not allow to go for regular and timely updating works. Satellite data from open sources could do the balance in this aspect. Problem is about the resolution of those images which are not enough to bring out necessary topographic details.

Taking this as paradigm, an attempt has been taken in this study for updating topographic map using open sources medium resolution satellite data and involving Geospatial techniques. One of the most recent and cloudless Landsat 8 data is taken to update 1:250,000 scales topography map of the study area Sylhet City, Bangladesh. More concentration has been given into the methods rather than the generalization and digitization works.

The research work started with feature extraction from the open sources data. Preprocessing works involved layer and spectral band compilation and transforming the coordinate system as similar to the coordinate system that is used in survey of Bangladesh. Level 1 data from Landsat TM is used that has both Geometric and radiometric rectifications. LULC classification is done following supervised classification with Maximum Likelihood technique. After validating the accuracy of the feature extraction quantitative and percentile statistics are brought out while processes have been followed for the map features after combining them to the similar features of open sources. To bring the map scale for its suitability to the open sources resolution the existing map of 1:25,000 scales have been compiled and then generalized to a smaller scale of 1:250,000. Both the statistics of Map and open source features are then compared to detect the changes occurred during the study span of recent five years (2010 to 2015). Finally, an insertion and deletion guide is prepared that led to the preparation of updated map of one of the features as test case. In the process, two sets of specification i.e. Specification for Map Generalization and Specification for Map Updating have also been prepared.

A3.1-0056-18 STUDY ON SPATIAL VARIABILITY OF LAND SURFACE VARIABLES AND HEAT FLUXES DURING THE HIWATER CAMPAIGN

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Surface heterogeneity, including the inhomogeneity of landscapes and surface variables, significantly affects the accuracy of evapotranspiration (ET) (or LE, i.e., latent heat flux) estimated from remote sensing satellite data. The method of using frequency distributions or generalized probability density functions (PDFs) which is called the “statistical-dynamical” approach is a good way to correct the ET or LE estimation error from the perspective of remote sensing model. However, implementing a PDF for each land-surface characteristic would greatly increase the complexity of this type of parameterization, as well as the computational burden of the model. To address this issue, the objective of this study is to analyze the temporal variation of turbulence heat flux heterogeneity and heterogeneity of surface variables, and attempts to find the most closely related surface variables associated with heterogeneity of turbulent heat flux. A mathematical expression method (i.e., entropy) was used to express the heterogeneity of the surface variables caused by the fluctuation of the surface variable values. Based on the airborne data and surface observation network data from Heihe Watershed Allied Telemetry Experimental Research (HiWATER), this study introduced a grey relational analysis and combined it with entropy to analyze the heterogeneity temporal variation relationships of each surface parameters. The results reveled entropy can be used to compare the spatial heterogeneity of different surface variables, and the heterogeneity of the most variable exhibits approximately parabola with the change of solar zenith angle. For albedo, not only its value presents a “bowl shape” diurnal changes, its heterogeneity also showed a similar “bowl shape” changes. By constructing a grey relational system under different weather conditions, we find that the heterogeneity of surface radiation temperature and soil moisture are the factors that must be taken into account in the construction of LE or ET calculation model for heterogeneous underlying surfaces.

A3.1-0057-18 AN ASSESSMENT ON THE QUALITY OF SURFACE SENSIBLE HEAT FLUX DERIVED FROM RE-ANALYSIS DATA BASED ON STATION OBSERVATIONS IN NORTHWEST CHINA

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The present study compares the seasonal and interdecadal variations of surface sensible heat flux over Northwest China between station observations and the ERA-40 and NCEP-NCAR reanalysis datasets for the period 1960-2000. While the seasonal variation of sensible heat flux is consistent between station observations and the two reanalysis, both the surface-air temperature difference and surface wind speed show remarkable systematic differences. The sensible heat flux displays obvious interdecadal variability that is season-dependent. The ERA-40 sensible heat flux in spring, fall, and winter shows interdecadal variations that are similar to observations. The NCEP-NCAR reanalysis sensible heat flux variations are inconsistent with and sometimes even opposite to observation data. While the NCEP-NCAR reanalysis surface wind speed shows interdecadal changes consistent with station observations, the surface-air temperature difference variations are very different from station observations. For the ERA-40, almost no consistency can be identified in the surface-air temperature difference and surface wind speed variations except for the temperature difference in fall and winter. These inconsistent pose a major obstacle to the application of the reanalysis surface sensible heat fluxes for climate studies.

A3.1-0058-18 MONITORING UNDERWATER ARCHAEOLOGICAL SITES WITH LIDAR

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The paper focuses on use of Light Detection and Ranging (LiDAR) technology in understanding the underwater archaeology in Brazil, primarily in City of Rio de Janeiro, the world's largest market for geophysics.

A3.1-0059-18 LAND-USE PLANNING WITH MINIMIZING UNEMPLOYMENT USING GIS AND LINEAR PROGRAMMING

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Geographic Information System (GIS) is now being used as a primary tool for a vast variety of land-use and earth science application. In this paper, Linear programming (LP) is used as a means for geo-spatial simulating in GIS. In spite of that LP is not exactly a spatial method, but it can be integrated to GIS for solving spatial problems. An example of the integration of LP in land cover/land use planning is illustrated, with reducing unemployment as the main objective. The Northern portion of Hyderabad, Sindh, Pakistan was selected as a study area for land-use planning. The objective of minimizing unemployment is restraint by the three sets of limitations, (a) Ecological, which insist upon to remain unchanged at least 75% of the forest during the land-use planning or modification, (b) Technical, which limits the placement of modified or new land-uses to the highly suited areas, i.e. Newly developed urban areas will be restricted to those areas where three requirements were satisfied: in-between 200-500 meters of urban land, 0.5km away but less than 2km from the road, and in-between 2km to 7km from the river, and (c) Financial constraint includes the amount of 2500 million rupees that is presumed to be available for the transformations of land-use. The required information was obtained by developing thematic layers, that include Land use/Land cover, elevation, and slope layers, derived from satellite imagery (Landsat 8) and SRTM DEM respectively, and Economic data that includes the requirement of labor and capital for transformation. These limitations were formulated as constraints according to LP technique to get the optimal solution. LP-model was solved using software named 'LINDO'. It gave the results in numeric values. The results were mapped out using auxiliary variables. This paper guides that LP is an appreciated mean for modeling land-use/land-cover using GIS framework. LP is also capable of solving different planning situations, by changing coefficients of the objective function and constraints both. The combination of GIS to LP has been reflected here as a technique for data assembling and mapping the outcomes. More attempts should be done to further enhance the spatial domain of the linear programming problems by taking out some more work on this ground.

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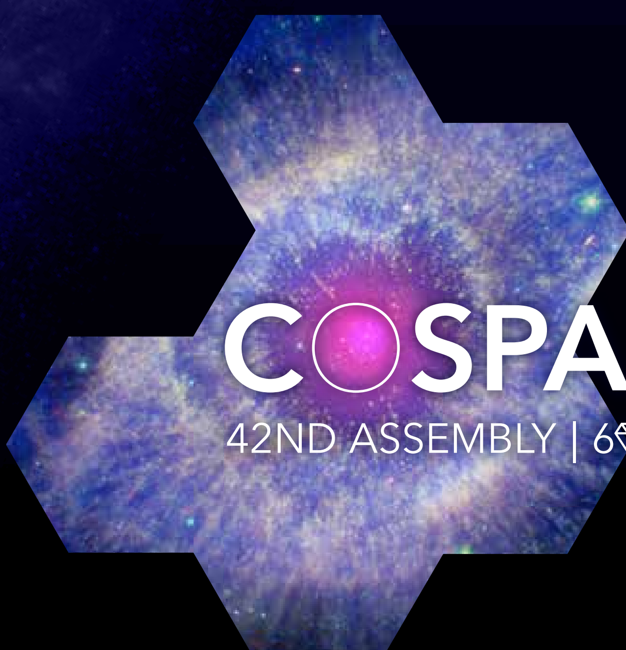
Space Studies of the Earth-Moon System, Planets, and Small Bodies of the Solar System (B)



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B0.1-0001-18 THE EXOPLANET CLOUD ATLAS

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Clouds have been readily inferred from observations of exoplanet atmospheres, and a trend is beginning to emerge where hotter planets appear “clearer” than cooler ones, though there is significant scatter in the data. Equilibrium condensation calculations suggest a myriad of species - salts, sulfides, silicates, and metals - could condense on these worlds, but how they form and evolve as clouds is uncertain. The behavior of clouds - their formation, evolution, and equilibrium size distribution - is controlled by cloud microphysics, which includes processes such as nucleation, condensation, and evaporation. In this work, we explore the cloudy exoplanet phase space by using a cloud microphysics model to simulate a suite of cloud species ranging from cooler condensates such as KCl/ZnS, to hotter condensates like iron and corundum. We investigate how the cloudiness and cloud particle sizes of exoplanets vary due to temperature, metallicity, and gravity, and how these changes may be reflected in current and future observations. We are able to reproduce the observed trend in cloudiness with temperature, as well as an apparent minimum in cloudiness at 1300 K, which could be due to the sinking of silicate and iron clouds into the deep atmosphere. In addition, we make predictions on the magnitude of cloud spectral features at JWST MIRI wavelengths to investigate how we can use these features to characterize exoplanet clouds.

B0.1-0002-18 MAPPING EXOPLANET CLOUDS WITH HIGH-DISPERSION SPECTRO-POLARIMET

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Polarization is an under-exploited technique in the investigation of exoplanet atmospheres. A polarization detection, particularly if extended over a broad spectral range, can potentially set valuable constraints on the gas and clouds in an exoplanet atmosphere that is not possible through brightness-only observations. I will present simulations that show that the polarization of a spatially unresolved exoplanet may be detected by cross-correlating high-dispersion linear polarization and brightness spectra of the planet-star system. In this approach, the Doppler shift of the planet-reflected starlight facilitates the separation of the signal from other polarization sources, including the star, the interstellar medium and the terrestrial atmosphere. I will elaborate on the case of close-in giant exoplanets with non-uniform cloud coverage, in which cases the hemispheres east and west of the sub-stellar point will produce different polarizations. The simulations show that high-dispersion polarimetry can separate some of the proposed cloud scenarios and, in particular, set additional constraints on the cloud particles optical properties.

B0.1-0003-18 APPLICATION OF TERRESTRIAL GLINTS TO EXOPLANET STUDIES

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Glints, small flashes of reflected light, found in images taken by spacecraft observing the Earth, are generally believed to be due to specularly reflected solar radiation. These glints have been found over both ocean and land. We show that glints over land are due to specular reflection off horizontally oriented ice platelets floating in the air, while glints over ocean have contributions from reflection off both platelets floating above the ocean and ocean waves. Although glints only cover a small proportion of the Earth's surface, they are highly polarized. We use a radiative transfer model to simulate different kinds of glints and to explore their properties. Exoplanets with specularly reflecting materials like icy cloud, surface ice and water could generate light variations that are very different from those with clear atmospheres. For example, rocky, Earth sized exoplanets in the TRAPPIST-1 system are now thought to contain up to 5% of their mass in water (Grimm et al, 2018), which could be observable as clouds, surface oceans or ice. This technique of comparing observations of terrestrial glints with model simulations may provide new information relevant to the search for habitable exoplanets.

B0.1-0004-18 GASEOUS ENVELOPES OF HOT JUPITER EXOPLANETS

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Hot Jupiter exoplanets have a number of outstanding features, caused mostly by their proximity to the host star, e.g.: gas outflowing from the planet's atmosphere to the star, as it happens in close binary stars. In addition, the short distance between the planet and the star results in a large planet's orbital velocity. If this velocity exceeds the local sound speed a bow-shock forms ahead of the planet. Gas dynamic and MHD modeling shows that, if the dynamical pressure of the stellar-wind is high enough to stop the outflow from the vicinity of the inner Lagrangian point, a quasi-closed non-spherical envelope, bounded by the bow-shock of a complex shape, forms in the system. In this report we discuss possible types of gaseous envelopes of hot Jupiters and compare their properties with available observations. We also consider the variations of flow patterns in the gaseous envelopes, occurring under the action of coronal mass ejections.

B0.1-0005-18 MODELING INSTRUMENTAL SYSTEMATICS IN TRANSMISSION SPECTRA FROM FORS2 USING GAUSSIAN PROCESSES

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Several transiting exoplanets, from Hot Jupiters to Super-Earths, are having their atmospheres investigated using the most powerful technique to date: transmission spectroscopy. This technique measures the wavelength-dependent absorption of starlight by the planet's atmosphere during a transit revealing the atmospheric composition. However, instrumental systematics can significantly affect the transmission spectra leading to some spurious detections. This is an important issue that has been overlooked in the scientific community due to the presence of instrumental systematics produced by many instruments (Hubble/NICMOS, FORS2, etc). The recently introduced technique of using Gaussian Processes (GP), also widely used in machine learning and Bayesian regressions, has been successfully used to model systematic or correlated noise and to infer accurate planet-to-star ratios and realistic precisions. In this work we develop a technique using such GPs to better analyse systematic trends in exoplanet transmission spectra taken in either MOS/MXU modes caused by the GRIS600zgrismof F ORS2. Our method can provide an effective tool to interpret transmissions signals in fut

B0.1-0006-18 ATMOSPHERIC RADIATION INTERACTION SIMULATOR (ATRIS): VALIDATION AND FIRST RESULTS

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During the next five years, considerable advancements in observational capabilities within the field of exoplanetary science are expected. In particular, upcoming missions, like the JWST and the E-ELT, will make it possible to further characterize the habitability of exoplanets orbiting M-dwarfs and K-stars, by determining the atmospheric composition using the transit spectroscopy method. In such systems, the expected resolution could be enough to detect substances produced by biological processes (biosignatures). Still, careful interdisciplinary analysis is necessary (physics, chemistry and climate), in order to account for possible false-positives and false-negatives. Furthermore, the high cost and limited life time of such missions make it obligatory to perform parametric studies to better understand the expected range of spectral signatures and thus enable a more efficient use.

Here we present the Atmospheric Radiation Interaction Simulator (AtRIS), a new Geant4- based code tailored specifically to enable parametric studies of radiation propagation through exoplanetary atmospheres. The main purpose of AtRIS is to calculate the electron-ion pair production rates, which are necessary as input for atmospheric chemistry models. However, AtRIS can also provide detailed information about the secondary particles that can be used to, for example, investigate the radiation environment at surface and thus directly characterize the habitability. We present validation studies against Earth measurements and first results.

B0.1-0007-18 INTERACTION OF COSMIC RAYS WITH ASTROSPHERES AND HABITABILITY PROBLEM

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The Kepler discoveries of terrestrial extrasolar planets candidates started the discussions of life conditions and possible conditions for habitable zone. Unfortunately, star winds and cosmic rays were almost omitted in consideration despite the fact that they are one of the main factors defining the space weather near Earth. It is important to know and be able to estimate fluxes of galactic and stellar cosmic rays (GCR and SCR) at different stages of evolution of stars and planetary systems. Previously the estimations were made about star wind properties and star and galactic cosmic rays near Proxima Centauri and Proxima b and Trappist system. Already the simplest models, which were derived for the Sun in 1950th–1960th, give the reasonable results for the star wind parameters and conditions on the orbit of Proxima b. We generalize these models for different astrospheres including hot O-B and A stars and try to estimate the possible star wind fluxes, astrosphere parameters and cosmic rays' fluxes and fluences taking into account values of the magnetic fields, coronal temperatures etc. Obtained results will be compared with Earth's and Archean Earth's conditions.

B0.1-0008-18 HABITABLE WORLDS IN MULTIPLE STAR SYSTEMS

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A large fraction of stars in our galactic neighborhood have close stellar companions. It is, therefore, not surprising that some of the best candidates for habitable worlds discovered so far populate a multiple star system (e.g., GJ 667). Given the presence of multiple sources of radiation as well as the gravitational pull of additional stars, one may wonder whether terrestrial planets can retain Earth-like conditions in such systems. In this contribution, we show that planets can indeed remain habitable in multi-star environments. The size of the habitable zone strongly depends on a planet's "climate inertia", however. The latter is a measure of how effectively an Earth-like planet's atmosphere and oceans can buffer changes in insolation. Recent results of the first 3D climate simulation of a water-rich circumbinary planet indicate that signatures of the orbit and consequent insolation forcing are mirrored in most climate indicators such as global surface temperature and precipitation.

B0.1-0009-18 C5H9N ISOMERS: SIGNALLING POTENTIAL BRANCHED CHAIN INTERSTELLAR MOLECULAR SPECIES

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The astronomical observation of isopropyl cyanide further stresses the link between the chemical composition of the interstellar medium (ISM) and molecular composition of the meteorites in which there is a dominance of branched chain amino acids as compared to the straight. However, observations of more branched chain molecules in ISM will firmly establish this link. In the light of this, we have considered C5H9N isomeric group in which the next higher member of the alkyl cyanide and other branched chain isomers belong. High-level quantum chemical calculations have been employed in estimating accurate energies of these isomers. From the results, the only isomer of the group that has been astronomically searched, n-butyl cyanide is not the most stable isomer and therefore, which might explain why its search could only yield upper limits of its column density without a successful detection. Rather, the two most stable isomers of the group are the branched chain isomers; tert-butylnitrile and isobutyl cyanide. Based on the rotational constants of these isomers, it is found that the expected intensity of tert-butylnitrile is the maximum among this isomeric group. Thus, this is proposed as the most probable candidate for astronomical observation. A simple LTE (local thermodynamic equilibrium) modelling has also been carried out to check the possibility of detecting tert-butyl cyanide in the millimetre-wave region.

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B0.1-0010-18 A THEORETICAL PREDICTION OF INTERSTELLAR BIO-MOLECULE ABUNDACES

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Understanding the origin of life is a long-standing problem and we are curious to know how life emerged in the universe. Very recently, Altwegg et al. (2016) showed that in a Jupiter family comet, 67P/Churyumov-Gerasimenko, the ratio between methylamine and ethylamine (precursor of glycine) 1 to 15. Vuitton et al. (2006) determines the abundance of many nitrogen-bearing molecules (HCN, HC3N, CH3CN, NH3, C2H3CN, C2H5CN, and CH2NH) in the upper atmosphere of Titan. The present atmosphere of Titan resembles the primeval atmosphere of Earth and thus is thought to be very important for the abiotic synthesis. Synthesis of simple and complex biomolecules or their precursors in the molecular cloud can be transferred to protplanetary disk or comet or further into the future planet. Here, we investigate six isomeric groups containing at least one aldimine or amine to review the presence of them within the ISM. We calculate chemical abundances of amines and aldimines for both isothermal and warm-up condition, enthalpies of formation, optimized energies, and expected intensity ratio to find out the most viable candidates for the future astronomical detection. We found that in the isothermal phase, the methylamine-to-ethylamine ratio is 17.7 in the ice phase, which is very close to the observed value (Altwegg et al. 2016).

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B0.1-0011-18 TIDAL EFFECTS (AND EXTINCTIONS) BY PASSING PLANETS AND-OR MINI-MOON BLACK HOLES IN OUR SOLAR SYSTEM

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The Earth has been formed by a huge mini-planet collision forming our Earth surface and our relic Moon today. Such a central collision hit was statistically rare. A much probable skimming or nearby encounter by other moons or planets had to occur more often. Indeed several observations suggest that many planetary-mass objects may be present in the outer solar system between the Kuiper belt and the Oort cloud. Gravitational perturbations may occasionally bring them into the inner solar system. Their passage near Earth could have generated gigantic tidal waves, large volcanic eruptions, sea regressions, large meteoritic impacts and drastic changes in global climate. They could have caused the major biological mass extinctions in the past in the geological records. For instance a ten times a terrestrial radius nearby impact scattering by a peripherical encounter by a small moon-like object will force huge tidal waves (hundred meter height), able to lead to huge tsunami and Earth-quake. Moreover the historical cumulative planet hits in larger and wider planets as Juppiter, Saturn, Uranus will leave a trace, as observed, in their tilted spin axis. In addition a large fraction of counter rotating moons in our solar system probe and test such a visiting mini-planet captur origination. Finally the Earth day duration variability in the early past did show a rare discountinuity, very probably indebt to such a visiting planet crossing event. These far moons in rare trajectory toward our Sun by their cannibal capture, might fed in the past thousands of such events, explaining sudden historical (solar and terrestrial) temperature changes. Similar effects (and a few surprising additional ones) are occuring also when hypothetical moon-mass like mini Black Hole (BH), that are acceptable candidate for cosmic Dark Matter mass, are crossing nearby our plane and-or are crossing inside planets like Juppiter or the Sun.
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B0.1-0012-18 FROM SOLAR TO STELLAR FLARE CHARACTERISTICS - A NEW SIZE DISTRIBUTION FOR KAND M-DWARF STAR FLARES

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Main sequence Kand Mstars are likely targets when it comes to hunting habitable (Earthlike) planets. However, their strong stellar activity, alongside high UVand X-ray intensities, will also produce high-energy particle fluxes which may be harmful to possible life. By now proton fluxes cannot be measured on Kand Mdwarf stars. Due to the fact that observations have shown that solar flares and active M dwarf stars obey common relationships (see, Butler et al., 1988), the measured stellar X-ray (flare) intensities can be used as a proxy for the proton fluxes of the most intensive flares.

The connection between solar energetic proton events and X-ray flares has been the focus of many studies over the past twelve years. In the course of these investigations, several peak size distribution functions based on GOES measurements of both quantities have been developed (see, e.g., Belov et al., 2005; Belov et al., 2007; Cliver et al., 2012). Here we compare the existing peak size distribution functions covering C to > X10 class flares to GOES measurements and extend the investigation down to "Q" (Quiet, 1010W/m2) X-ray flare intensities by utilizing SphinX data covering X-ray flare measurements during the solar minimum conditions in 2009. Using all observational evidence at hand, we develop a new peak size distribution function. Furthermore, we investigate the impact of the newly developed peak size distribution function for Kand M-dwarf stars and show that previous studies underestimate the stellar proton flux by roughly one to four orders of magnitude.

B0.1-0013-18 ON THE CORRELATION BETWEEN PARTITION FUNCTION AND ASTRONOMICAL OBSERVATION OF INTERSTELLAR ISOMERS

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The unsuccessful astronomical searches for some important astrophysical and astrolobiological molecules like the amino acids and the few number of known cyclic interstellar and circumstellar molecules have been linked to the large partition function of these molecules. This letter reports an extensive investigation of the relationship between partition function and astronomical observation of interstellar isomers using high level quantum chemical calculations.120 molecules from 30 different isomeric groups with at least one known interstellar molecule from each group have been considered. Partition function and thermodynamic stabilities are determined for each set of isomeric species. From the results, there is no direct correlation between partition function and astronomical observation of the same isomeric species. Though interstellar formations processes are generally controlled by factors like kinetics, thermodynamics, formation and destruction pathways. However, the observation of the isomers seems to correlate well with thermodynamics. For instance, in all the groups considered, the astronomically detected isomers are the thermodynamically most stable molecules in their respective isomeric groups. The implications of these results in accounting for the limited number of known cyclic interstellar/ circumstellar molecules, unsuccessful searches for amino acid and the possible molecules for astronomical observations will be presented.

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B0.2-0001-18 A CONSOLIDATED VIEW OF SCIENCE WITH SMALLSATS/CUBESATS

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This paper takes a look at what science can be achieved by SmallSats and CubeSats. Here, we assume that CubeSats are in the range of 4 to 25 kg (3U to 12U), and SmallSats are in the range 25 to 100 kg. In recent times, there has been a strong impetus to determine not only the technological capabilities of CubeSats and SmallSats, but also their potential to be used as science platforms beyond proof-of-concepts demonstrations. More specifically, quantification of science return vs. cost and risk is being assessed at JPL via ongoing decadal-class science concepts and new ideas for the next Planetary Science Decadal Survey. Due to the low cost of SmallSats and CubeSats, new modalities of scientific observations are possible, specifically exploiting the concepts of constellation or formation, and of sensor disaggregation [2]. With constellations and formations of CubeSats and SmallSats, a few significant general characteristics emerge. For example, instrument resolution (strength, direction) is dictated by spatial sampling in the measurement, leading to novel constellation types. High sensitivity in the frequency band of interest is dictated by temporal sampling, leading to novel requirements in instrument bandwidth. Exploiting such reachness in spatial and/or temporal sampling allows for observations of physical processes thus far precluded, such as highly dynamic changes needing high resolution. From the engineering standpoint, the advantage of large scale distribution of small spacecraft is that a large number of nodes leads to considerations of robustness, and potential graceful degradation. The potential for extended field mapping is enabled by different types of measurement colocation vs. non-colocation. High resolution on the ground is proportional to wavelength and aperture size, while orbit design considerations pose limits on frequent revisit and coverage, thus leading to new remote sensing approaches, keeping in mind that the need for a flexible scan area or for continuous dwell results in more or less demanding pointing considerations. The tracing of science to measurement types and mission requirements for three Planetary Science themes: Building New Worlds, Planetary Habitats, Solar System Workings, is discussed in the paper. Similar flow-down is being carried out in other science domains, such as Heliophysics, Astrophysics, and Earth Science, thus providing a systematic approach at tracing science across all disciplines of

interest. Acknowledgments: This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

B0.2-0002-18 NASA'S SPACE LAUNCH SYSTEM: SECONDARY PAYLOAD ACCOMMODATIONS IN BLOCK 1 AND BEYOND

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Launching from pad 39B at Kennedy Space Center no earlier than December 2019, NASA's Space Launch System (SLS) will send the Orion crew vehicle to a distant retrograde lunar orbit in order to test and validate the new systems developed for SLS, Orion and Kennedy Space Center's Exploration Ground Systems (EGS). In addition to these primary mission objectives, the first integrated fight of NASA's new deep space exploration system, Exploration Mission-1 (EM-1), offers accommodations for 13 6U CubeSats, which will be deployed in deep space after Orion separates from the SLS Interim Cryogenic Propulsion Stage (ICPS). In 2017, the SLS Program, managed by NASA's Marshall Space Flight Center (MSFC) in Huntsville, Alabama, completed the ICPS and delivered it to the EGS Program, which has responsibility for stacking and launch operations. The 13 EM-1 secondary payloads will reside in the Orion Stage Adapter (OSA), which connects the ICPS to Orion's spacecraft adapter. The OSA is essentially complete with preparations being made for transporting the hardware to Kennedy Space Center with accommodations for secondary payload dispensers and with the secondary payload avionics unit installed.

The rest of the Block 1 SLS vehicle has completed manufacturing and is being outfitted for flight, including the 212-foot core stage. Boeing is building the core stage at Michoud Assembly Facility near New Orleans, Louisiana. Propulsion for the heavy-lift vehicle is supplied by twin five-segment solid rocket boosters, being built by Orbital ATK, and four RS-25 engines supplied by Aerojet Rocketdyne. The four RS-25 main engines, and their new computerized controllers are complete for EM-1. Those engines will be integrated into the completed core stage and fired simultaneously at NASA's Stennis Space Center during a "green run" test, scheduled for 2019. The Block 1 vehicle will have the capability to launch at least 70 metric tons (t) of payload. A more powerful configuration, Block 1B, will be available in the 2020s, and will provide incremental performance improvements that will boost the vehicle's capabilities to at least 32 t to trans-lunar injection (TLI) in the crew configuration and at least 37 t to TLI in the cargo configuration. Block 1B will offer an 8.4 m fairing; other fairing sizes are being studied. Block 1B will offer more accommodations for smallsats on a payload adapter than Block 1 provides in the OSA. A variety of CubeSat sizes from 6U to 27U may be accommodated in Block 1B. The smallsat payloads selected for EM-1 include NASA research experiments and spacecraft developed by industry, international partners and academia. The payloads are: Near Earth Asteroid (NEA) Scout, Lunar Flashlight, BioSentinel, Lunar Icecube, LunIR, the CubeSat 2 Mission to Study Solar Particles (CuSP), LunaH-Map, ArgoMoon, the EQUilibriUm Lunar-Earth point 6U Spacecraft (EQUULEUS), and the Outstanding MOon exploration TEchnologies demonstrated by Nano Semi-Hard Impactor (OMOTENASHI). In addition, three CubeSat payloads that have completed the final ground tournament of NASA's Cube Quest Challenge and are now competing for further prizes are manifested on EM-1: Cislunar Explorers, from Cornell University in Ithaca, New York; the University of Colorado-Earth Escape Explorer (CUE3) and Team Miles, of Tampa, Florida.

This paper will provide an overview of the status of the SLS Block 1 launch vehicle and an overview of the 13 EM-1 6U payloads. Work on the Block 1B vehicle is already underway, which will offer more space for smallsats; those planned accommodations will also be discussed.

B0.2-0003-18 SMALL SATELLITES FOR SPACE SCIENCE (4S) COSPAR ROADMAP

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IDA Science and Technology Policy Institute, Washington, District of Columbia, United States COSPAR Roadmap Study Team: Small Satellites for Space Science

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In 2016, COSPAR commissioned an international scientific roadmap on Small Satellites for Space Science (4S), focusing particularly on CubeSats and CubeSat-technology enabled small satellites. The report is motivated by recent progress and results summarized in a published paper (Zurbuchen, von Steiger et al., Performing High-Quality Science on CubeSats, Space Research Today, Vol. 196, pp. 10-30, August 2016) and a study by the US National Academies (Zurbuchen, Lal, et al., Achieving Science with CubeSats: Thinking Inside the Box, The National Academies Press, Washington, DC, 2016).

The roadmap has been developed by a study team that covers a broad range of scientific and technological disciplines, from Earth to planetary science, and from solar system science to astronomy. The team is composed of scientists and engineers working in universities, public research institutions and industry. The report is structured into three main parts:

I. Our Neighborhood: current status of technology and scientific potential of small satellites and CubeSats II. Visions for the Future: potential ideas for what small satellites could be used for in the future III. Challenges to Further Development and Progress, and Ways to Overcome Them: roles of agencies, industry, policies, international collaboration and exchange

In this presentation, members of the study team will give an overview of the roadmap and summarize the findings of the study team, concentrating on the parts relating to planetary science in particular. The final report is intended to be of value to space agencies internationally and their supporting governments, as well as non-profits and other private sector organizations that would be interested in promoting global smallsat-based missions.

B0.2-0004-18 CIS-LUNAR OBJECT DETECTOR WITHIN THERMAL INSULATION (CLOTH) FOR THE 6U CUBESAT EQUULEUS

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The Cis-Lunar Object Detector within Thermal Insulation (CLOTH) is a hybrid instrument between multi-layer thermal insulation and piezoelectric film sensor onboard the 6U cubesat EQUULEUS, which is scheduled for launch in the late 2019. The engineering purpose of this instrument is to game-change dust measurement in space by making it possible even with cubesat class spacecraft, which are usually impossble to secure large detection area of a dedicated dust sensor. The scientific purpose is first to measure dust flux in the Earth-Moon lagrange 2 (EML2) region by distinguishing between background sporadic meteoroids and potential EML2 dust population by impact signature characteristics due to respective impact velocities. For data interpretation, impact calibration experiments are conducted with ground facilities for the two distinct velocity regimes.

B0.2-0005-18 THE LUNAR POLAR HYDROGEN MAPPER MISSION

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Results from previous orbiter missions to the Moon have identified the presence of water/frost within permanently shadowed regions (PSRs) at the poles, however, there remains uncertainty about the bulk (non-surficial/frost) abundance of these enrichments and whether these smallscale enrichments are pervasive throughout lunar south pole PSRs. Placing constraints on the bulk hydrogen abundance within PSRs will help point to specific processes and delivery sources for polar volatiles, and can help resolve mechanisms operating over long time scales (e.g. solar wind) from other, much shorter time scale delivery mechanisms (e.g. passing asteroids or comets). Small-scale bulk hydrogen abundance maps can also be correlated with other polar datasets (i.e. temperature) to help untangle the relationship between volatile distributions and other surface properties. Hydrogen enrichments between 500 to 600 ppm at a spatial scale of 5-15 km could provide robust evidence for discerning hypotheses regarding transport processes of polar hydrogen enrichments.

The Lunar Polar Hydrogen Mapper (LunaH-Map) is a 6U CubeSat selected for flight on the Space Launch System (SLS) Exploration Mission 1 (EM-1) under NASA's Small, Innovative Missions for Planetary Exploration (SIMPLEx) program. The LunaH-Map spacecraft is equipped with gimbaled solar arrays, 3 reaction wheels, a star tracker, an X-Band radio, a command and data handling system, power control system, neutron spectrometer array, and a low-thrust propulsion system. The current mission science phase achieves 282 orbits over two lunar days and preliminary analysis of the miniature neutron spectrometer (Mini-NS) sensitivities shows the mission will be capable of identifying small-scale (<15 km^2) regions of hydrogen enrichments on the order of 600ppm +/- 120ppm. Communication with Earth will be achieved via the Iris radio, to be used on the MarCO spacecraft at Mars, and will be coordinated with the Deep Space Network. Spacecraft operations, telemetry and science data analysis will be conducted at the Mission Operations Center at Arizona State University (ASU). After deployment from SLS EM-1, LunaH-Map will maneuver and perform a lunar flyby targeting the EarthMoon L2 point and eventual capture by the Moon within two months. Upon lunar capture the spacecraft will spiral down to an elliptical low-altitude science orbit with perilune at the South Pole. During the science phase, the Mini-NS will measure neutron counts about the perilune (lowest altitude passes) of each orbit to enable the mapping of hydrogen enrichments within permanently shadowed regions (PSRs) at spatial scales less than 15 km. The mean perilune altitude is designed to achieve between 10 to 15 km above terrain poleward of 85°S throughout the science phase, but will vary depending upon the final SLS EM-1 launch date and trajectory. The SLS EM-1 launch trajectory will directly impact the parameters of the science orbit of the LunaH-Map spacecraft. The resulting

perilune altitudes and science phase ground tracks will determine the maximum achievable spatial resolution and sensitivity of hydrogen enrichments within south pole PSRs.

B0.2-0006-18 ACHIEVEMENTS AND FUTURE PLAN OF INTERPLANETARY CUBESATS AND MICRO-SATS IN JAPAN

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This paper introduces Japanese achievements and future plans of CubeSats and Micro-Sats for deep space exploration.

As the first step toward deep space missions by such tiny spacecraft, University of Tokyo and Japan Aerospace Exploration Agency (JAXA) developed the world's first deep space microspacecraft PROCYON. Its mission objective is to demonstrate a micro-spacecraft bus technology for deep space exploration and proximity flyby to asteroids performing optical measurements. PROCYON was launched into the Earth departure trajectory on December 3, 2014 together with Japanese asteroid sample return mission Hayabusa-2. PROCYON successfully completed the bus system demonstration mission in its interplanetary flight.

Currently, Japan is not only pursuing the improvement and utilization of the demonstrated micro-sat deep space bus system with a weight of tens of kg or more for more practical scientific deep space missions, but also trying to develop smaller spacecraft with a weight of less than tens of kg, namely CubeSats, for deep space exploration. We are developing two self-contained 6U CubeSats for the rideshare opportunity on the USA's SLS EM-1 mission, one of which (EQUULEUS) will fly to a libration orbit around Earth-Moon L2 point and perform scientific observations of the Earth and the Moon, and the other (OMOTENASHI) is planning to perform "semi-hard" landing on the moon by using a solid rocket motor onboard.

We are also seeking the possibility of CubeSats which is carried by a larger spacecraft to the destination and supports the mission by taking advantage of its low-cost and risk-tolerable feature. As an example of such style of CubeSat missions, we are studying a CubeSat for close observations of an asteroid, which will be carried to the target asteroid by a larger mother spacecraft. This CubeSat is released from the mother spacecraft to make a close flyby for scientific observations, which is difficult to be performed by the mother spacecraft if we consider the risk of the collision to the target asteroid or dust particles ejected from the asteroid. In order to utilize the large deep space maneuverability of the mother spacecraft, the CubeSat is retrieved by the mother spacecraft after the close flyby observation and it is carried to the next target asteroid to realize multiple asteroids flyby exploration.

B0.2-0007-18 THE LUNAR ICECUBE EM-1 MISSION: PROSPECTING FOR LUNAR WATER ICE

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Lunar IceCube, a 6U CubeSat designed to prospect for water in solid (ice), liquid, and vapor forms and other lunar volatiles (i.e. OH, H2S, CO2 and CH4) from a low-perigee, highly inclined lunar orbit, was selected by NASA's Advanced Exploration Systems (AES) for a flight opportunity on Exploration Mission -1 (EM-1). The mission is a partnership between Morehead State University, NASA Goddard Spaceflight Center (GSFC), the Jet Propulsion Laboratory (JPL), and the Busek Space Propulsion Company. Lunar IceCube will be deployed by the Space Launch System (SLS) and uses an innovative RF Ion engine to achieve lunar capture and a science orbit (inertially locked, highly elliptical, 100 km periapsis) to investigate the distribution of water (water ice, water vapor, water components) and other volatiles. These volatile distributions will be investigated contextually, as a function of time of day, latitude, and regolith composition in the context of mineralogy. IceCube will include the Broadband InfraRed Compact High Resolution Exploration Spectrometer (BIRCHES), developed for CubeSats by GSFCa compact version of the successful volatile-seeking OSIRIS-REx Visible and nearIR Spectrometer (OVIRS) and New Horizons Ralph instruments. The mission will address NASA Strategic Knowledge Gaps related to lunar volatile distribution, and will complement the scientific work of Lunar Flashlight and LunaH-Map by focusing on the abundance, location and transportation physics of water ice on the lunar surface at a variety of latitudes, thus not restricted to permanently shadowed regions (PSRs). IceCube incorporates radiation-hardened subsystems, the JPL Iris transponder, and a high power (120W) solar array. The RF Ion engine (Busek BIT-3 Iodine engine) generates significant delta-v (> 1.2 kms-1 for the 14 kg spacecraft) and is one of the primary enabling technologies that will make this and other interplanetary CubeSat science missions feasible. Experts at GSFC are providing trajectory design and modeling, navigation and tracking support, and orbital products.

The primary science objectives of the Lunar IceCube mission are to enable spectral determination of the composition and distribution of volatiles in the lunar regolith as a function of time of day, latitude, regolith age and composition and to provide a geological context for those measurements through spectral determination of mineral components. Although previous missions (e.g. Clementine, Chandrayaan-1, and LRO/LCROSS) discovered various signatures of OH/H2O, they were not optimized for volatile characterization. BIRCHES is designed with the high spectral resolution (5 nm) and wavelength range (1 to 4 m) needed to fully characterize water and other volatiles, and to distinguish forms of water, including ice. Because the emphasis was on maximizing coverage during the nominal mission, even LRO was not designed to provide repeated systematic (by time of day) measurements of representative features at higher and lower latitudes. IceCube is designed to provide such systematic measurements. The mission also has the potential to lend insight into understanding the role of solar wind proton and micrometeorite bombardment in formation, trapping, releasing of water and exosphere formation. The 13 secondary payload CubeSats that will be included on EM-1, including Lunar IceCube, will usher in a new era of solar system exploration with CubeSats and other small satellite platforms.

B0.2-0008-18 SUPERROTATION STUDY IN THE ATMOSPHERE OF VENUS BY MEANS OF BALLOON PROBES.

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Advanced explanation of the physical mechanism of superrotation is proposed. The reason is solar light pressure. The atmosphere of Venus was remotely studied for approximately 100 years and with spacecrafts for nearly half a century. As a result, there was a dramatic modernization in terms of views. The main finding is the detection of a unique phenomenon: the superrotation of the atmosphere. For the first time, this was detected from orbit in 1974 via the spacecraft Mariner, and this is the main element of atmospheric dynamics. The superrotation study was conducted in the UV range at altitudes of 65-69 km and in the IR range of 51-59 km, and also, during the course of the experiment, using a VEGA balloon at 53-55 km. At intermediate altitudes, systematic measurements were not carried out. It is proposed to introduce lightweight balloon probes into the atmosphere at different altitudes, but with increased durability. Envelopes are made of metalized PET foil. The payload mass on each probe is 1 kg. The diameter of the envelope depends on the altitude and at an altitude range 50-70 km is within the range of 1-3 meters. The expedition should last approximately 30 Earth days.

B0.2-0009-18 MAPPING OF ATMOSPHERE AND SURFACE OF VENUS THROUGH A ROBOTIC GLIDER VEHICLE

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One of the driving forces of mankind is the "Nahi Jnanena Sadrusham" or "Nothing is Equal to Knowledge", which has been the dynamo of our civilization. Since the dawn of the human civilization, man has looked up to the heavens with wonder about, what is out there! As one of the first planets to be visited by spacecraft, Venus witnessed many failed attempts as missions. This paper attempts to design a robotic mission to the surface of the Venus with the explicit goal of mapping the atmospheric composition and studying the surface. Proper mission architecture and vehicle design will be developed that maximizes the science data return within the predefined cost and schedule. Trade studies on various mission designs at the architecture and system levels will be given to demonstrate the fitness of the chosen mission and system design. It would include vehicle architecture, launch vehicles, science instruments, orbital mechanics, spacecraft subsystem level designs, and other mission level system trades assessed on the bases of benefit, risk, and cost. A detailed description of the scientific approach, including traceability of specific measurements to science objectives, planned observations, the design of the science instruments, and collection periods will be inculcated. Surface experiment operations and communication data plans will be presented briefly. Although many successful missions have previously have descended into the atmosphere of Venus, through this paper, we are presenting a much economical way to reach to Venus, descend into its atmosphere, map its atmospheric composition and land on its surface, and send the data back to Earth. Comprehensive trade study will be given, in order to strengthen the argument behind selection of the sensors. Venus is a necessary waypoint for missions to Mercury and even though the possibility of such a mission is probably nonexistent for this decade, such challenging missions would test the mankind's drive for space exploration. In addition, this paper hopes to establish some general guidelines for such exploring missions.

B0.2-0010-18 FLIGHT MODEL DEVELOPMENT STATUS OF LUNAR IMPACT FLASH OBSERVING CAMERA DELPHINUS ON EXPLORATION CUBESAT EQUULEUS

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EQUULEUS (EQUilibriUm Lunar-Earth point 6U Spacecraft) will be the world's smallest spacecraft to explore the Earth-Moon Lagrange2 point (EML2). The spacecraft will be jointly developed by the University of Tokyo and JAXA which will be launched by NASA's SLS (Space Launch System) EM-1 (Exploration Mission-1) in late-2019. The spacecraft will fly to a libration orbit around the EML2 point and demonstrate trajectory control techniques within the Sun-Earth-Moon region. DELPHINUS (DEtection camera for Lunar impact PHenomena IN 6U Spacecraft) is one of the scientific instruments onboard EQUULEUS to observe the Lunar impact flashes and near-Earth asteroids. When a meteoroid impacts the moon at several 10s of km/s, a brilliant flash at the point of impact can be observed as a flash in visible and near-infrared light. The influx rate of interplanetary dusts onto the Earth-Moon surface are essential for understanding solar system evolution and are useful information for the future human space activities in the CisLunar space that is the volume within the Moon's orbit. Thus, it is very important to investigate size distributions, influx rate and daily variation of meteoroids. Lunar impact monitoring has a great advantage to detect large meteoroids in the mass range between 10s of grams and few kilograms corresponding to centimeters and tens of centimeters, which is as a bridge between visual meteors and small asteroids. This paper will describe the Flight Model of DELPHINUS onboard EQUULEUS.

B0.2-0011-18 CUBESAT X-RAY TELESCOPE (CUBEX) FOR LUNAR ELEMENTAL ABUNDANCE MAPPING AND MILLISECOND X-RAY PULSAR NAVIGATION

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The elemental compositions of lunar mantle and lower crust carry critical clues for the earliest stages of Earth-Moon's formation and evolution. CubeX is a SmallSat mission with a compact, highly radiation-tolerant, focusing X-ray telescope that identifies and spatially maps lunar crust and mantle materials excavated by impact craters, and also serves as a pathfinder for autonomous precision deepspace navigation using X-ray pulsars.

X-ray observations of planetary bodies provide a powerful diagnostic tool for remotely determining elemental abundances including major rock forming elements such as Mg, Al, Si, and Fe since X-ray fluorescence (XRF), induced either by solar X-ray flux or energetic ions, carries decisive signatures of elemental composition. Through high-resolution XRF imaging spectroscopy, CubeX uses selected lunar sites to search for small patches of elusive lunar lower crust and upper mantle material excavated within and around impact craters. Informed with the surface topography from LRO and the gravity data from GRAIL, CubeX's measurements of regional compositional variations of lunar sites such as Schrödinger and South Pole Aitken Basins assist and provide the context for future sample return missions recommended by the Decadal Survey.

CubeX also uses high resolution X-ray imaging and time series measurements to conduct Xray pulsar timing based navigation (XNAV) and to evaluate its performance for deep space navigation, a critical component for small planetary missions. XNAV may enable low-cost autonomous deepspace navigation and has the potential to greatly assist, or even outperform, NASA's Deep Space Network (DSN) or ESA's European Space Tracking (ESTRACK). The Moon's relative proximity enables a straightforward evaluation of the XNAV performance through DSN.

CubeX carries two X-ray instruments: an X-ray Imaging Spectrometer (XIS) and a Solar X-ray Monitor (SXM). The XIS conducts both XRF observations and XNAV operations, while SXM monitors solar X-ray activity during lunar XRF observations. The XIS employs Miniature Wolter-I X-ray optics (MiXO) with high angular resolution (<1 arcmin), whose lightweight small form factor is suitable for low-cost SmallSat missions. The XIS focal plane combines high spectral resolution (<150 eV at 1 keV) CMOS X-ray sensors and a high timing resolution (< 1 usec) SDD X-ray sensor. This novel combination of instruments enables both XRF observations and XNAV operations without moving parts. CubeX rideshares to the Moon as a secondary S/C during the next solar maximum (2023-2027). After insertion into an initial elliptical lunar orbit, CubeX transfers to a science-optimized, low maintenance 6000 km quasi-frozen circular polar orbit for the 1-year science operation.

B0.2-0012-18 OCEAN WORLDS GRAVITY INVESTIGATION USING SMALLSAT MISSIONS

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The Ocean Worlds Europa and Ganymede in the Jupiter system and Titan and Enceladus in the Saturn system are primary targets for future exploration given their habitability poten- tial. Many questions regarding their evolution and habitability can be addressed by upcoming missions to the outer Solar System. NASA's Europa Clipper mission will focus on the habitability and evolution of Europa. ESA's JUpiter ICy moons Explorer (JUICE) mission aims to determine the interior and extent of the internal oceans of Jupiter's largest moons: Ganymede, Europa and Callisto, thus providing key constraints on their habitability. In addition, several missions have been proposed within both NASA and ESA to further explore Titan and Enceladus in the Saturn system. Radio science measurements are powerful tools to determine the static and dynamic gravity field of a body, posing constraints on its radial interior structure and assessing mass anomalies. In particular, gravity investigations of the ocean worlds could provide information on the internal dynamics and evolution, ocean properties, crustal thickness and thermal state. Traditionally, the observable quantities used by interplanetary gravity science experiments are obtained by means of spacecraft tracking at microwave frequencies from a ground antenna. The generation of these observable quantities requires the spacecraft antenna to point in the direction of the Earth and to use an onboard coherent radio transponder. Using both of these simultaneously impacts spacecraft resources including mass, power, and attitude control. Moreover, the geometry and the operations of the entire mission must be carefully designed to meet all science requirements, including the ones posed by the gravity experiment, through a complex and expensive trade-off process. In the recent years it was proposed to use smallsat companion missions, dedicated only to specific investigations, to complement the science observations of a traditional larger exploration spacecraft. This represents a promising option since smallsats provide relatively low-cost and versatile platforms for scientific observations. Here we present a mission concept consisting of one or two smallsats to be released in orbit around an ocean world (we use Europa, Titan, and Enceladus as reference scenarios) and capable of globally characterize its gravity field through a combination of Satellite-to-Satellite Tracking (SST) between two smallsats or between one smallsat and the mothership. This mission proposal is intended to complement a traditional larger mission to Europa, Titan or Enceladus. The observables are generated and decimated on-board the smallsats and transmitted back to Earth for data analysis and gravity field reconstruction, using the main mission as a relay spacecraft.

B0.2-0013-18 MARCO: PREPARING FOR INTERPLANETARY FLIGHT WITH SMALL SPACECRAFT

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In May of 2018, the MarCO spacecraft will launch alongside InSight, separate from the launch vehicle, and commence independent travel to Mars. The two spacecraft will provide entry, descent, and landing relay communications for InSight as it descends to Mars, demonstrating the capability for low-cost relay during critical missions periods.

As the first flown interplanetary CubeSats, significant trailblazing was required to successfully achieve flight readiness. Much of the technology within MarCO is planned for use with the EM-1 CubeSat missions, including the Iris radio and utilization of the Deep Space Network. Several missions will also utilize other onboard hardware components. Each component went through a flight qualification process leading to integration and test, including thermal-vacuum, vibration, and deployment testing relevant to the expected environment. Additional limited analyses were completed regarding radiation and electromagnetic compatibility.

MarCO is also pioneering meeting planetary protection requirements within the framework of a CubeSat mission. Classified as a Planetary Protection Category III flyby mission, the project is required to address both impact constraints for launch vehicle elements and the potential for contaminating InSight. Meeting these requirements by adopting the contamination analysis and control architecture typically applied to Mars missions would limit the benefits of the low-cost, highly-adaptable CubeSat paradigm. Instead, a strategy comprising bioassays of specific hardware, conservative bioburden estimation, and worst-case vehicle breakup and burnup analyses was employed to ensure Planetary Protection compliance.

Flight operations have been planned to coordinate with the Deep Space Network and the InSight mission, achieving a safe, reliable flight path, which includes multiple trajectory correction maneuvers to establish the Mars flyby trajectory. Given energy and thermal constraints, the MarCO spacecraft have limited opportunities for communications and ranging, and these activities must be balanced with attitude control maneuvers. Operations have been carefully planned to address these concerns.

Overall, the MarCO spacecraft are launching on a novel technology demonstration mission, not required for InSight success, yet paving the way for near-term CubeSat deep space projects. This talk will discuss the strategies used and lessons learned to prepare MarCO for flight, as well as recent flight status.

B0.2-0014-18 AN INTERPLANETARY CUBESAT MISSION TO PHOBOS

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Martian moon Phobos may hold vital clues to the origin of Mars. The moon exhibits several unique features such as surface striations, arguably due to its being within Mars' Roche limit. Phobos has been suggested as a low delta-v stop-over site and staging base for human missions to Mars. It is feasible to teleoperate Mars surface assets via a base on Phobos. To one day take advantage of Phobos as a strategic location for future human exploration to Mars, much more needs to be known about the moon's origin, composition and surface-properties. CubeSats offer the opportunity to perform low-cost focused science exploration, with rapid turn-around times between multiple missions. The high failure rate of past Phobos missions must be considered when developing future missions, and the cost/risk involved in large missions needs to be carefully weighed.

We propose development of a 6U, 14-kg or 12U, 24 kg interplanetary CubeSat called LOGIC (Low Orbit Geology Imaging CubeSat) that would perform thermal and visible imaging of Phobos at resolutions of 25 m/pixel and 5 m/pixel, respectively. The mission concept of operations is shown in Figure 1. LOGIC is inspired by JPL's INSPIRE and MarCO CubeSats. This CubeSat mission would be a pave the way for a subsequent, larger Phobos surface lander mission. This CubeSat mission to Phobos would provide an unprecedented view of the moon, including coverage of more than 50% of the surface. The spacecraft contains two science instruments, namely the e2V Cires Visible camera and FLIR Tau thermal camera. The spacecraft is powered using a pair of onboard deployable solar panels such as the E-HaWK from MMA Design. The solar panels have 1 DoF of gimballing. The back side of the solar panels contains an X-band reflect-array for communication and will utilize JPL's IRIS v2 X-band radio. The spacecraft will charge 2 Gomspace NanoPower BPX lithium ion batteries with a total energy capacity of 154 Wh.

The LOGIC CubeSat would launch as a secondary payload much like JPL's MarCO CubeSats on a Mars-bound spacecraft and is expected to be ejected once it is on an Earth-escape trajectory. The spacecraft will be propelled using a chemical propulsion unit such as green-monoprop to get into a Mars-insertion orbit. The spacecraft will enter into a highly elliptical orbit much like ISRO's Mangalayaan and perform aerobraking to enter into a co-orbit with Phobos. Alternately, LOGIC can perform elliptical flybys of Phobos to minimize the need for aerobraking. To adhere to planetary protection guidelines, the spacecraft disposal orbit has been designed to avoid probability of collision with Mars or Phobos for 50 years.

Interplanetary CubeSats offer a compelling path forward towards short, focused science missions that act as trailblazers for larger, longer missions. Even if one fails, a CubeSat mission may be assembled with a relatively short turn-around time. Phobos is an excellent target to better understand small-bodies, their origins and compositions, and could be crucial for making a future human mission to Mars a reality.

B0.2-0015-18 GLOBALLY DISTRIBUTED AND HIGH-RESOLUTION MARS ATMOSPHERIC PROFILES FROM SMALL SPACECRAFT CONSTELLATIONS

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Radio occultation experiments have been carried out on numerous planetary missions since 1965, when Mariner IV flew by Mars. The observations of radio links from spacecraft to ground stations have yielded valuable information on the structure of planetary ionospheres and neutral atmospheres. By utilizing links from a single orbiting spacecraft, global coverage of the atmospheric measurements can be achieved, but only after extended periods of time, often many months or more. However, following work by the Earth atmospheric community that advanced crosslinks between spacecraft in Earth orbit, the transmitter side being a Global Positioning System GPS spacecraft, crosslink occultations can be envisoned at Mars and other planets. Crosslink occulations between two or three spacecraft can produce much more rapid global coverage that enables examination of the variability of vertical profiles of temperaturepressure and ionospheric electron density profiles on daily, seasonal, and annual time scales. Such small-spacecraft planetary constellations are enabled by recent

advances in small and less costly spacecraft, such as CubeSats. Such smallsat occultation missions offer a means to dramatically improve knowledge of atmospheric structure and dynamics for several planets and the moon Titan.

We report on our studies for a small constellation of Mars satellites that perform atmospheric/ionospheric occultation studies. We developed a science traceability matrix that yielded technical design specifications linked to key science goals such as the atmospheric temperature accuracy and dense geographical/ temporal measurement distribution that would allow global determination of atmospheric variations from diurnal to seasonal scales over the entire planet. Radio link systems scenarios were examined that met the measurement accuracy requirements at maximum spacecraft ranges. We also explored various mission design concepts and an initial Cubesat design that included considerations of cost, size, power, mass, longevity, and radiation tolerance. The occultation data obtained by each smallsat would be relayed to a large orbiter which then sends the data on to the Earth, so the CubeSats themselves are not required to have Earth communication capability. Precision knowledge of the CubeSat orbits is also required to properly interpret the occultation data. This is achieved by Doppler measurements on radio links between the CubeSats before or after each occulation and by occasional radio contact between each CubeSat with the large orbiter whose position and velocity are well known from Earth-based tracking by the Deep Space Network.

B0.2-0016-18 MARS AEROSOL TRACKER (MAT): AN AREOSTATIONARY SMALLSAT TO MONITOR DUST STORMS AND WATER ICE CLOUDS

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We have elaborated a mission concept to put a SmallSat (up to about 60 kg of mass) in an areostationary orbit around Mars -17,031.5 km altitude above the equator. The planned areostationary orbit would be the first of its kind, offering the unequaled possibility to obtain a novel set of frequent observations over a region of the planet that can extend up to 80° away from the sub-spacecraft point.

The overall goal of this mission concept is to track Martian dust storms and water ice clouds, helping to address the scientific questions: What are the processes controlling the dynamics of dust and water ice aerosols, and promoting the evolution of regional dust storms into planetaryencircling storms?

The SmallSat uses a solar electric propulsion system based on micro Hall-effect thrusters that allow it to reach, optimize and maintain its orbit, dramatically improving its lifetime and control. The propellant is gaseous xenon. The power source is guaranteed by deployable, flexible, high specific power (160 W/kg) solar arrays designed to meet the power needs of the Hall-effect thruster and payload. Communication is provided in the X-band by the JPL IRIS Deep Space transponder in association with a KaPDA antenna.

The payload is comprised of one off-the-shelf visible camera (fixed-focus, narrow-angle lens, 5 MP resolution), and two thermal infrared cameras (fixed-focus, narrow-angle lens, 0.3 MP resolution). The infrared cameras are equipped with filter wheels for selecting multiple spectral ranges, and the uncooled micro-bolometer image sensors are responsive out to 20 µm to include CO2, dust, and water ice absorption lines. Retrievals of aerosol optical depth throughout the local times will provide quantitative observations at a spatial resolution up to 60 km/pixel and temporal resolution up to half an hour, complementing the high-resolution daylight visible images (resolution up to 4 km/pixel).

We have studied three possible mission scenarios: 1) Ridesharing on a primary orbiter mission directed to Mars, with deployment after the initial capture burn (operated by the mothership). This scenario, which limits the use of thrusters, allows for the lowest mass and size; 2) Ridesharing on a primary mission directed to Mars with deployment a few weeks ahead of Mars capture (operated independently from the mothership); 3) An independent journey to Mars all the way from Earth GTO. In all three cases, the duration of the (primary) science mission at Mars is planned for one Martian year.

B0.2-0017-18 MARSCAT: MARS ARRAY OF IONOSPHERIC RESEARCH SATELLITES FORMING THE CONSTELLATION FOR AERONOMY AND TOMOGRAPHY

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The MARSCAT Mission will be a multiple 6U CubeSat mission to study the ionosphere of Mars. The mission will investigate the plasma and magnetic structure of the Martian ionosphere, including how the ionosphere responds to solar wind dynamics, what small scale structures exist in the lower ionosphere of Mars, and what processes are responsible for the maintainance of the nighttime ionosphere. The Mars transit proposed is piggy back with a major mission, using an on-board thruster burn or a carrier burn for Mars Orbit Injection (MOI).

MARSCAT will make correlated multipoint studies of the ionosphere and magnetic field of Mars. MARSCAT will make in situ observations of the energetic particle flux, plasma density, temperature, and convection in the ionosphere of Mars. They will also make total electron content measurements along the line of sight between any two of two spacecraft. Following the successful exploration of the Mars ionosphere and its interaction with the solar wind and the crustal magnetic field of the planet, there remain several key questions, which will complete a description of the space environment of Mars. The key questions involve the transport properties of the ionospheric plasma, its role in redistributing the plasma and the role of the magnetic field in modifying the plasma motions. A focus for advancing our current understanding may be obtained by addressing the following key questions. How does the ionosphere respond to solar wind dynamics? What small-scale structures exist in the lower ionosphere of Mars? What processes are responsible for the maintenance of the nighttime ionosphere? The key to advancing or understanding lies in using multiple platforms to increase the temporal cadence with which a particular volume of the ionosphere can be sampled. With recent advances in small satellite capabilities it is now possible to consider the deployment of a small satellite constellation to accomplish this task. Suitably instrumented satellites could be carried as a secondary payload to a major Mars mission in much the same way as small CubeSat missions have been successfully conducted in low Earth orbit.

B0.2-0018-18 NEARCUBE: USING AUTONOMOUS 3U CUBESATS TO FLYBY NEAR-EARTH ASTEROIDS

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CubeSat technology is rapidly evolving and now the first missions beyond low-Earth orbit (LEO) have been planned [1-4]. These first 6U interplanetary CubeSats (<12 kg) will be launched using NASA's Atlas V and its new Space Launch System (SLS), and are designed to observe and land on the Moon, flyby a near-Earth asteroid, flyby Mars in support of NASA's InSight mission, and more.

The use of CubeSats for planetary exploration represents an attractive solution to reduce the development and implementation costs of missions in comparison to traditional spacecraft [5]. However, ground segment operations—which require extensive workforce and the use of large, costly ground stations such as the Deep Space Network (DSN)—remain as one of the key challenges for interplanetary CubeSats, and still represent a very significant (sometimes inviable) fraction of the mission budgets [6]. In response to the current interest in understanding the potential of CubeSats and possible applications for planetary exploration, this work studies the feasibility of autonomously flying by a near-Earth asteroid using a 3U CubeSat (<4 kg).

The proposed mission, which is named Near-Earth Asteroid Reconnaissance using CubeSats (NEARCube), is therefore envisioned as a feasibility demonstration of small-body exploration missions using autonomous and smaller CubeSats than ever before. Considering the current state of CubeSat technology, this work evaluates the flyby altitudes that can be achieved by autonomous CubeSats, and assesses the potential scientific impact that such a mission could have. If proven possible, autonomous 3U CubeSats could provide a low-cost solution to support current efforts to determine initial stages of solar system formation through asteroid exploration (or the primordial sources of organic matter if used for cometary exploration) [13], they could be used to identify potential targets for future missions, to complement the scientific objectives of larger missions, or to support the emerging asteroid mining industry [14], etc.

The NEARCube mission specifically considers the possibility of deploying a CubeSat from a larger spacecraft in a periodic orbit around the first (L1) or the second (L2) Sun-Earth Lagrange points. These points provide a prime location to observe the Sun and outer space, and have been extensively used in the past by mission such as SOHO, Herschel, Planck, or LISA Pathfinder

[7-10]. The James Webb Space Telescope (2019) and Euclid (2020) missions will be launched to L2 in the upcoming years as well [11, 12]. In addition, the span of the mission is limited here to 150 days to confine the demanding implications and systems requirements of long-duration, deep-space travel, and the spacecraft is primarily designed using currently-available off-the-shelf components (for reduced development and implementation costs).

This study is comprised of three overarching parts: (1) a trajectory design and target selection analysis to understand if 3U CubeSats can travel far enough to encounter a near-Earth asteroid, and to identify asteroids that could be flown by in the upcoming years, (2) a navigation and sensitivity analysis to study if a CubeSat could autonomously estimate its position and velocity, and to characterize the accuracy of the flybys and attainable flyby altitudes, and (3) a systems engineering analysis to propose a 3U CubeSat design, recommend potential science payloads, and assess the measurements and scientific objectives that could be accomplished by such a mission.

Preliminary results show that a total of 11 near-Earth asteroids (larger than 100 meters) could be encountered between 2019 and 2025, out of which 6 could be flown by a 3U CubeSat performing autonomous navigation. Flyby altitudes of 500 km are found to be possible with currently available components and an allocated space of approximately 0.8U for the science payload. A variety of scientific instruments are available (including off-the-shelf components), and proposed here for the NEARCube mission. Potential scientific objectives are also assessed, and include performing ultraviolet, visible or infrared imaging spectroscopy, measurements of remnant magnetic fields, or even mass spectroscopy if used for cometary exploration.

This work therefore identifies an opportunity for small-body planetary science using autonomous 3U CubeSats. The mission concept, upcoming asteroid flyby opportunities, and potential scientific merit of the proposed NEARCube mission are presented and discussed here in detail.

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B0.2-0019-18 EXPLORATION OF "ONCE IN A LIFETIME" PLANETARY BODIES WITH CONSTELLATIONS OF SMALL SPACECRAFT

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We suggest novel strategies for the exploration of planetary objects with very long periods (referred to as LPOs). These bodies include Oort cloud comets, Manx objects and, now, interstellar objects, such as the recently discovered 'Oumuamua [1]. Long-period comets are the most primitive witnesses of the early solar system. Interstellar visitors are suggested to be ejecta of extrasolar planets subject to catastrophic collisions. Hence the scientific value of exploring these objects is unbounded. A very broad range of measurements are sought at these bod- ies. They include the characterization of their physical properties (shape, density, morphology, dynamical properties), composition (elemental composition, mineralogy, isotopes), interior, geological traits that might inform on origin and possible long-term evolution, and interactions, in particular of a coma when it exists, with the solar wind. The corresponding instruments already exist in a small form factor. Encounters with LPOs are challenging to plan. These bodies have a broad range of inclinations and encounter velocities are in excess of 50 km/s. The only attempt to explore a comet with a longer period (75 years) up-close was the encounter with Comet Halley in 1986. Its visit was deemed such an important event that six spacecraft were sent by different space agencies. Similarly, future exploration of LPOs might be best approached by sending a very large number of spacecraft by multiple space agencies, and in a coordinated manner. It is envisioned that up and coming telescopic facilities such as the Pan-STARRS2 Observatory combined with the Pan-STARRS1 telescope, and later the Large Synoptic Survey Telescope (LSST), will enable the discovery of LPOs a decade and more before these objects reach perihelion. This timeline is a priori sufficient to implement and launch spacecraft that may encounter the LPO as it approaches its perihelion. Constellations, formations, and swarms of small spacecraft have been identified as game changers for enabling new space science [2]. In recent times, there has been a tremendous development in regards to the

technology maturation level achieved by smallsats [3]. Smallsats offer a number of advantages, in particular advanced distributed spacecraft architectures that can be used to address the above challenges and enable wholesome science investigations over a short observation window. This includes:

(1) a loose coordination to synthesize a single, large, virtual instrument [4]; (2) innovative distributed, possibly heterogeneous measurement, and data analysis techniques; (3) autonomous operations; (4) communication relay strategies; and (5) novel orbital organization approaches for constellations or more effective swarming and to enable observations from multiple vantage points.

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B0.2-0020-18 THE GEOPHYSICAL RECONNAISSANCE ASTEROID SURFACE PROBE (GRASP), A LANDER MISSION TO DETERMINE ASTEROID DENSITY DISTRIBUTION

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The Geophysical Reconnaissance Asteroid Surface Probe (GRASP) is a proposed Canadian space mission to explore the surface of a small asteroid. The asteroid lander/rover nanosat spacecraft (12U cubesat) will be brought to a small (< 1 km in diameter) near-Earth asteroid aboard a host mothership spacecraft, which will drop GRASP onto the asteroid's surface. GRASP will carry two geophysical instruments, a novel space gravimeter located in GRASP's central bus structure, and a set of magnetometers located in GRASP's feet. GRASP will use its rockets to hop from one location to another, eventually covering the entire surface of the asteroid, making science measurements at 100 or more surface locations. These geophysical measurements will be used to constrain the asteroid's interior structure and composition, specifically, asteroid mass, density distribution and magnetic susceptibility and will ultimately be applied to (i) answering fundamental science questions about the origin, formation and evolution of the Solar system, (ii) assessing asteroid mining potential, and (iii) asteroid re-direct strategies. Based on forward and inverse models of asteroid surface gravity observations, the mission will result in well constrained asteroid mass and internal density distribution, which is considered a first. In addition to enabling the field of asteroid surface gravimetry, GRASP will also include optical imaging sensors and on-board rover cameras, which in combination with the geophysical data will allow for the development of a comprehensive asteroid composition model.

B0.2-0021-18 BIRDY - PLANETARY GEODESY OF SMALL BODIES THROUGH CUBESATS IN AUTONOMOUS NAVIGATION

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Bringing a CubeSat that could autonomously navigate in the vicinity of small bodies would be an ideal platform to perform radio-science from multiple locations at low altitudes that are too risky for a mothercraft. The perturbations due to the asteroid during the orbit or multiple flybys of the CubeSat allow the reconstruction of its detailed gravitational field by planetary geodesy and, eventually, the identification of its internal structure. To this purpose, we are developing the BIRDY concept of interplanetary CubeSat, accompanying a mothercraft for planetary geodesy of small bodies (asteroids, comets, satellites). Besides, classical radio tracking can be coupled to other techniques such as space astrometry and VLBI [1]. Interplanetary CubeSats need to overcome a few challenges before reaching successfully their deep-space objectives: link to ground-segment, energy supply, protection against radiation, etc. Besides, the Birdy CubeSat - as our basis concept - is designed to be accompanying a mothercraft, and relies partly on the main mission for reaching the target, as well as on data-link with the Earth. Autonomous navigation could then provide a way to perform a new kind of planetary geodesy, particularly well adapted to small bodies.

Future mission for space exploration or sample return could hence take profit of having accompanying nano-orbiters, as complementary or deported instruments with increased autonomy. Furthermore, in the current context of more and more small satellites being launched in solo or in network/swarms missions, the operational cost of such projects is booming; especially because of the required ground segment. This kind of technology could greatly increase the feasibility of such projects (by moving the decision making to the satellite), for example high frequency imaging of the Earth, Radio Interferometry from space, simultaneous multi-point in situ study of the solar wind, etc. A performant autonomous navigation function for small satellite could hence unlock new scientific missions and commercial applications.

This autonomous attitude and orbit determination and control function (a.k.a autonomous navigation) for small satellites, in addition to radio science fro planetary missions, is currently being developed by a Consortium made of laboratories LESIA and IMCCE from Observatory of Paris in France, and the National Cheng Kung University and ODYSSEUS Space Co., Ltd in Taiwan. Before going to deep-space, and performing planetary science, our project will start with BIRDY-1 orbiting the Earth, to validate the concepts of adopted propulsion, IFOD and orbit maintenance, as well as the radio-science.

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B0.2-0022-18 COMPUTATIONAL AND EXPERIMENTAL PREDICTION FOR DETECTION OF TWO DUST POPULATIONS IN THE EARTH-LUNAR LAGRANGE 2 POINT BY THE EQUULEUS-CLOTH SYSTEM

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Cis-Lunar Object Detector within THermal Insulation (CLOTH) is the micrometeoroid penetration sensor mounted on EQUilibriUm Lunar-Earth point 6U Spacecraft (EQUULEUS), a joint deep-space cubesat mission between The University of Tokyo and Japan Aerospace Exploration Agency (JAXA), which will be launched in the late 2019. This is the first opportunity to reveal the micrometeoroid distribution around the Earth-Moon Lagrange point 2 (EML2). It is expected that CLOTH will detect two components of micrometeoroids during the cruise to EML2 region, i.e. sporadic dust particles originated from the interplanetary space and the EML2 ejecta particles produced by temporary captured orbiters (TCOs). The CLOTH sensor has laminated structure composed of polyvinylidene fluoride film sensors and the multilayer insulation (MLI) of spacecraft. Due to its sensor structure, CLOTH can detect particles that penetrates the outermost layer film of MLI. In this presentation, we report the micrometeoroid detection performance of CLOTH focusing on the damage and penetration of the outermost layer obtained by hypervelocity impact (HVI) experiments and computational simulations. HVI experiments were performed by using the two-stage light gas gun at JAXA/ISAS and the laserinduced particle impact test (LIPIT) facility at Massachusetts Institute of Technology. In the experiments, we used soda-lime glass particles of 4-30 μm diameter accelerated at 1-7 km/s. For complementing the HVI experiments, computational simulation with finite element method in AUTODYN® was performed. From the experiment and simulation results, we revealed the clear difference in detectable impact condition for the two components of micrometeoroids.

B0.2-0023-18 METEORIX: A CUBESAT MISSION DEDICATED TO THE DETECTION OF METEORS

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Here, we present a cubesat space mission dedicated to the detection and characterization of meteors. The detection of meteors brings information on the flux of meteoroids and space debris in Earth environment and on the nature of the meteoroids that come from two reservoirs: comets and asteroids [1]. Such study brings information on the formation of the solar system. Several methods have been developed from Earth ground and airborne to detect meteors or space debris. However, the advantage of a space mission dedicated to meteors observation is to be able to probe a large volume of the Earth atmosphere and to avoid weather constraints [2]. The primary objective is to assess a robust statistics on meteoroids and space debris that enter into the Earth atmosphere. At present, their fluxes and properties are not yet determined accurately [3]. These estimates will allow to quantify the delivery of extraterrestrial material on Earth, and possible consequences on aeronomy (e.g. noctilucent clouds and atomic layer). These estimations are also crucial to estimate impact risks for artificial satellites during meteor showers. There are several secondary objectives such as to bring information on ablation, fragmentation, rotation processes by photometry variation; to determine the trajectory in connection with Earth-ground network such as FRIPON network developed in France in order to find the dynamical origin of the meteoroid; and to detect other fainter luminous atmospheric. This cubesat is a 3U developed by students from Sorbonne University and the project is presently in phase B [4]. The launch would be scheduled in four years. Support from CNES-JANUS, ESEP, and IDEX Sorbonne Universités are acknowledged.

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B0.2-0024-18 SCIENCE ENABLING CAPABILITIES OF SHORT ELECTRODYNAMIC TETHERS FOR PICOSATS TO CUBESATS AND MITEE MISSIONS

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The promise of CubeSats as a platform for technology demonstration and education has been well understood since the beginning. With ever-advancing miniaturization and flight heritage, CubeSat missions have started to be proposed and flown to address important questions of space science. One such set of missions are the Miniature Tether Electrodynamics Experiments (MiTEE), student-led CubeSat missions developed and operated at the University of Michigan. MiTEE-I is geared towards investigating the electron current collection behavior of a picosatellite end-body and is slated to launch in 2018. MiTEE-II will build upon the lessons learned of MiTEE-I to study the dynamics and control of asymmetric tethered CubeSat systems.

The long-term focus is to develop short (10-30 m) electrodynamic tether (EDT) systems for PicoSats (< 100g) that provide propellantless propulsion for drag make-up and satellite repositioning, support double probe science, and antennas for communications and science.Here we will also present the space science enabled by the MiTEE missions. Langmuir probe implementation techniques and technologies that are being developed to overcome measurement errors induced by the smaller collection profile of Cubesats. These developments enable a wide array of new space science missions when flown on small spacecraft.

B0.2-0025-18 ON-ORBIT PLANETARY SCIENCE USING CUBESAT CENTRIFUGE LABORATORIES

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There are thousands of asteroids in near-Earth space and millions in the Main Belt, offering many mission targets. Yet landing on an asteroid and manipulating its surface material remains a daunting challenge. Current missions to asteroids such as Hayabusa II and OSIRIS-REx will perform touch-and-go operations instead of landing, to limit these risks.

Fundamental research is required to understand asteroid surface behavior, with regard to landing, mobility, and subsurface exploration. Presently we lack even the most basic knowledge, for instance whether they will act as a hard, rugged materials or fluidize like quicksand under modest vibration. The same can be asked of comets and small moons.

Although similar challenges exist for determining the best form of mobility, manipulation and mechanical processing on the Moon and Mars, the milligravity environment is unique and quite challenging to simulate. Therefore we have proposed and have been developing a low cost CubeSat mission called Asteroid Origins Satellite I (AOSat 1) that will operate in Low Earth Orbit (LEO) as a centrifuge science laboratory. The whole spacecraft will spin at 1-2 RPM, giving a 2U research chamber a milligravity environment corresponding to an asteroid the size of Itokawa. Crushed meteorites in the chamber will mimic a layer of asteroid regolith.

This approach provides a low-cost pathway to producing realistic asteroid physical and thermal conditions, for science and for engineering validation. The laboratory is equipped with cameras and piezoelectric actuators to observe and manipulate regolith. Basic experiments are planned to measure the general behavior, friction coefficient, stiction and other parameters that can feed into asteroid surface dynamics simulators. Beyond AOSat 1, our efforts are focused on developing a series of larger, 6U CubeSats with increasingly sophisticated experiments that enable direct simulations of robotic surface landing, manipulation and resource processing/extraction. We have been developing detailed plans for instrumentation to perform penetrometery, excavate, acquire samples, process regolith and extract water.

Centrifuge science laboratories, from CubeSat and larger scales, can be used to recreate the low-gravity off-world conditions of the asteroids, Moon, Mars and other small bodies in the solar system. The laboratories can provide a persistent link to better understand and perform hypothesis-testing of planetary surface processes, being able to fully recreate them in controlled laboratory

conditions on-orbit. Furthermore, this technology can be applied to de-risk next generation spacecraft technology with increased confidence and long-term planning.

B0.3-0001-18 OBSERVING THE OUTER PLANETS WITH ASTROPHYSICAL ASSETS

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Space-based astrophysical telescopes are a perfect platform for long duration and frequent cadence observations of the outer planets. These missions are optimized for high spatial resolution observations over a large field of view, and often have very long mission lifetimes. Unlike ground-based, or very close planetary, observations, these telescopes can observe a planet over a full rotation cycle or more, often capturing the entire planet within the instrument field of view. These aspects are critical to providing global context for deep space missions. Even more importantly, they allow us to revisit the very dynamic and variable atmospheres of the gas and ice giant planets throughout their long seasonal cycles. This talk will briefly discuss the challenges of observing the giant planets, including how JWST, WFIRST, LUVOIR, and other future astrophysics missions can provide breakthrough planetary science. We also summarize the outstanding recent results from the Hubble Space Telescope Outer Planet Atmosphere Legacy (OPAL) Program, and from the Kepler K2 and Spitzer Neptune observations.

B0.3-0002-18 EXPLORING JUPITER'S AURORAE WITH THE CHANDRA AND XMMNEWTON X-RAY OBSERVATORIES

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Jupiter's polar X-ray aurora is dominated by a bright dynamic hot spot that is produced by precipitating 10 MeV ions [Gladstone et al. 2002; Elsner et al. 2005; Branduardi-Raymont et al. 2007]. These highly energetic emissions exhibit pulsations over timescales of 10s of minutes and change morphology, intensity and precipitating particle populations from observation to observation and pole to pole [e.g. Dunn et al. 2017]. Surrounding the soft X-ray emission there is an oval of hard X-ray bremsstrahlung from precipitating electrons. The acceleration process/es that allow Jupiter to produce these high-energy X-ray emissions remain poorly understood, but vary with solar wind conditions [Dunn et al. 2016; Kimura et al. 2016] and the soft X-ray emissions are expected to relate to processes on the boundary between Jupiter's magnetosphere and the solar wind.

We present a decade of remote X-ray observations of Jupiter from 2007 to 2017 using the Earth-orbiting X-ray telescopes Chandra and XMM-Newton. We compare these high spatial and spectral resolution X-ray data with in-situ measurements of the solar wind and the Jovian magnetosphere conducted by NASA's New Horizons and Juno spacecraft. Analysing X-ray spectrograms and X-ray auroral videos we probe time-varying accelerations, precipitating particle populations and auroral morphologies and further connect these with their solar wind and in-situ drivers.

Finally, we compare X-ray observations with UV observations to enrich multi-waveband connections and deepen our understanding of how Jupiter generates its highly energetic polar auroral precipitations.

B0.3-0003-18 EVERYTHING UNDER THE SUN: OBSERVATIONS OF SOLAR SYSTEM BODIES FROM HELIOPHYSICS OBSERVATORIES

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In this presentation, we give an overview of the wealth of solar system bodies observed from the ESA/NASA Solar and Heliospheric Observatory (SOHO) and NASA Solar Terrestrial Observatory (STEREO). With continuing lifetimes now spanning more than 11-years (STEREO) and 23-years (SOHO), the coronagraphs and heliospheric imagers aboard these spacecraft have observed every class of solar system body: all the planets except Uranus and Neptune; dwarf planets Ceres and Vesta; several Jupiter moons, Titan, and our own Moon; dozens of asteroids (minor planets), including active asteroids such as 3200 Phaethon; and, perhaps most famously, more than 3,500 comets.

We will provide a broad introduction to the SOHO and STEREO missions, and the instruments with which we observe solar system bodies. Included in this will be the limitations and constraints imposed upon these observations by instruments that are intended to study only one solar system body (i.e. the Sun). We then briefly discuss some of the science investigations of solar system bodies that have been, or could be, driven by these data. Finally we conclude with a brief preview of solar system observing prospects from the Naval Research Laboratory's Heliospheric Imager instrument (WISPR) aboard the NASA Parker Solar Probe mission, set for launch in 2018.

B0.3-0004-18 COMETS, ASTEROIDS AND INTERPLANETARY DUST AS SEEN IN NEARTO FAR-INFRARED WITH AKARI

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AKARI, the Japanese satellite mission dedicated to infrared astronomical observations, was the third mission to survey the whole sky at midand far-IR wavelength regions. AKARI was launched in February 2006 and exhausted its liquid helium in August 2007. Together with the all-sky survey at 9, 18, 65, 90, 140, and 160 µm, a number of pointed observations were also made for deep imaging and spectroscopy from the near-infrared to far-infrared. After the exhaustion of the cryogen, near-infrared imaging and spectroscopic observations had continued until 2011 May. Although most of the targets for the AKARI observations were the Galactic and extragalactic objects, the data of the AKARI observations are extremely important not only for the studies of the Galactic and extragalactic sciences, but also for the Solar System sciences on comets, asteroids, TNOs, and interplanetary dust.

With the mid-infrared all-sky survey data, the asteroid catalog using AKARI (AcuA) was produced. It is an unbiased, homogenous asteroid catalog, containing a total of 5120 objects down to a diameter of 20 km in the main belt. Taking advantage of the sky

coverage with the midand far-infrared all-sky map data, AKARI reveals the global and small-scale structure of the zodiacal dust cloud. AKARI detects asteroidal dust bands and a circumsolar ring structure in the zodiacal emission spatial profiles with much higher resolution than IRAS and COBE/DIRBE. These data provide us the information on the dynamical evolution of the Solar System.

AKARI also has a spectroscopic capability in nearand mid-infrared wavelength region. We carried out spectroscopic observations for tens of asteroids and comets in 2.5–5 μm. AKARI detects a clear absorption feature related to hydrated minerals in many asteroids and carbon dioxide in cometary comae. AKARI also made the spectroscopy of the zodiacal emission in the mid-infrared (5.5–12.5 μm) and detects the silicate feature around 10-μm region toward the various ecliptic latitude regions. These data sets are almost the largest spectroscopic database so far and provide us the information on the physicochemical environment in the proto-solar nebula.

AKARI has already provided many precious data sets and scientific outcomes, but it is just the tip of the iceberg. We will summarize the successful results of the AKARI Solar System sciences and introduce ongoing scientific analyses.

B0.3-0005-18 SEARCH FOR SERENDIPITOUS TRANS-NEPTUNIAN OBJECT OCCULTATION IN X-RAYS

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Small Trans-Neptunian Objects (TNOs), of kilometer size and below, are too dim to observe directly. Observations of serendipitous occultation events caused by these small TNOs provide a way to study their population properties such as the size distribution. Limited by the effect of diffraction, optical occultation events can be used to explore TNOs only down to kilometer size, while with X-ray ones it can be pushed down to about 30 meters. In this talk I will report our efforts and results of using Rossi X-ray Timing Explorer (RXTE) observations in this endeavor. With the same technique, we also obtained observational constraints to the size distribution of small Oort Cloud Objects without any model assumptions. Feasibilities of observations using facilities like ASTROSAT/LAXPC and Athena/WFI will be discussed.

B0.3-0006-18 SCIENCE OF SOLAR SYSTEM OBJECTS WITH THE GAIA MAPPING MISSION AND THE GDR CATALOGUES.

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Since the beginning of its scientific programme, in mid-2014, the ESA space mission Gaia has regularly scanned the whole scan, providing astrometry, spectrometry, and spectro-photometry, of about a billion of stars and also Solar System Objects (SSOs). Although it is not specifically designed for observation of moving objects, the Gaia satellite provides photometric and astrometric measurements, with unprecedented accuracy, for a very large number of SSOs, mainly asteroids. The unique capabilities of Gaia allow for the collection of an extensive and homogeneous data set of some 350,000 asteroids (that is almost half of the known population), some planetary satellites, and comets, down to the limiting magnitude of G20.7 mag, at the sub-milli-arcsec and milli-mag level accuracy. Thanks to large number of sources, the systematic character of the survey, and the measurements of metrological precision into play, Gaia will open a new era in asteroid science. Gaia has already started to provide its harvest with the first two Gaia data releases, DR1, published in September 2016. Gaia DR1 did provide positions for about 1 billion stars and proper motion for the Tycho-Gaia TGAS of 2 million stars. The second data release, DR2 to be published in April 2018, will be the major step in the Gaia mission, providing all astrometric parameters (including parallax and proper motion) for a billion stars, in an absolute reference frame - to become the optical ICRF. Gaia DR2 will also provide for the first time epoch astrometry and photometry for about 14000 asteroids from its direct observations, down to magnitude G20.7. The Gaia performance remains excellent over the entire available brightness range. We will present the Gaia data reduction pipeline for the SSOs, within the framework of the Data Processing and Analysis Consortium (DPAC), and the validation process of the DR2 data. We illustrate the peculiar properties of each single observation, as these properties will affect the subsequent exploitation of the mission data. Overall, we expect to derive masses, sizes, average densities, spin properties, reflectance spectra, albedos, as well as new taxonomic classifications for a very large numbers of asteroids. We will discuss the improvement brought by Gaia over 5 years of nominal mission, starting with DR1, and focusing especially on the dynamics of asteroids and other Solar System Objects. This includes use of the catalogue for calibrating future and past photometric and astrometric observations, new perspectives for orbit determination and stellar occultations, detection of small acceleration or perturbations for the asteroids. Also we illustrate the ground-based activity coordinated by the Gaia-FUN-SSO network for follow-up observations of newly discovered Near Earth Object. We will further focus on the areas that will benefit from complementary observational campaigns to improve the scientific return of the mission, and on the involvement of the planetary science community as a whole in the exploitation of the Gaia survey.

B0.3-0007-18 THE PRESENCE OF DUST AND ICE SCATTERING IN X-RAY EMISSIONS FROM COMETS

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We present evidence of dust and ice as sources of X-ray scattering emissions from comets. Emission spectra are modeled from first principles using the charge-exchange interaction with solar wind ions as well as coherent scattering of solar X-rays from dust and ice grains. Scattering cross-sections are interpolated over the 1 nm-1 cm grain radius range using approximations based on the optically thin or thick nature of grains with different sizes. Archival comet observations from the Chandra X-ray Observatory are fit with the theoretical emission model. The best fits show charge-exchange to dominate the emission spectral intensity below 1 keV, while dust and ice scattering is the dominant mechanism at energies greater than 1 keV. Grain size dependences calculated from the scattering results are consistent with independent observations and simulations of such systems, and the dust/ice density dependence on grain radius is shown to vary significantly between comets.

B0.3-0008-18 MESSENGER OBSERVATIONS OF THREE COMETS AT SMALL HELIOCENTRIC DISTANCES

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During the extended MESSENGER mission, the opportunity arose to make both spectral and imaging observations of three comets: 2P/Encke, C/2012 S1 (ISON), and C/2013 V5 (Oukaimeden). MESSENGER's position in the inner solar system provided a unique view of these comets at small heliocentric distances, and through the efforts of the spacecraft and instrument teams, observing campaigns for these three comets were conducted. Its instrument payload, though not designed with comets in mind, was both capable and flexible enough to provide a variety of observations, including both wideand narrow-angle images, images in different filters, and high-resolution spectra that spanned wavelengths from 100-600 nm. Of particular note are the ultraviolet observations of various atomic and molecular species. These observations are uncommon for comets close to the Sun due to the viewing restrictions of most telescopes in space. We will report on the analyses of the science data that were collected during these observing campaigns, with a focus on the temporal evolution of the coma dust and gas. Equally important, we will discuss the lessons learned from the experience - what worked and what did not - and present suggestions for future observations of the same genre with spacecraft that also were not designed for the task. Such observations are essentially mini-spacecraft missions to the objects involved and thus represent a potentially high science return for a reasonably small impact on the primary mission.

B0.3-0009-18 DETECTION AND CHARACTERIZATION OF MINOR PLANETS USING NEOWISE

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NEOWISE is the NASA planetary-funded mission that uses data from the Wide-field Infrared Survey Explorer (WISE) spacecraft to detect and characterize moving objects. WISE was originally designed as an NASA astrophysics mission, with the goal of mapping the sky in the mid-infrared to search for the closest stars and the most luminous galaxies.

WISE surveyed the sky in four infrared wavelength bands (3.4, 4.6, 12 and 22-µm) between January and September 2010, when its solid hydrogen cryogens were exhausted. Survey operations continued using the shorter two wavelength bands until January 2011, after which the spacecraft was put in to hibernation. During this phase of the mission, over 158,000 minor planets were detected, including over 160 comets and 34,000 newly discovered minor planets.

In December 2013, the telescope was taken out of hibernation and renamed NEOWISE, with the new goal of detecting, tracking, and characterizing near-Earth objects (NEOs). The restarted NEOWISE mission uses only the shorter two wavelength bands (3.4 and 4.6-µm), and uses the same survey strategy as the original mission. Since the restart of the mission (as of February 2018), over 30,000 solar system small bodies have been observed, including over 800 NEOs, and over 130 comets. NEOWISE thermal infrared measurements have been used to measure diameters for over 22,000 asteroids in the first three years of the restarted mission, with observations and analysis ongoing as of February 2018.

In this presentation, we will discuss an overview of the results of the NEOWISE mission, with a focus on the minor planets detected during the mission.

B0.3-0010-18 PLANETARY SCIENCE WITH THE TRANSITING EXOPLANET SURVEY SATELLITE (TESS)

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The Transiting Exoplanet Survey Satellite (TESS) is a NASA-sponsored Astrophysics Explorerclass mission that will perform an all-sky survey to search for planets transiting nearby stars. The primary goal of TESS is to discover planets smaller than Neptune that transit stars bright enough to enable follow-up spectroscopic observations that can provide planet masses and atmospheric compositions. TESS is scheduled to launch in Spring 2018 and will be placed in a highly-elliptical 13.7 day orbit around the Earth. In its 2-year prime mission, TESS will monitor about 200,000 main-sequence dwarf stars with four wide-field optical CCD cameras to detect periodic drops in brightness caused by planetary transits. Photometry of these pre-selected targets will be recorded every 2 minutes. TESS will also obtain full-frame images (FFIs) of the entire, four camera field-of-view (24 x 96 degrees) at a cadence of 30 minutes to facilitate additional science. The TESS Mission will have a robust Guest Investigator (GI) Program under which the astrophysics and planetary science community may propose new 2 minute cadence targets and investigations using the 30 minute cadence FFI data. TESS GI awards will enable science in exoplanet, stellar, extragalactic, and solar system science (including solar system planets, asteroids and comets). I will present a post-launch update of the TESS mission and a summary of the approved GI programs, and discuss planned and possible capabilities of TESS during its 2-year primary mission, and potential science for an extended mission.

B0.3-0011-18 SOLAR SYSTEM SCIENCE WITH EUCLID

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The ESA Euclid mission has been designed to map the geometry of the dark Universe. Scheduled for launch in 2020, it will conduct a six-years visible and near-infrared imaging and spectroscopic survey over 15,000 deg2 down to VAB 24.5. Although the survey will avoid ecliptic latitudes below 15°, the survey pattern in repeated sequences of four broad-band filters seems well-adapted to Solar System objects (SSOs) detection and characterization.

I will present a study of the impact of Euclid on planetary sciences. For that, I use current census of SSOs to extrapolate the total amount of SSOs detectable by Euclid, i.e., within the survey area and brighter than the limiting magnitude. For each different population of SSO, from neighboring near-Earth asteroids to distant Kuiper-belt objects (KBOs) and including comets, With current survey design, about 150,000 SSOs, mainly from the asteroid main-belt, should be observed by Euclid. These objects will all have high inclination, which contrasts with many SSO surveys focusing on the ecliptic plane. There is a potential for discovery of several 104 SSOs by Euclid, in particular distant KBOs at high declination, which will not be covered by LSST.

I will present the expected Euclid astrometry, photometry, and spectroscopy with SSO properties to estimate how Euclid will constrain the orbits of SSOs, their morphology (activity and multiplicity), physical properties (rotation period, spin orientation, and 3-D shape), and surface composition. Euclid observations, consisting in a suite of four sequences of four measurements, will refine the spectral classification of SSOs by extending the spectral coverage provided by Gaia and the LSST to 2 microns. The time-resolved photometry, combined with sparse photometry such as measured by Gaia and the LSST, will contribute to the determination of SSO rotation period, spin orientation, and 3-D shape model. The sharp and stable point-spread function of Euclid will also allow to resolve binary systems in the Kuiper Belt and detect activity around Centaurs.

In summary, the depth of Euclid survey (VAB 24.5), its spectral coverage (0.5 to 2.0 micron), and observation cadence has great potential for Solar System research. A dedicated processing for SSOs is being set in place within Euclid consortium to produce catalogs of astrometry, multicolor and time-resolved photometry, and spectral classification of some 105 SSOs, delivered as Legacy Science.

B0.3-0012-18 NEW INSIGHTS INTO THE INFRARED SOLAR SYSTEM WITH JWST

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The James Webb Space Telescope (JWST) is an infrared-optimized observatory with a 6.5mdiameter segmented primary mirror and instrumentation that provides wavelength coverage of 0.6-28.5 microns, sensitivity 10X to 100X greater than previous or current facilities, and high angular resolution (0.07 arcsec at 2 microns) and low-moderate spectral resolution (R 100- 3000) [1,2]. It offers multiple capabilities through 4 science instruments including: imaging, spectroscopy (slit, IFU, grism/prism), coronography, and aperture mask interferometry. These instruments, along with the telescope's moving target capabilities, will enable the infrared study of solar system objects with unprecedented detail. This presentation features highlights of planned guaranteed time solar system observations with JWST as well as other potential science cases highlighted in a Special Issue of PASP (see [1] and references therein).

REFERENCES [1] Gardner, J.P., et al. Space Science Reviews, 123, p 485-606, (2006). [2]

Milam, S.N., et al. PASP, 128, 959, (2016).

B0.3-0013-18 SOLAR SYSTEM SCIENCE WITH WFIRST

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NASA's next great observatory, the Wide Field Infrared Survey Telescope (WFIRST), is designed to complement the capabilities of concurrent platforms, such as NEOCam, LSST and JWST, while combining the capabilities of high throughput and high-resolution imaging with a wide field of view. WFIRST will launch in the mid 2020s. Some 20% or more of the observing time has been set aside for a community-based guest observer (GO) program that could address any science topic, and may increase to nearly 100% during an extended WFIRST mission. The GO program and guest investigator (GI; allocated survey science) programs alike can be utilized for an array of solar system science investigations. GI program data may be mined for statistical data of small bodies, particularly main belt asteroids, Jupiter Trojans, and comets. The GO program may be used to search for volatile absorption features on distant surfaces and gas emissions in comets within the 0.6-2.0 µm wavelength region with high spatial resolution. A deep survey with WFIRST could detect objects orbiting at distances greater than 100 AU, a region of the solar system currently beyond the capabilities of any current facilities. We will present the scope of the solar system science capabilities that are achievable with the recently updated design parameters of the telescope.

B0.3-0014-18 PLATFORM CAPABILITIES FOR PLANETARY SCIENCE WITH ASTROPHYSICS ASSETS

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Planetary Science has benefited greatly from observational platforms whose highest priorities have not originally emcompassed the studies of bodies within our solar system. The first meaurements of X-rays from giant planet aurorae and comets, the discovery of comet and asteroid dust trails, and the largest surveys of asteroid and comet diameters were the results of observations using assets originally intended for astrophysical studies. The great observatories, Hubble Space Telescope, Spitzer Space Telescope, and Chandra X-ray observatory, have done a comprehensive array of planetary science investigations, and future assets, such as JWST and LSST, will make further rich contributions. Findings by NASA planetary assessment groups in 2017 encouraged the further use of astrophysics assets by planetary scientists, and the formation and definition of the necessary capabilities for these platforms to support planetary science. To that end, NASA Planetary Science Division has constituted a group to investigate and receive input as to the desired functionalities of future astrophysics assets, with the long-term idea of providing a list of these faculties to inform future missions during the early technical design phases. We will present the progress and preliminary findings from the activities of this group in its efforts to compile a uniform set of basic capabilities and to maximize the yield of Solar System science with future Astrophysics assets while allowing those missions to achieve their Astrophysics priorities.

B0.3-0015-18 OBSERVING THE SOLAR SYSTEM WITH TWINKLE

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Twinkle is a small space telescope conceived to observe spectroscopically hundreds of extrasolar planets over a broad wavelength range. Twinkle will be able to reveal the chemical composition, weather and history of worlds orbiting distant stars. Additionally, the high stability and sensitivity of its instrumentation mean Twinkle could be utilised for observing a multitude of other targets. Twinkle's ability to study Solar System objects has been explored by determining when objects are observable as well as the data quality and resolution obtainable. The targets considered in this work include planets, moons, dwarf planets and asteroids.

It was found that many celestial bodies would have long periods during which they could be observed with observation windows occurring on a periodic basis. Having determined that a target was observable, the SNR for photometric and spectroscopic data was calculated for a given exposure time. For a number of targets, including the outer planets, their large moons and bright asteroids, the model created predicts short exposure times will achieve high quality (SNR > 100), high resolution (R 300, $\Lambda <$ 2.42µm; R 70, $\Lambda >$ 2.42µm) spectroscopic data. For other targets this is found to not be achievable in one observation and thus multiple observations will be required if resolution or data quality cannot be reduced. Very small or distant objects (e.g. the outer dwarf planets, Haumea, Eris) are deemed too faint for Twinkle to obtain photometric or spectroscopic data of reasonable quality (SNR > 10) without requiring large amounts of observation time.

In conclusion, the Solar System is found to be permeated with targets which could be readily observed by Twinkle at visible and near infrared wavelengths.

B0.3-0016-18 INFERRING COMPOSITIONAL INFORMATION OF NEAR-SUN COMETS FROM MULTI-COLOR SOHO LIGHTCURVES

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Since Solar and Heliospheric Observatory (SOHO) launched in late 1995, more than 3,000 comets have been discovered in its images. The vast majority of these are dynamically related to each other as part of the Kreutz family of "sungrazing" comets and reach perihelion at distances (q) of 1-2 solar radii. Most Kreutz comets are observed for a few hours to days and are destroyed prior to reaching perihelion. The short observing arcs and the comets' low contrast with the sky so close to the Sun generally preclude significant investigations into their compositions.

SOHO's typical observations are made through either a clear or orange filter. Additional color filters are available, but are acquired infrequently. Fortuitously, two bright Kreutz comets have been detected sufficiently early to permit execution of full color sequences during their transit through the SOHO fields of view: C/2011 W3 Lovejoy and C/2012 E2 SWAN. We will report on our analyses of these multicolor lightcurves as a means of inferring compositional information about the comets.

We have developed a model to fit SOHO multi-color lightcurves that incorporates prominent atomic lines (Na, Fe, K, etc.) seen in spectroscopic data of the spectacular Kreutz comet C/1965 S1 Ikeya-Seki, emission features seen in comets at larger heliocentric distances (CN, C2, etc.), and a thermal component due to the extreme heating near the Sun. This allows a cursory inventory of a comets' composition, including estimates of non-volatile metals that are otherwise impossible to constrain without in situ measurements. It may also allow us to probe the extent to which a comets' volatiles have been depleted by previous perihelion passages.

The modeling may yield insight into the scales at which the Kreutz parent comet was heterogeneous. Most Kreutz comets are estimated to be a few to tens of meters in diameter, significantly smaller than estimates for C/2011 W3 Lovejoy. The small Kreutz comets are comparable in size to the boulders observed on the surface of comet 67P/Churyumov-Gerasimenko by Rosetta and the smallest detected fragments of newly split comets, e.g., C/1999 S4 LINEAR and 332P/Ikeya-Murakami. Thus, this study may help to understand the sizes at which cometary fragments are most strongly held together, which may be diagnostic of the characteristic sizes of the planetesimals out of which the bodies in the early Solar System formed.

This work benefited from discussions with the international team "The Science of Near-Sun Comets" led by G. Jones at ISSI (International Space Science Institute) in Bern, Switzerland in 2014-2015. MMK was supported by NASA Outer Planets Research grant NNX13A102G. KB was supported by the NASA-funded Sungrazer Project.

B0.3-0017-18 MONITORING THE EVOLUTION OF COMET 96P/MACHHOLZ 1 FROM ITS LIGHTCURVE

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One of SOHO's most surprising comet-related discoveries is the existence of groups of short period comets on low perihelion distance orbits. Two of these groups, the Marsden and Kracht groups, are dynamically related to comet 96P/Machholz 1, an enigmatic object with a perihelion distance of 0.12 AU that makes it unobservable by most Earth-based telescopes around perihelion. Comet 96P has transited the SOHO fields of view during all five of its perihelion passages since 1996, and several faint fragments were observed accompanying it during its 2012 and 2017 apparitions. We report on our analysis of 96P's SOHO lightcurve, its secular evolution over the last 20 years, and on the evidence of ongoing fragmentation that might have produced the new fragments. We also report on our ground-based efforts to characterize 96P using the 4.1-m SOAR telescope. We observed 96P prior to perihelion in July 2017 and have post-perihelion observations scheduled for June and July 2018.

This work benefited from discussions with the international team "The Science of Near-Sun Comets" led by G. Jones at ISSI (International Space Science Institute) in Bern, Switzerland in 2014-2015. NE, MMK, KB, and MSPK were supported by NASA Near Earth Object Observations grant NNX17AK15G.

SPACE STUDIES OF THE EARTH-MOON SYSTEM, PLANETS, AND SMALL BODIES OF THE SOLAR SYSTEM (B)

THE GOLDEN AGE OF SMALL BODIES, SCIENCE AND EXPLORATION (B1.1)

B1.1-0001-18 ROSETTA AT COMET 67P: DECIPHERING THE ORIGIN OF THE SOLAR SYSTEM, THE EARTH AND LIFE

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After more than 12 years the Rosetta spacecraft crash-landed on comet Churyumov-Gerasimenko on September 30, 2016. It has traveled billions of kilometers, just to study a small (4 km diameter), black boulder named 67P/Churyumov-Gerasimenko. The results of this mission now seem to fully justify the time and money spent in the last decades on this endeavor. In the talk I will look back on the craziest mission ever flown by the European Space Agency and point out its technical challenges and scientific highlights. We will show how the results of this mission change our understanding about the formation of the solar system, the Earth and finally life itself.

B1.1-0002-18 CATASTROPHIC DISRUPTIONS AS THE ORIGIN OF 67P/C-G AND SMALL BILOBATE COMETS

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Images of comets sent by spacecraft have shown us that bilobate shapes seem to be common in the cometary population. This has been most recently evidenced by the images of comet 67P/CG obtained by the ESA Rosetta mission, which show a low-density elongated body interpreted as a contact binary. The origin of such bilobate comets has been thought to be primordial because it requires the slow accretion of two bodies that become the two main components of the final object. However, slow accretion does not only occur during the primordial phase of the Solar System, but also later during the reaccumulation processes immediately following collisional disruptions of larger bodies. We perform numerical simulations of disruptions of large bodies. We demonstrate that during the ensuing gravitational phase, in which the generated fragments interact under their mutual gravity, aggregates with bi-lobed or elongated shapes form by reaccumulation at speeds that are at or below the range of those assumed in primordial accretion scenarios. The same scenario has been demonstrated to occur in the asteroid belt to explain the origin of asteroid families and has provided insight into the shapes of thus-far observed asteroids such as 25143 Itokawa. Here we show that it is also a more general outcome that applies to disruption events in the outer Solar System. Moreover, we show that the porosity is maintained in the process and high-temperature regions are very localized during the impact process, which solves the problem of the survival of organics and volatiles in the collisional process. The advantage of this scenario for the formation of small bilobate shapes, including 67P/C-G, is that it does not necessitate a primordial origin, as such disruptions can occur at later stages of the Solar System. This demonstrates how such comets can be relatively young, consistent with other studies that show that these shapes are unlikely to be formed early on and survive the entire history of the Solar System. A last implication is that observed prominent geological features, such as pits and stratified surface layers, may not be primordial.

B1.1-0003-18 ON THE ORIGIN OF INTERNAL LAYERS IN COMET 67P/ CHURYUMOVGERASIMENKO

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Guided by the results of calculations by Tancredi, Rickman and Greenberg (1994, Astron. Astrophys. 286, 659-682) on the propagation of an amorphous-ice to crystalline phase-change front in an amorphous water-ice simulated comet nucleus, we hypothesize that the strata and intra-strata layers seen in the interior of 67P/ChuryumovGerasimenko are the result of the rapid passage (within 2000 y) of horizontally fronts throughout the interior of the comet during its late stage orbital evolution as a Centaur.

The bi-modal rates of propagation of the fronts (an essentially stationary "quiescent" mode over short radial distances alternating with an "active" rapid spurt mode propagation (100 m/y) over much larger distances) lead to the establishment of alternating strata boundaries and the intra-strata layers. The varied structures found within the strata are the result of different modes of fluidization during the active phase. The independence of the layer systems in the lobes (Massironi and 58 colleagues, 2015, Nature 526, 402-405) is explained by the postulated break-up of the comet from a bi-lobate shape into a close binary configuration at the time of onset of crystallization that weakens the surface. Eventually, the comet returns to a physically connected bi-lobate shape well after the crystallization of the interior is complete. This "phasechange mechanism" may eradicate or overprint evidence in the interior structure of the way the comet was originally formed in primitive times.

B1.1-0004-18 CONSERT PROBING OF 67P/C-G NUCLEUS DURING THE ROSETTA MISSION, OPERATIONS AND RESULTS

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The structure and composition of cometary nuclei is one of the major unknowns in cometary science. These were the scientific objectives of the Comet Nucleus Sounding Experiment by Radiowave Transmission (CONSERT) aboard ESA spacecraft Rosetta. The knowledge of the interior is important to understand the formation and evolution of comets. CONSERT was a bi-static radar composed of two parts, one on the lander Philae on the comet's surface, and another on Rosetta spacecraft (Kofman et al., 2007). CONSERT operated during 9 hours after the landing and made measurements through the small lobe (head) of 67P/C-G. The analysis and interpretation have been done using measurements of the propagation time of the signal through the comet, the shape of the received signals and then 3D modeling of the propagation through the comet. The modelling and the propagation time inside the comet permit to derive the bulk permittivity value (= 1.27) of the cometary interior (Kofman et al, 2015). Permittivity values for porous mixture of ices and dusts were compared with laboratory experimental values in order to obtain constraints on the possible constituents of the comet nucleus (ices, silicates and organics) and its porosity (70-85%). The minimum required content of carbonaceous material is 75 % in volume. This suggests that comets represent a massive carbon reservoir (Kofman et al., 2015, Herique et al., 2016). The shape of the signal, very close to the shape of the calibration one, shows that the scattering by inhomogeneities in the medium is not observable. This indicates that the interior is homogenous at the scale of few wavelengths (Kofman et al., 2015). 3D simulations of the signal propagation in non-homogeneous media have been run to define the sensitivity of CONSERT to inhomogeneities and to find constrains on the internal structures in terms of size and composition at a scale commensurate with the wavelength. Given the high bulk porosity of about 75% inside the sounded part of the nucleus, a likely model would be obtained by a mixture, at this 3-m size scale, of voids (vacuum) and blobs with material made of ices and dust with a porosity larger than 60%. The absence of any pulse spreading due to scattering allows us to exclude heterogeneity with higher contrast (0.25) and larger size (3m) (but remaining on the few wavelengths scale, since larger scales can be responsible for multipath propagation) (Ciarletti et al., 2017). Properties of meterscale inhomogeneities inside the comet are essential to understand cometary formation. The knowledge of the precise position of Philae on the comet, since the September 2016, permitted to improve the determination of the propagation paths inside the comet and therefore to describe better the interior. The influence of the close environment on antennas lobes and polarization was calculated using the Digital Terrain Model of the landing site and used to study the received signal power. We will describe shortly measurements that explored the interior of the comet, discuss results, their interpretation in terms of the internal structure and composition. References [1] Ciarletti et al, CONSERT constrains the internal structure of 67P at a fewmetre size scale, MNRAS, 469 (Suppl. 2), pp.S805-S817, 2017 [2] Herique et al, Cosmochemical implications of CONSERT permittivity characterization of 67P/CG, MNRAS 462, S516-S532, 2016 [3] Kofman et al, The Comet Nucleus Sounding Experiment by Radiowave Transmission (CONSERT). Space Science Reviews, Volume 128, Issue 1-4, 413-432, 2007 [4] Kofman et al, Properties of the 67P/Churyumov-Gerasimenko interior revealed by CONSERT radar, Science, 349, 6247 aab0639, 2015.

B1.1-0005-18 LARGE SCALE MORPHOLOGICAL CHANGES IN THE HAPI REGION ON COMET 67P/ CHURYUMOV-GERASIMENKO

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The Hapi region is located on the northern hemisphere of comet 67P/C-G at the neck that joins the two lobes of the nucleus. It primarily consists of granular material that is unresolved at 0.35 m/pixel resolution and that forms a smooth surface with small slopes with respect to local gravity. The OSIRIS cameras on the ESA spacecraft Rosetta observed Hapi regularly since its rendezvous with the comet in August 2014. No changes were seen during the first five months in orbit but on December 30, 2014, two spots appeared in Hapi. Over the course of two months they grew gradually into a 110 by 70 meter shallow depression with a depth of about 0.5 meters. We use OSIRIS observations to characterize the morphology and spectrophotometry of the region. We use measurements of the thermal emission of the comet by the MIRO millimeter and submillimeter radiometer in combination with thermophysical modeling to characterize the surface temperature, near surface temperature gradient, and thermal inertia of the region. The formation mechanism of the depression is discussed in view of these empirical data.

B1.1-0006-18 THREE-DIMENSIONAL VIEWS OF THE NUCLEUS OF COMET 67P/ CHURYUMOVGERASIMENKO - APPLICATION TO THE CHARACTERIZATION OF ACTIVE PITS

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The Narrow Angle Camera (NAC) of the OSIRIS imaging system aboard ESA's Rosetta spacecraft has acquired approximately 25000 images of the surface of the nucleus of comet 67P/Churyumov-Gerasimenko at various spatial scales down to centimeters per pixel. The bulk of these images have been obtained in sequences and the combined displacement of the Rosetta orbiter along its trajectory and the rotation of the nucleus allow associating many pairs of images appropriate to stereoscopic viewing. This is achieved by constructing anaglyphs after rotating the images so that the relative shift appears horizontal. The shift is set to limit the parallax to approximately 2° (with a maximum value of 4°) for the foreground so as to avoid image deformation. A time of writing, approximately 1000 anaglyphs have been produced. In addition to offering spectacular stereoscopic views of the nucleus, these anaglyphs allow studying the topography of the nucleus at spatial scales unachievable by DTMs. Further coupling with spectral images, we have been able to locate ice patches at the bottom of several narrow pits which indicate the presence of sub-surface ice at depths of a few meters. These narrow pits are most likely the sources of collimated jets widely seen in the coma of 67PC-G.

B1.1-0007-18 SURFACE CHANGES ON THE IMHOTEP REGION - INTERPRETATION OF VIRTIS DATA WITH THE HELP OF A THERMOPHYSICAL MODEL

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The Rosetta mission and the huge amount of data on the comet 67P/CG has given us the opportunity to test and improve in an unprecedented way the models describing the thermophysical properties of cometary nuclei. Using this kind of models and comparing their results with the observations, it is possible to determine the properties of the nucleus surface and how they change with time, and to infer the conditions of the interior, shedding some light on the formation and evolution processes. In this talk the preliminary results will be shown of the interpretation of the surface temperatures derived from the VIRTIS spectrometer. With the help of the thermophysical model and using a feedback process it is possible to interpret the temperatures derived from VIRTIS spectra in order to determine the amount of ice that is present in the surface layers and its variation along the orbit. It is also possible, using the VIRTIS data, to infer other thermophysical properties of the surface such as the porosity and the roughness. The area on which this analysis has been performed is the Imhotep region, selected for its variety of different terrains and structures and the good and continuous coverage along the time of the mission.

B1.1-0008-18 THE MASS LOSS OF COMET 67P/CHURYUMOV-GERASIMENKO AND IMPLICATIONS

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The Rosetta Radio Science Investigations experiment (RSI) determined the mass and the degree and order two gravity field of the nucleus of comet 67P/Churyumov-Gerasimenko after arrival in summer 2014 and again before the ultimate end of the mission in fall 2016. The comparison of the two mass values revealed a substantial mass loss by gas and dust of about 10 million tons. The low bulk density of 537 kg/m3 and reasonable assumptions of the compact dust material density implies a high porosity of about 75% and a high dust-to-ice mass ratio of the nucleus body. The ROSINA and MIRO gas observations, however, integrated over the mission time reveal a mass loss by the gas alone which does not allow a high dust-to-ice mass ratio for the material in space beyond a certain distance from the nucleus where the material does no longer fall back to the nucleus. The dust-to-ice mass ratio must be smaller than 1 in order to agree with the total mass loss determined by RSI. Only a small amount of the lifted mass at an active spot on the surface reaches space. Most of the dust mass falls back and is redistributed on the surface.

B1.1-0009-18 THE CAESAR NEW FRONTIERS MISSION

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The Comet Astrobiology Exploration SAmple Return (CAESAR) mission is one of two mis-sions selected for Phase A study by the NASA New Frontiers Program. CAESAR will acquire and return to Earth for laboratory analysis a minimum of 80 g of surface material from the nucleus of comet 67P/Churyumov-Gerasimenko. CAESAR will characterize the surface region sampled, preserve the collected sample in a pristine state, and return evolved volatiles by capturing them in a separate gas reservoir. NASA Goddard provides project management, systems engineering, safety and mission assurance, contamination control, and mission operations. Orbital ATK develops the spacecraft, based on Dawn mission heritage, which like CAESAR uses solar electric propulsion. Cornell University, under the guidance of Principal Investigator Steven Squyres, manages the science team.

Comet sample analyses can provide unparalleled knowledge about presolar history through the initial stages of planet formation to the origin of life. CAESAR's sample analysis objectives ad-dress questions regarding the nature of Solar System starting materials and how these fundamental components came together to form planets and give rise to life.

The CAESAR Camera Suite enables collection of a sample from the surface of comet 67P. When sampling a poorly-explored or unexplored comet, a substantial payload of instruments would be needed to study the nucleus thoroughly enough to allow wise sample selection. By going to a comet that has already be studied in detail by Rosetta, this need is reduced. The guiding principal of the CAESAR mission is that "it is all about the sample". This guiding principle allows our precious and limited resources to be focused on maximizing the scientific value of the returned sample. A set of six cameras collect images to support sample site selection, optical navigation, and documents the sample before, during, and after collection. The Camera Suite also provides images of the geologic context for the sample and documents changes to 67P since the Rosetta encounter.

CAESAR's Sample Acquisition System (SAS) is specially designed to collect a sample of the surface of comet 67P, based on observation by the Rosetta/Philae mission. It contacts the comet surface during a 5-second touch-and-go (TAG) maneuver, mounted on a three-degreeof-freedom TAG Arm. During surface contact, pneumatic jets direct the sample into a 1.5-liter sample container. Direct imaging of the sample container interior verifies sample collection and a load cell in the TAG Arm measures sample mass. Once successful sample collection has been verified, and while the sample is still cold (< -80 °C), the TAG Arm inserts the sample container into the Sample Containment System (SCS), mounted inside the Sample Return Capsule (SRC). The SCS immediately seals the sample, preventing material from escaping into space.

The SCS then slowly warms the sample from the cold temperatures of the collection to the temperature of the comet surface near perihelion. As gases evolve from the solid sample, they pass from the SCS into a 5-liter passively cooled gas reservoir in the Gas Containment System (GCS), also mounted in the SRC, separating them from the solid sample and thereby protecting the solid sample from alteration. Once H2O has sublimated from the solid sample, the GCS is sealed to capture the volatiles it contains, and the SCS is vented to space to maintain the solid sample under vacuum.

The SRC, which is provided by the Japanese Aerospace Exploration Agency (JAXA), lands at the Utah Test and Training Range (UTTR) and the team places it in cold storage immediately. The team transports all recovered hardware to the Johnson Space Center, where the samples are re-moved and delivered to the dedicated CAESAR curation facility. After preliminary examination, samples are made available to CAESAR science team and the worldwide scientific community.

B1.1-0010-18 DUST COMPOSITION OF COMET 67P AS MEASURED BY THE COSIMA MASS SPECTROMETER OVER TWO YEARS OF THE ROSETTA MISSION

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COSIMA was a Time-Of-Flight Secondary Ion Mass Spectrometer (TOF-SIMS) on board the Rosetta spacecraft [1, 2]. During two years, the instrument allowed in situ analysis of the dust particles released from 67P/Churyumov-Gerasimenko before and after the comet's perihelion.

Compared to the previous space missions targeting a comet, COSIMA collected the cometary dust at a lower impact velocity (<10 m.s–1 [3]) that largely preserved the dust chemical properties and part of its physical structure such as the particle porosity [4, 5]. More than 35,000 particles were collected during the mission [6] and about 400, ranging from 50 to 1000 µm in size, were analyzed by TOF-SIMS.

We will report the elemental composition of the cometary dust as deduced from COSIMA measurements [7, 8, 9]. The average elemental composition measured for 67P's dust will be compared to previous results obtained from the Giotto and Vega missions for comet 1P/Halley and the Stardust mission for comet 81P/Wild 2, to the composition of Chondritic Porous Interplanetary Dust Particles (CP-IDPs), and to the CI chondrite composition. The dust collected and analyzed by COSIMA is representative of 67P's non-volatile composition. The average minerals to organics ratio deduced from the TOF-SIMS measurements gives constraints on 67P's surface and nucleus characteristics. The astrochemical implications of COSIMA results will also be discussed with a focus on the high carbon content found in the cometary dust [7].

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B1.1-0011-18 THE ISOTOPIC COMPOSITION OF COMETARY DUST MEASURED WITH ROSETTA/ COSIMA

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The isotopic composition of a substance can provide important information about the substance's history, since isotopic fractionation is sensitive to many conditions such as chemistry, temperature, and radiation. The isotopic ratios of elements have been measured in many extraterrestrial materials, such as chondritic meteorites, interplanetary dust particles, and comets. The great majority of such cometary measurements have been in the gas phase, with relatively few measurements in the dust [1, 2, 3]. Here we present measurements of isotopic composition for several elements measured in cometary dust using the COSIMA instrument.

COSIMA was a Time of Flight - Secondary Ion Mass Spectrometry (ToF-SIMS) instrument aboard the Rosetta orbiter that spent approximately 2 years within tens to hundreds of kilometers of the nucleus of comet 67P/Churyumov-Gerasimenko [4, 5]. COSIMA collected 35000 dust particles and fragments from 67P. Practical considerations restricted the number of particles upon which ToF-SIMS analysis was performed to a few hundred, and a subset of these particles will be discussed here. Comparison to measurements of the isotopic composition of other extraterrestrial matter will be made and the implications for the history of comets will be considered.

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B1.1-0012-18 NON-SPHERICAL DUST DYNAMICS IN THE 67P/CHURYUMOV - GERASIMENKO COMA CONSTRAINED BY GIADA AND ROSINA DATA

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To interpret Grain Impact Analyser and Dust Accumulator (GIADA) data, we performed dust dynamical numerical simulations with both spherical and non-spherical (spheroids) shapes. This allowed us to analyse how the grain nonsphericity affects the data interpretation. We considered two GIADA observational periods, 19- 27 February 2015 and 13-28 March 2015. Gas parameters of the coma gas field were calibrated with ROSINA measurements. The dust grains are assumed to be out of the near nucleus coma, i.e. where the gas velocity is radial and constant, therefore were either aligned or have random but constant orientation with respect to the gas drag.

We reproduced the terminal velocities, in agreement with the GIADA measurements, using two different spheroidal shapes and spheres. We obtained: 1) that the dust particle shapes which reproduced best the GIADA dust speeds were consistent with the mass versus cross-section relationship found in the GIADA data; 2) different terminal velocities for spherical and nonspherical particles of the same mass; 3)rotational frequencies of the spheroidal particles that best fit the GIADA measurements in these periods.

This research has recently been published (Ivanovski et al. MNRAS 469, S774-S786 (2017) doi:10.1093/mnras/stx3008).

B1.1-0013-18 DERIVATION OF GAS AND DUST SURFACE FLUXES ON COMET 67P

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In August 2014 the ESA Rosetta space probe approached less than 100 km to the nucleus of comet 67P/Churyumov-Gerasimenko (67P), when it was at 3.00 AU from the Sun. During the following several months it gathered information on the dusty-gas atmosphere in the immediate vicinity of the nucleus.

We describe the models developed to predict the gas and dust environment of comet 67P and their methods of adjustment to the observational data obtained by Rosetta before its lander Philae landed on 67P surface.

Ideally speaking, the optimization of the gas model would have resulted from a succession of predictions of the local gas parameters along optimal Rosetta trajectories, as well as of the gas parameters inside the field-of-view of the remote-sensing instruments, followed by the comparison with the in-situ and remote-sensing instruments data. This turned out to be impossible for many reasons. Actually, predefined Rosetta trajectories and instrument view directions turned to be non-optimal for adjusting the model parameters. Therefore, we focused on: (1) fitting the measurements performed by the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA - Balsiger H., et al., Space Sci. Rev., 128, 2007) with the gas model, and (2) fitting the dust coma images acquired by the Optical, Spectroscopic, and Infrared Remote Imaging System (OSIRIS - Keller et al., Space Sci. Rev., 128, 2007), taking into account the dust size distribution (Fulle et al., ApJ, 821, 2016) obtained by the Grain Impact Analyser and Dust

Accumulator (GIADA - Della Corte et al., J. Astron. Instrum., 3, 2014), with our dust model. We present the resulting distribution of gas and dust fluxes over 67P surface.

B1.1-0014-18 THE DUST COMA ENVIRONMENT OF 67P/CHURYUMOV-GERASIMENKO AS OBSERVED BY VIRTIS

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ESA's Rosetta spacecraft had the unique opportunity to be in the vicinity of comet 67P/ChuryumovGerasimenko for 2.5 years, observing the regions of the coma within a few km of the surface and to study the dynamical and physical properties of the emitted dust. In this work, we will present a summary of the dust coma investigations during the pre-perihelion and the perihelion passage, performed by the Visible InfraRed Thermal Imaging Spectrometer (VIRTIS) onboard Rosetta, in the spectral range between 0.2 to 5 m (Coradini et al. 2007). During the pre-perihelion period, the main dust results can be summarized as follows: 1-The general spatial distribution of the dust is strongly correlated with the presence of H2O emission and is significantly different from the distribution of CO2 emission; 2-The sunward radial profiles of the dust show that the dust particles, lifted off the nucleus, are accelerated by the gas in the first 4-5 km and then transit into the free flowing collision-less zone with a 1/ column density profile, where is the distance from the center of the comet; 4- The colour of the dust in the coma has a fairly steep red slope in the VIS of about 9 to 12 ± 1 % per 100 nm and a much shallower slope in the IR with values of 1.7 ± 0.2 % per 100 nm. The colours do not show any spatial variation, nor any variation with distance from the nucleus. This indicates that the dust expelled into the coma from the nucleus is quite uniform, although it could also be that any changes in its composition (Rinaldi et al. 2016). 5- Combining the VIRTIS data with those by GIADA, the dust detector onboard Rosetta, we evaluate the dust size distribution power-law index that is greater than -3.1. This index matches the one determined using GIADA (Della Corte et al. 2016) March 2015 data indicating that the inner coma radiance is dominated by particles larger than 10 m (Rinaldi et al. 2017). During the perihelion period, we focused on the analysis of the outburst events. The outbursts are characterized by a sudden and short increase of the dust emission, from localized areas with variable degree of collimation, followed by a gradual decrease of activity with a life time ranging between 6 to 24 minutes. The quick onset is correlated with a change of the visible dust colour from redder with 15-18 ± 3 %/100 nm, to bluer with values around 7-10 ± 0.3%/100 nm (Rinaldi et al. 2018, in preparation). The combination of VIS and IR dust properties reveals the presence of very small (less than 100 nm) and bright grains in the ejecta that could be formed by silicate material, implying the thermal degradation of the carbonaceous material, or icy grains (Bockelée-Morvan et al 2017). The dust coma from the outburst was found to expand at speeds between 22.2 ±2.2 to 30.2 ±

1.4 m/s for the "big" outbursts and 38.4 ± 2.1 to 64.9 ±10.6 m/s for "mini" ones. The total ejected mass during an outburst event is estimated to lie between 100 to 6000 kg for a duration of 6 - 24 minutes, assuming a size distribution indexes between -2.5 to -3 (Rinaldi et al. 2018, in preparation).

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B1.1-0015-18 MULTI-INSTRUMENT ROSETTA DATA AND MODEL COMPARISON FOR THE INNERMOST COMA OF 67P FOR THE PERIOD AROUND EQUINOX (MAY 2015)

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University of Bern, Bern, Switzerland OSIRIS, ROSINA, MIRO, and VIRTIS

Rosetta noindent From August 2014 to September 2016 ESA's Rosetta spacecraft escorted comet 67P/Chury-umov-Gerasimenko (hereafter 67P) on its journey into the inner solar system and out again. The mission provides, via various dust and gas instruments, unprecedented data on the nature of cometary activity. The determination of the activity distribution on the surface of a comet is a key goal of any mission to investigate the interaction of the comet with the Sun.

noindent As the ice sublimates the gas expands into space it fills the near-nucleus environment. Individual sources of activity have been observed on the surface but it remains uncertain where the bulk of the mass is lost and how the processes that are involved work in detail. There are several reasons for this. First, imaging experiments use the dust as a proxy for the gas activity. Because the optical depth of the dust is orders of magnitude below 1 in all but a few cases, it is not possible to trace dust filament back to the source against the backdrop of the illuminated surface. Second, remote sensing instruments detecting gas emission (i.e. infrared and sub-mm spectrometers) may suffer with limited spatial and temporal resolution. In addition, the spectra lines may be optically thick and the line-of-sight direction usually cuts through inhomogeneous coma (in density or temperature) which further complicates their interpretation considerably. However, as we will show, with good a-priori estimates of coma structures spectral lines can be accurately inverted to provide constraints of the gas coma down to a few hundreds of meters above the surface (e.g. MIRO). The in-situ instruments (e.g. ROSINA, or GIADA) must consider possible biases due to the spacecraft position relative to the nucleus and respective illumination conditions on the surface. For instance, the frequent use of terminator orbits by Rosetta introduced a significant problem because the measured local densities are at points remote from what we assume to be the main direction of outflow, namely near the sunward direction. In addition, the possible inhomogeneities of the outgassing at the surface cannot be detected due to the fact that the rapid gas expansion smoothens the coma. Therefore, measurements taken tens of kilometers above the nucleus surface are rather insensitive and provide only ambiguous results.

noindent The difficulties described above show the need for predictive models that can reproduce multiple measurements in one self-consistent framework. We will present results from our study of diverse Rosetta data sets (including OSIRIS, VIRTIS, MIRO, and ROSINA), constraining the gas emission into the coma and to establish whether the data enable us to reach appropriate conclusions on the activity distribution on the nucleus surface. The models can be used on the one hand to constrain certain properties of the activity and on the other hand they provide clues on the limits of the interpretations of some of the available datasets. We focus here on the time around May 2015 (equinox). While this period is a few months prior to perihelion, the spacecraft was close to the comet, providing a relatively high spacial resolution of the remote sensing observations such that, in principle, they can be more easily linked with the in-situ measurements.

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B1.1-0016-18 PLASMA AT COMET 67P/ CHURYUMOV-GERASIMENKO: IMPLICATIONS FOR COMETARY ACTIVITY

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The european Rosetta mission expands upon results of previous missions to comets with the significant improvement of long-term observations. Its two-year mission allows for a detailed study of the evolution of the cometary plasma environment and its dependence on cometary activity as well as solar wind parameters. There have been several previously unobserved features, like low-frequency waves and atypical draping, that have been found to depend heavily on cometary activity. Some features only exist at specific activity levels and others change with it. Here we present a general overview of the magnetic field evolution and the occurence of features such as the diamagnetic cavity as dependent on the outgassing rate. It is found that the classical picture of magnetic field lines draping around the comet is only valid in a very small time interval around the comet's closest approach to the Sun. Further out the draping changes to a kinetic regime and vanishes entirely at large heliocentric distances. However, the magnetic field is often dominated by large scale ($\Delta B/B$ 1) fluctuations which are related to the diurnal variations in outgassing rate. Contrary to that the field strength is primarily given by the solar wind conditions.

B1.1-0017-18 STUDY OF ELECTRON ACCELERATION BY LOWER HYBRID WAVES AT COMET 67P

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We report on the observation by the Ion and Electron Sensor (IES) on board Rosetta of energetic (>1 keV) electrons in the plasma environment of comet 67P. Rosetta was 1.8 AU from the Sun and 100 km from 67P at that time (Dec. 3, 2015). Most of the electrons in the cometary coma are expected to be of solar wind or photoionization origin so they should be at much lower energy than this. Although, during the Vega flybys of comet Halley, 1keV electrons were observed and these have been explained as having been accelerated by lower hybrid (LH) waves resulting from the two-stream instability involving the solar wind and pickup ion flows. These waves resonate with the cyclotron motion of the ions and the longitudinal motion of electrons. We postulate that the energetic electrons we have observed on Dec. 3, 2015 (and intermittently during the rest of that month) are also the result of such a process and that Landau damping causes the abrupt decrease in this energy (also seen at Halley). Studies using measurements by the Langmuir probe instrument (LAP) on board Rosetta identified occurrences of LH waves with frequency the order of several Hz during October and November 2015 although IES did not see high-energy electrons during those periods. However, we frequently do see electrons accelerated to 100s of eV, which could also be the result of acceleration by LH waves produced under other conditions.

B1.1-0018-18 RESULTS OF DAWN'S EXTENDED MISSION AT CERES: A NEW LOW

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Dawn completed its primary mission, achieving all of its Level-1 requirements, in June of 2016 after spending 7 months in a low altitude mapping orbit (LAMO) at 385 km. NASA approved a one-year extension of mission operations (extended mission 1, or XM1) at Ceres to refine the primary mission data sets and obtain repeat observations to look for surface changes. The objectives of XM1, described below, were achieved with sufficient hydrazine remaining on the spacecraft to support continued operations. In October 2017, NASA approved a second extended mission for Dawn at Ceres (XM2), spanning perihelion passage (April 2018), to obtain new high-priority science data until the spacecraft runs out of hydrazine. The two extended mission phases are described here, as well as the science objectives achieved and planned. XM1 began in July 2016 at the LAMO altitude (385 km), where additional observations were made by the Gamma Ray and Neutron Detector (GRaND) for over 9 weeks to improve counting statistics. At the same time, additional off-nadir imaging was obtained to enlarge the data set used to construct a high-resolution topographic model at 35m/pixel. Additional radiometric tracking data contributed to an increase in the resolution of the gravity field to degree and order 18. High-resolution framing camera (FC) color imaging and visible and infrared mapping spectrometer (VIR) spectra were obtained for several high-priority targets, including Occator crater. Dawn then spiraled up to an orbit at 1500 km altitude, equivalent to the first highaltitude mapping orbit (HAMO) in the prime mission, and obtained full 7-filter color mapping with the FC in the south

polar region. Repeat coverage was obtained over the rest of Ceres to compare to the previous HAMO full-color data set. Infrared spectra of high-priority targets (including Juling and Oxo craters) were obtained, which had proved difficult to capture in LAMO. In the third phase, Dawn spiraled up to an elliptical orbit above 7200 km altitude to obtain GRaND background spectra to improve the signal to noise ration of data acquired at low altitude. In the final phase of XM1, the spacecraft ascended and rotated the orbit plane to perform an opposition observation at 20,000 km. The phase curve was obtained down to 0 degrees in the panchromatic and seven color filters. The spacecraft stayed in a high altitude, hydrazine-conserving orbit to complete acquisition of GRaND background data and monitor for solar energetic particles implicated in sputtering a transient exosphere, while the XM2 proposal was being evaluated. In October 2017, NASA approved XM2 at Ceres with the goal of obtaining elemental concentrations with high sensitivity and spatial resolution. Proximity to the target is key to improving the strength of the gamma ray and neutron signals, as well as improving the ability to spatially resolve the elemental variations. Dawn will enter an eccentric orbit with periapsis lower than 50 km, enabling GRaND to directly measure the elemental composition of surface units with spatial resolution at least 7x better than in LAMO. The measurements will occur during a particularly quiet period of solar activity, ensuring the intensity of galactic cosmic rays, used to interrogate the surface, is maximum. Limited longitudinal coverage will be obtained in a resonant orbit that focuses on coverage of Occator crater and its ejecta, while also characterizing the ancient heavily cratered terrains in the north, and large Urvara and Yalode basins in the south. Combining these very low altitude data with the extended background time series will improve the entire GRaND data set and yield a deeper understanding of surface geochemistry, including the concentration and distribution of subsurface ice, as well as the elemental concentration of the ice-free regolith which provides clues about processes that shaped the regolith, crust, and interior. In the course of achieving the low resonant orbit, VIR observations of the better-illuminated southern hemisphere will be obtained, as well as FC color imaging of high-priority targets to obtain new or repeat coverage. Along with the GRaND results, these data will contribute to the goal of testing hypotheses of Ceres' origin and hydrothermal evolution, as well as understanding cyromagmatic processes. Once the spacecraft runs out of hydrazine, it will lose the ability to maintain the solar arrays pointing to the sun, and the spacecraft will lose power. It will continue to orbit Ceres stably in the eccentric orbit for decades to come in accordance with the planetary protection requirements.

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B1.1-0019-18 GEOPHYSICAL CONSTRAINTS ON CERES' INTERIOR COMPOSITION AND STRUCTURE AS REVEALED BY NASA'S DAWN MISSION

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Before the arrival of NASA's Dawn mission, the dwarf planet Ceres was generally considered to be differentiated, with a thin rocky regolith hiding a water-ice mantle tens of kilometers thick, beneath which lay a rock "core" [1, 2, 3]. Models assuming an undifferentiated porous interior were also consistent with available data [4]. Data returned from the Dawn spacecraft have revolutionized our understanding of Ceres' interior structure, composition, and evolution. Framing camera (FC) images revealed Ceres' surface to be heavily cratered, contradicting expectations of an ice-dominated surface morphology in which crater topography is rapidly muted by viscous relaxation [5]. High-resolution shape

models from Dawn indicate that most large craters (>80 km in diameter) are more than 2 km deep relative to the surrounding terrain [6]. Numerical simulation of the evolution of these craters indicates that Ceres' outer "crust" must contain no more than 35% water ice by volume to preserve the observed crater topography [6]. The pre-Dawn conception of a relatively pure ice layer at depth can therefore be rejected. Yet the crust is unlikely to be ice-free. Analysis of latitudinal variations in the topographic power spectrum at low spherical harmonics indicates that power is lower at low latitudes than at high [7]. Thus, viscous relaxation is, in fact, occurring at long wavelengths (>246 km) [7, 8], implying that the viscosity of Ceres' crust is not rock-like. These observations are consistent with Gamma Ray and Neutron Detector (GRaND) measurements of 20% water ice by volume in the top few meters of regolith at high latitudes [9], Visible and Infrared Spectrometer (VIR) detection of small amounts of exposed water ice on Ceres' surface [10], and crater simplecomplex transition diameters similar to icy bodies [11].

Additional constraints on the interior were provided by Dawn's characterization of Ceres' gravity field and shape [7, 12, 13], which indicate that Ceres' is slightly denser than previously inferred (ρ = 2.162 0.008 g/cc) and at least modestly differentiated (normalized mean moment of inertia of C/MR2 = 0.37). Admittance analysis suggests Ceres' outer crust is 40 km thick, with a density of just 1.2-1.4 g/cc, depending on the isostatic model [7]. The deeper interior has a density of 2.4 g/cc [7, 14]. The combination of the low density and high viscosity of the crust places constraints on its bulk composition, which cannot be a simple combination of ice and hydrated silicates. Instead, a significant fraction of the crust (at least 30% by volume) must be one or more strong, but low-density phase, such as salts or clathrate hydrates [5, 7, 8]. The bulk composition of Ceres' crust, which is roughly 33% water ice, 33% salts/clathrates, 33% hydrated silicates (a range of compositions are possible - the fraction of salts determines the amount of silicates) may result from the freezing of a past ocean [15].

In addition to revealing these bulk interior properties, Dawn data has shown that Ceres' crust is heterogeneous over large spatial scales [e.g., 16, 17]. The thickness of Ceres' crust is variable, and several mass anomalies have been identified in association with geomorphic features [7]. Such anomalies might suggest compositional variation: a mascon at Ceres' largest crater, Kerwan, has been attributed to volatile loss and densification of the crust during the impact that formed the crater [18]. Ceres' many tholi (mounds) might also result from subsurface flow of lowviscosity material within the stronger crust: a process analogous to salt tectonics on Earth [19]. In these cases, Ceres' internal heterogeneity is directly manifesting itself in its surface morphology. Testing models of Ceres' origin and evolution, and past and present habitability derived from Dawn's data requires understanding the past and present distribution of volatiles within the interior, which only a new mission to the dwarf planet can provide.

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B1.1-0020-18 (1) CERES: STUDY OF THERMAL CONVECTION IN THE MANTLE AND ITS MECHANICAL EFFECTS

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Ceres is the largest body of the Main Belt, which is characterized by a huge abundance of water ice in its interior. This feature is suggested by its relatively low bulk density (2162 kg m-3, Russell et al. 2016, Park et al. 2016) and by several geological and geochemical evidences (specific minerals or salts produced by acqueous alteration, icy patches on the surface, lobate morphologies interpretable as surface flows (De Sanctis et al. 2016, Carrozzo et al. 2018, Raponi et al. 2018, Zolotov 2017 and Schmidt et al., 2017). Ceres is partially differentiated as suggested by its normalized moment of inertia, 0.37 (Park et al. 2016). A typical internal structure proposed for Ceres is: a rocky core (300-350 km), an icy (or muddy) mantle (100-150 km) and a rocky crust some kilometers in depth (eg. Mc Cord Sotin 2005, Neveu Desch, 2015). The temperature gradient across the mantle, estimated through numerical modelling (e.g. McCord Sotin 2005, Neveu Desch 2015) would be large enough to initiate a thermal convection in the mantle. Since the mantle is not uniquely defined from a composition point of view, in this work we explore how the composition and, in particular the "degree" of muddiness of the mantle, can influence the characteristic of thermal convection. We also estimate the thickness of the top conductive boundary layer and the mechanical stress, which can cause its deformation.

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B1.1-0021-18 CERES SUBSURFACE MINERALOGY DETECTED BY VIR DATA ANALYSIS OF CRATER CENTRAL PEAK MATERIAL (CCP)

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The dwarf planet Ceres has been intensively studied since 2015, when the NASA Dawn spacecraft entered its orbit and acquired images by means of a Framing Camera (FC) and a hyperspectral Visible and Infrared Mapping Spectrometer (VIR). Reflectance spectra revealed a cerean crust mainly composed of a dark component, mixed with Mg-phyllosilicates, NH4- phyllosilicates and Mg/Ca-carbonates, creating absorption bands at 2.7, 3.1, 3.4 and 4.0 μm [1]. Colour images showed that Ceres is a heavily cratered rocky body, where complex craters with central peaks are observed to be widespread across its surface. Central peaks form when complex craters with a minimum diameter of 25 km [2] are created. They are composed of subsurface material uplifted by the impact [3, 4]. The material composing the central uplift is termed crater central peak material (ccp) and its spectral analysis can provide information about the composition of the Ceres subsurface. Reflectance spectra of 32 ccps are reported in this work. We observed a relation between the ccps' ages and

infrared spectral slope (between 1.2 and 1.9 μm). This is probably related to a fragmentation of the regolith into finer grains or to differences in composition. The mineralogical composition of ccps is similar to that of the Ceres surface. However, some differences can be noted in ccps located at poleward latitudes and in ccps excavated from deeper layers of the subsurface. Ccps located at poleward latitudes show deeper absorption bands at 2.7 and 3.1 μm, suggesting that subsurface deposits closer to poles are richer in Mgand NH4-phyllosilicates. Furthermore, 3.1 μm band depths are deeper in ccps coming from greater depth of excavation, indicating that the abundance of NH4-phyllosilicates increases with increasing depth in the subsurface. Carbonates are globally diffused in Ceres subsurface, since the 4.0 μm band depth does not show a particular trend at different latitudes or with increasing depth of excavation. Na-carbonates are part of the mineralogical composition of Ernutet, Haulani and Ikapati ccps whose excavation depths are between 6 and 9 km.

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B1.1-0022-18 CERES' SURFACE COMPOSITION OBSERVED BY DAWN/VIR INDICATES AN OCEANIC WORLD

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The Dawn spacecraft [1] arrived at Ceres in early 2015, the second of its targets, and performed a detailed study of its surface and internal properties. Dawn is equipped with a Visible and InfraRed Mapping Spectrometer (VIR) [2] to study the surface composition of the mission targets. The VIR instrument observed Ceres' surface at different spatial resolutions and revealed the presence of different minerals. The average thermally-corrected reflectance spectrum of Ceres shows several bands in the 2.6-4.2 m wavelength region, at 2.72, 3.05-3.1, 3.3-3.5, and 3.95 m. The most prominent is a strong and narrow absorption centred at 2.72-2.73 m indicative of OH-bearing silicates. The other bands indicate the presence of ammonia bearing species and carbonates [3,4,5,6]. The surface is mainly composed of a dark and spectrally neutral component (carbon, magnetite), Mg-phyllosilicates, ammoniated clays, carbonates and salts. The observed species and their distribution suggest endogenous, global-scale aqueous alteration [7]. While mostly uniform at regional scale, Ceres' surface shows localized areas characterized by different chemical species and/or variations in abundances. Water ice was found in localized small patches, especially at high latitudes [8] in the North hemisphere. In a specific crater, not far from the equator in the southern hemisphere [9], water ice was found to varies with time. Sodium carbonates have been identified in several areas on the surface, notably in Occator bright faculae [10,4] and in many of the bright areas that punctuate the surface of Ceres. Organic matter has been discovered in several places, most conspicuously in a large area close to Ernutet crater [11]. The signature is associated to aliphatic organics. Ceres shows mineralogy and geology dominated by the action of water and other volatile ices mixed with rocks. The surface displays clearly the products of aqueous alteration and ice on the surface and subsurface. Moreover, Ceres shows clear sign of “recent” hydrothermal activity [4]. The presence of ammonia in phyllosilicates and salts [3,4,5] indicates the accretion of volatiles, such as ammonia in the original material from which Ceres formed, suggesting a cold formation environment. Moreover, the presence of organic species on Ceres, mixed with minerals formed by water alteration and hydrothermal processes, suggest a favourable environment for the developing of molecules precursor of biological molecules.

Acknowledgements

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B1.1-0023-18 THE FORMATION AND EVOLUTION OF CERES’ OCCATOR CRATER AND ITS FACULAE

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When the Dawn mission explored Ceres from 2015 to 2018, it revealed intriguing bright regions inside the 92-km-diameter Occator impact crater, which were named Cerealia Facula and Vinalia Faculae. Here we synthesize together studies that investigate the driving forces behind the formation of Occator and its faculae, which are presented in a special issue of the journal 'Icarus'. Occator's ejecta blanket, terraces and hummocky floor material formed during and/or immediately after crater formation. The lobate material is interpreted as a slurry of impactmelted water, soluble salts and boulders of unmelted silicates/salts that flowed around the crater interior before solidifying. It is suggested that the central pit formed when an initial liquid water central uplift drained into impact induced fractures. The outer edge of Cerealia Facula is interpreted as a residual salt deposit derived from relatively short-lived impact-induced hydrothermal circulation. The majority of Cerealia Facula is located within the central pit, and is thought to have formed significantly later than Occator, from brines derived from a pre-existing reservoir and/or an impact-induced reservoir. A part of the lobate material was likely inflated by cryomagmatic intrusion, giving it a hummocky texture and forming fractures. It is proposed that brines used these fractures to travel to the surface and form the Vinalia Faculae. The central dome is located in the central pit, along with the majority of Cerealia Facula, and was one of the last features to form in the crater. Small, bright impact craters superpose the faculae, indicating that the faculae have slightly darkened from mixing and/or space weathering. Occator's faculae are the freshest endmember of an evolutionary pathway for Cerean bright regions. Unlike Cerealia and Vinalia Faculae, the majority of bright regions on Ceres are formed from re-excavated material. We find that Ceres is an active world where briny liquids have been mobile in the geologically recent past, driven by either entirely impact-derived or impact and endogenic driving forces. Faculae have likely formed throughout Ceres' history, but Occator's are currently striking because they are geologically young. Part of this work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract to NASA. Government sponsorship acknowledged.

B1.1-0024-18 THERMAL ANALYSIS OF SPECIFIC REGIONS OF INTEREST ON CERES

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We describe the thermal behavior of some notable features, investigated by the Dawn spacecraft on the dwarf planet Ceres, using thermal infrared data acquired by the Visible and InfraRed mapping spectrometer (VIR), and comparing them with the local geology and mineralogy of those areas. Based on experience gained at Vesta, thermal information at unprecedented spatial resolution is useful in constraining thermophysical properties, which ultimately allow a comprehensive interpretation of the observed features. On Ceres, the feature that displays the largest thermal contrast, both on a regional and local scale, is the 34-km crater Haulani, located in the equatorial region and close to the prime meridian. Its central peak, rim and its nearest ejecta appear cooler than surrounding terrains observed under similar illumination conditions and local solar time. While Haulani is one of the youngest surface features of Ceres (<6 Myr), its thermal contrast is not found in other young craters like Oxo, Juling and Kupalo, making it difficult to invoke age and space weathering as the sole reason for this observational evidence. Rather, the characteristics of the impact event that generated Haulani, which triggered hydrothermal activity in the shallow subsurface, could have exposed material with higher density and/or characterized by different thermal conductivity compared to most of the other surface features.

Bright material units were discovered on Ceres by the Dawn spacecraft during approach in early 2015. The brightest cluster of spots is found in the 92-km complex Occator crater. VIR data acquired in the near infrared revealed that Cerealia Facula (the brighest spot) is made up of an outcrop of anhydrous sodium carbonate, which is the solid residue of crystallization of brines erupted from below. Despite their compositional uniqueness on Ceres, Occator's faculae do not show any substantial thermal contrast at spatial resolutions of kilometers down to a few hundreds of meters, suggesting that albedo does not strongly constrain daytime surface temperature on Ceres.

With an average height of about 4 km, Ahuna Mons is the highest mountain discovered on Ceres, believed to be cryovolcanic in origin. A thermal analysis of Ahuna Mons carried out with VIR highlights that the northern flank and the summit of Ahuna could be inherently cooler than the surrounding regions observed at the same local time. Because surface composition is quite homogeneous within Ahuna Mons, this evidence could be related to a different compactness of the surface regolith in these areas.

Dawn/VIR spectra allowed a safe identification of water ice-rich materials on the surface of Ceres. About a dozen of ice-rich units were discovered in as many craters located poleward of 30°, favored by the peculiar local topography, which allows ice to be shielded from direct sunlight for most of the Cerean day. In this respect, crater Juling is particularly interesting since the the extension of its ice-rich unit has been discovered to change with time, suggesting a potential connection with the sporadic emissions of water and hydroxyl observed from space. Because pure surficial H2O ice would sublime under current thermal conditions on Ceres, where daytime surface temperatures span the range 180-240 K, direct thermal mapping enabled by VIR infrared data can put constraints on the ice loss rate of ice-rich materials, helping us to establish their origin.

B1.1-0025-18 ROUGHNESS OF CERES FROM HIGH-RESOLUTION SHAPE MODELS

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The Dawn spacecraft has been orbiting dwarf planet Ceres since March 2015. Images from the Dawn's Framing Camera (FC) have been used to create shape models of Ceres using stereophotogrammetry [1] and stereophotoclinometry [2,3] techniques. These shape models have since been used for orthorectifcation of the FC images and computing photometric corrections [4], conducting local geomorphologic studies [e.g. 5] as well as constraining the internal structure of Ceres [6,7].

The goal of this paper is to characterize the roughness of Ceres topography at a range of scales. We follow the methodology from [8] to compute scale-dependent roughness. First, we compute differential slopes, which are differences of slopes between two (long and short) baselines. The roughness is then computed as the interquartile width (using 25th and 75th percentiles) of the differential slope distribution within a certain area (0.5circ bins in our case). We computed roughness between the following short and long baselines: 246 meters and 574 meters, 574 meters and 902 meters; 902 meters and 1558 meters. These baselines are multiples of 82 meters (or 0.01circ).

Unlike for the Moon or Mercury, the roughness maps for Ceres do not reveal any large-scale dichotomy, such as, for example, lunar highlands versus lunar maria. The roughness is mostly controlled by regional scale geology. We observe that young craters such as Dantu, Occator, Haulani, Ikapati and Azacca are surrounded by ejecta that is than the surrounding terrains, which suggests a high degree of ejecta fluidization. Curiously, this behavior is different from that of lunar crater ejecta. Lunar craters are often surrounded by rings of smoother proximal ejecta, while distal ejecta becomes rougher with increasing distance from the crater [9]. The difference in the ejecta roughness pattern is likely explained by the different target composition. Indeed, it is likely that Ceres' crustal material, which is volatile-rich, could reach low viscosity or even partial melting upon impact heating. Also, contrary to large lunar basins, Kerwan-the largest and oldest confirmed basin-has no distinct roughness signature. On the other hand, the next two largest younger large basins Urvara and Yalode do have roughness signatures. The younger and smaller of the two-Urvara-has a relatively smooth interior, whereas the bigger and older-Yalode-appears rougher than the surrounding terrains.

In summary, the produced maps reveal that roughness of Ceres' topography is mostly controlled by regional geologic processes. The roughness maps can be used to facilitate the mapping of crater ejecta as well as to determine relative surface ages.

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B1.1-0026-18 THE DISCOVERY OF A PRIMORDIAL ASTEROID FAMILY HELP US TO IDENTIFY THE ORIGINAL PLANETESIMAL POPULATION OF OUR SOLAR SYSTEM

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We will report about the discovery of a primordial asteroid family in the Main Belt (Delbo et al. 2017. Science 357, 1026), which was created by the impact break up of a parent body 4 Gyr ago or even earlier. The family was identified by our novel method that searches for a correlation between the distance in orbital semimajor axis of its members from the centre of the family and their size (Bolin et al. 2016, Icarus 282, 290). This size-dependent correlation is due to the asteroid mobility caused by the non gravitational thermal force known as the Yarkovsky effect. The dispersion of the distribution of the eccentricities and inclinations of the orbits of the primordial family members suggests that the family formed before the instability of the giant planets. The family spans the entire inner portion of the Main Belt, contains low-albedo objects most of which have physical properties similar to those of carbonaceous chondrite meteorites, and include most low-albedo asteroids in that area previously unlinked to other families. When the members of this and other families are removed from the inner Main Belt, few asteroids remain that cannot be included in any of the presently known families. We interpret these asteroids as the original inhabitants of the Main Belt, i.e. the planetesimals that formed directly from the accretion of the dust in the protoplanetary disk. These objects could be considered as interesting targets of feature space missions devoted to understand the composition of the first minor bodies that formed in our Solar System.

B1.1-0027-18 SPECTRAL OBSERVATION OF VESTA IN THE MID-INFRARED: A PYROXENE RICH FINE REGOLITH

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Vesta has been explored and mapped in detail by the Dawn space mission [1]. The measurements obtained by the VIR spectrometer demonstrated that Vesta is the parent body of the HED meteorites [2] and that there are hemispherical variabilities. In this work we present new telescopic observations of the Vesta asteroid made at the Subaru Telescope by using the COMICS IR spectrometer during 2016 and 2017 campaigns. We applied standard data reduction for the Mid-IR telescopic observations and a thermal model has been applied to retrieve the spectral emissivities. We compared our results with previous observations in the mid-IR, i.e. the ISO telescope with ISO-PHOT instrument [3], the Kuiper Airborne Observatory (KAO) [4] and the Palomar observatory in the framework of the MIDAS project [5]. Unfortunately, the KAO data have not been used because they are not reliable [Cohen, personal communication]. Our results, show that the Subaru spectra have a low spectral contrast, with a S/N of 100-300 and show weak but definitely real features attributable to residual Reststrahlen bands and a Christiansen peak. The latter feature is very different if obtained with Subaru or the ISO data (8.52 and 9.08 m) pointing to a pyroxene and olivine composition, respectively. As matter of fact, olivine is very rare on Vesta and its low abundance [6,7] cannot account for the presence of a Christianesen peak located a that wavelenghts. Nonetheless, the ISO spectrum seems to exhibit other weaker features similar to the Subaru's one. The more robust comparison is with MIDAS observations that similarly to the Subaru spectra, present an emissivity with very low spectral contrast and show at least two weak residual Reststrahlen pyroxene features. However the Christiansen feature in the MIDAS observations is not clear. The footprint of the Subaru spectra point at different location on the surface of Vesta and they show a little variability confirming a light hemispherical differentiation. Finally, our results seem compatible with the presence of pyroxene minerals and a fine grain regolith.

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B1.1-0028-18 OBSERVATIONS AND CHARACTERIZATION OF BINARY NEAR-EARTH ASTEROID 65803 DIDYMOS, THE TARGET OF THE AIDA MISSION

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Binary near-Earth asteroid 65803 Didymos is the target of the proposed Asteroid Impact and Deflection Assessment (AIDA) space mission. The mission concept consists of two spacecraft, the

Double Asteroid Redirection Test (DART) spacecraft that would impact the asteroid's satellite and the Asteroid Impact Mission (AIM) spacecraft that would observe the impact.

We used radar observations obtained at Arecibo and Goldstone in 2003, and lightcurve data from Pravec et al. (2006) to model the shapes, sizes, and spin states of the components. The primary is top shaped and has an equatorial ridge similar to the one seen on 2000 DP107 (Naidu et al. 2015). A 300 m long flat region is also seen along the equator. The primary has an equivalent diameter of 780 m (+/- 10 %) and its extents along the principal axes are 826 m, 813 m, and 786 m (10% uncertainties). It has a spin period of 2.2600 +/- 0.0001 h. A grid search for the spin pole resulted in the best fit at ecliptic (longitude, latitude) = (296,

+71) degrees (+/- 15 degrees). This estimate is consistent with the spin pole being aligned to the binary orbit normal at (310, -84) degrees. Dividing the primary mass of 5.24e11 kg (Fang Margot 2012) by the model volume we estimate a bulk density of 2100 kg m-3 (+/- 30 %).

We summed multiple radar runs to estimate the range and Doppler extents of the satellite. We estimated the motion in successive images and used a shift-and-sum technique to mitigate smearing due to translational motion. This boosted the SNRs and allowed us to obtain size and bandwidth estimates of the satellite. The visible range extent of the satellite is roughly 60-75 m at the 15 m resolution of the Arecibo images. Assuming that the true extent is twice the visible extent, we obtain a diameter estimate of 120-150 m. The bandwidth of the satellite suggests a spin period between 9-12 h that is consistent with the orbit period of 11.9 hours and with synchronous rotation.

B1.1-0029-18 EQUILIBRIUM SHAPE OF LARGE TRANS-NEPTUNIAN OBJECTS

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The large trans-Neptunian objects with radii larger than 400 km are thought to be in hydrostatic equilibrium. Their shapes can provide clues regarding their internal structures that would reveal information on their formation and evolution. Notably, we model equilibrium shapes of moonless trans-neptunian objects assuming homogeneous and heterogeneous interior models by numerically integrating Clairaut's equations of rotational equilibrium expanded up to third order in the geodetic parameter. Indeed, a level of accuracy better than a few kilometers is required for modeling those objects that are rapid rotators. We show that the difference between the equilibrium figures for homogeneous and heterogeneous assumptions can reach several kilometers for fast rotating and low density bodies. Such a difference could be measurable by ground-based and by space techniques.

B1.1-0030-18 EVIDENCE FOR WATER-RICH EXTRA-SOLAR ASTEROIDS

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Similar to the Earth, many, maybe most habitable exo-planets are probably born dry, and require the delivery of water to provide the opportunity for life to develop. One possible source of delivering surface water to planets are water-rich asteroids such as Ceres. While studying exo-asteroids orbiting main-sequence stars is in its infancy, it has been demonstrated throughout the last decade that the bulk composition of exo-planetary bodies can be accurately measured, in total analogy to Solar-system meteorite studies, from the spectroscopic analysis of white dwarfs accreting debris from tidally disrupted planetesimals. I will discuss the evidence for extra-solar water-rich planetesimals: the water-rich nature of some of these exo-asteroids has been demonstrated through the detection of significant oxygen excess in the accreted material, with respect to the oxygen content expected from metal-oxides. In addition, hydrogen can serve as a long-term tracer of the accretion of water onto white dwarfs as it accumulates near their surface, and I will present statistical evidence that a significant number of old, evolved planetary systems still contain water-bearing planetesimals.

B1.1-0031-18 ASTEROID INTERIOR AND REGOLITH STRUCTURE: TWO RADARS FOR A DIRECT OBSERVATION

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Our knowledge of the internal structure of asteroids entirely relies on inferences from remote sensing observations of the surface and theoretical modeling [1]. Is the body a monolithic piece of rock or a rubble-pile, how high is the porosity? What is the typical size of the constituent blocs? Are these blocs homogeneous or heterogeneous? The body is covered by a regolith whose properties remain largely unknown in term of depth, size distribution and spatial variability. Is it resulting from fine particles re-accretion or from thermal fracturing?

After several asteroid orbiting missions, theses crucial and yet basic questions remain open. Direct measurements of asteroid deep interior and regolith structure are needed to better understand the asteroid accretion and dynamical evolution and to provide answers that will directly improve our ability to understand the formation and evolution of the Near Earth Asteroids (NEA), that will allow us to model the mechanisms driving NEA deflection and other risk mitigation techniques.

Radars operating at distance from a spacecraft are the only instruments capable of achieving this science objective of characterizing the internal structure and heterogeneity from submetric to global scale for the benefit of science as well as for planetary defense or exploration. Two complementary radars, operating at different frequencies are needed to meet the objectives requirements [1]. The deep interior structure tomography requires a low-frequency radar (LFR) in order to propagate throughout the complete body and characterize the deep interior: this LFR will be a direct heritage of the CONSERT radar designed for the Rosetta mission. The characterization of the first ten meters of the subsurface with a metric resolution to identify layering and to reconnect surface measurements to internal structure will be achieved with a higher frequency radar (HFR). The design of HFR is based on the WISDOM radar developed for the ExoMars mission. The low and high frequencies radars has been redesigned in the frame of the AIDA/AIM phase AB [2,3] and for HERA/ESA mission. These instruments havee been proposed for next M4 and M5 classes European missions. They are under discussion for future mission like SPS/Jaxa to Jupiter Trojans or Discovery missions.

We will present the rationale of asteroid interior investigation, proposed instruments, performances and science return.

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B1.1-0032-18 RADAR OBSERVATIONS OF NEAR-EARTH ASTEROID 2012 TC4

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Near-Earth asteroid 2012 TC4 approached within 0.00035 au (6.9 Earth radii of Earth's surface) on 2017 October 12. This was one of the closest near-Earth asteroid encounters known in advance and it provided an outstanding opportunity to investigate this object's physical properties. Here we report radar observations obtained between Oct. 9-14 with the 70 m DSS14 and 34 m DSS-13 antennas the Goldstone Deep Space Communications Complex and with the 100 m Green Bank Telescope. 2012 TC4 has an absolute magnitude of 27, suggesting a diameter within a factor of two of 15 meters. Despite its diminutive size, the flyby was so close that we expected to observe extremely strong radar signal-to-noise ratios (SNRs) that would permit imaging at the highest range resolutions currently attainable at Goldstone. Monostatic detection of the asteroid occurred at DSS-14 (8560 MHz, 3.5 cm) on October 9 but at weaker SNRs than expected, possibly indicating that the diameter was significantly smaller than 15 meters. Monostatic DSS-14 delay-Doppler imaging on Oct. 11 at 3.75 m resolution placed only two range pixels on the object. The highest resolution images were obtained on Oct. 12 when transmissions were at DSS-13 (7190 MHz, 4.2 cm) and reception was at Green Bank. The images achieved a range resolution of 1.875 m/pixel that is the finest ever obtained at Goldsone for any near-Earth asteroid. The images reveal an elongated, angular, asymmetric, and rapidly rotating object and place lower bounds on its long and intermediate axes of about 6 x 12 meters. The rotation evident in the images is consistent with the 12 minute period that is prominent in the lightcurves obtained by W. B. Ryan (pers. comm.). The ratio of samesense circular (SC) to opposite-sense circular (OC) polarization, SC/OC, is about 0.6, which probably indicates that this object has an unusually rough surface at decimeter spatial scales. Circular polarization ratios have been obtained for hundreds of near Earth asteroids, and the ratio for 2012 TC4 overlaps the upper end of the values reported for Cand SQ-class NEAs and the lower end for Eand V-class objects. Combined with an effective diameter in the realm of 7-10 meters, the implication is that 2012 TC4 is an optically-bright object. The radar images are suitable for estimation of the 3D shape and spin state, which may have changed due to tides during the extremely close approach. When combined with the area/mass ratio estimated independently from orbit fitting (D. Farnocchia, pers. comm.), the physical model will be used to obtain the mass and the bulk density, information that is generally not available for solar system objects in this size regime.

B1.1-0033-18 GRAVITY FORWARD/INVERSE MODELING OF ASTEROIDS AND SURFACE BOULDERS TOWARD DESIGNING ASTEROID SURFACE GRAVIMETRY

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Asteroid mass and density distribution are among the most fundamental physical parameters that can contribute towards understanding the origin of the solar system. To date, insufficient information is known about asteroid density and composition. The main techniques utilized for estimating asteroid mass include albedo, photometric, and spectrometric observations. Radio tracking methods have also been used to measure gravitational deflection from orbiting satellites. All of these methods exhibit high uncertainty and low accuracy, in particular for small asteroids. Asteroid surface gravimetry could provide improved measurements of asteroid mass and density distribution. In this study, forward modeling of several asteroid (e.g., Bennu, 25143 Itokawa, 2008 EV5) density models is used to estimate gravity and gravity gradient at the surface. This research aims to quantify the survey requirements for the proposed Gravimetric Asteroid Surface Probe (GRASP) mission. Models of surface gravity from homogeneous and heterogeneous density distributions, including centrifugal acceleration and the effects of surface boulders are studied. Specifically, analysis is conducted on the differences between heterogeneous and homogeneous density models that can be resolved from surface gravity surveys. Results show that boulder effects (volume of 8 m3) on gravity are at the microGal (nanoG) level, which, in principle, are detectable using the latest space gravimeter, however, differences between homogeneous and heterogeneous models impact surface gravity at the milliGal (microG) level. Inverting surface gravity for the boulder mass is not feasible. The gravity differences between homogenous and heterogeneous density distributions are in fact resolvable from surface measurements and inversion models of such data could therefore by used in order to create constrained asteroid density models.

B1.1-0034-18 JAXA/ISAS SMALL BODY EXPLORATION PROGRAM AND MMX

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Ever since the successful return of Itokawa samples back to Earth in 2020, small body exploration including sample return missions has been one of the pillars of the ISAS activities. We have constructed a program for small body exploration which is composed by our L-class missions, M-class missions and participation to grand missions led by foreign agencies (that ISAS cannot afford to lead). The focus as of now is on the small bodies born outside the snow line. The scientific importance of the systematic investigation of these small bodies stems from the idea that they must have played substantial roles in enabling the habitability of our planet, transporting water and other volatiles to the planet was born dry in the inner part of the solar system. MMX, an ISAS L-class mission to be launched in 2024 that will return samples from Phobos, is one of the main constituents of the program. In my talk, I will describe the small body exploration program and put highlight on the MMX mission.

B1.1-0035-18 THE IMPACT OF THE ESA GAIA MISSION IN OUR KNOWLEDGE OF COLLISIONAL FAMILIES

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Knowing the asteroid belt is the key to provide a reliable history of our solar system. The main question which has been raised in the last years is: given our available data, does our classification of asteroid into families provide a reliable history of the collisional evolution of our solar system?

We have done huge steps forward, but the real revolution is represented by the ESA Gaia mission. Starting from April 2018, Gaia will provide observations of solar system objects with sub-mas accuracy, completely changing our vision of the asteroid belt.

We present an overview of the main results achieved by the second Gaia data release, focusing our attention especially on cratering families, which are the results of past collisions between asteroids that have produced many small fragments from a large parent body.

We present our classification of cratering families, including their age determination computed mixing dynamical and physical properties that the asteroids share in the same family.

B1.1-0036-18 MISSION STATUS OF HAYABUSA2 - ARRIVING AT ASTEROID RYUGU

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Hayabusa2 is the second sample return mission from an asteroid after Hayabusa mission. The target asteroid is (162173) Ryugu, which is a C-type asteroid. The main science objective is to investigate organic matters and water at the beginning of the solar system. The technological purpose is to maturate the new technology developed by Hayabusa and to develop other new technology for space missions. Hayabusa2 was launched December 3, 2014 by an H-IIA launch vehicle from Tanegashima Space Center in Japan. Just one year later, on December 3, 2015, Hayabusa2 came back to the Earth to execute the Earth gravity assist, which was successfully done and its orbit was changed toward Ryugu. We observed the Earth and the moon by using the remote sensing instruments on board at the Earth gravity assist. Then after three long-term ion engine operations, Hayabusa2 will arrive at Ryugu in June or July of 2018. At first, we will observe Ryugu carefully by using four science instruments (ONC: Optical navigation camera, LIDAR: Lager Altimeter, NIRS3: Near Infrared Spectrometer, TIR: Thermal Infrared Imager) and decide the landing place. Then we will release the lander and rovers, execute touchdown once or twice, and try the experiment of the impactor. Hayabusa2 will leave Ryugu at the end of 2019 and bring back the sample of Ryugu to the Earth at the end of 2020.

B1.1-0037-18 MASCOT ABOARD HAYABUSA2: STATUS OF LANDING PREPARATIONS

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MASCOT ('Mobile Asteroid Surface Scout') is a 10 kg mobile surface science package on-board JAXA's Hayabusa2 spacecraft, which, by July 2018, will have reached the near-Earth asteroid (162173) Ryugu. MASCOT has been developed by the German Aerospace Center (DLR) in cooperation with the Centre National d'Etudes Spaciales (CNES). The concept of MASCOT is to perform in-situ measurements on the asteroid's surface and to support the Hayabusa2 mission in the sampling site selection. MASCOT is equipped with 4 scientific instruments: a wide angle camera, an IR spectrometer, a radiometer, and a magnetometer.

The data provided by the instruments aboard the Hayabusa2 spacecraft from June till September 2018 will be used to select both, sampling sites for the main spacecraft but also the best landing site for MASCOT. Besides of scientific preferences, the main selection criteria will be illumination (thermal), flight dynamics, visibility from main spacecraft and minimum interference between sampling and landing sites. The landing of MASCOT is scheduled for October 1, 2018.

The paper will give an update of the status of MASCOT operations planning and landing site selection, 3 months before the actual landing.

B1.1-0038-18 THE OSIRIS-REX ASTEROID SAMPLE RETURN MISSION: ANTICIPATING ASTEROID (101955) BENNU

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In May of 2011, NASA selected the Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) asteroid sample return mission as the third mission in the New Frontiers program [1]. The spacecraft departed for near-Earth asteroid (101955) Bennu aboard an United Launch Alliance Atlas V 411 evolved expendable launch vehicle at 7:05 p.m. EDT on September 8, 2016, on a seven-year journey to return samples from Bennu. The spacecraft is on an outbound-cruise trajectory that will result in a rendezvous with Bennu this fall. The science instruments on the spacecraft will survey Bennu to measure its physical, geological, and chemical properties, and the team will use these data to select a site on the surface to collect at least 60 g of asteroid regolith. The team will also analyze the remotesensing data to perform a detailed study of the sample site for context, assess Bennu's resource potential, refine estimates of its impact probability with Earth, and provide ground-truth data for the extensive astronomical data set collected on this asteroid [2].

The spacecraft will begin observing Bennu in August 2018, when the asteroid is just bright enough for detection by the PolyCam long-range imager. These first science observations mark the beginning of asteroid proximity operations. The Approach Phase will be followed by Preliminary Survey, which consists of a series of hyperbolic trajectories that cross over the North and South poles and the equator at a range of 7 km. After this phase, the spacecraft will be placed into a 1.5-km orbit, beginning the Orbit-A Phase. In this phase the spacecraft enters into a gravitationally bound orbit about the asteroid. The characterization of Bennu begins in earnest with the Detailed Survey Phase, which requires multiple hyperbolic passes of Bennu to obtain the wide range of viewing angles necessary to characterize the asteroid's global properties. At the end of Detailed Survey, the spacecraft will enter a close orbit around Bennu and commence the Orbit-B Phase, with a focus on global mapping of the topography and gravity field of Bennu. The Orbit-B phase will conclude with a down-select to a primary and a secondary sampling site. These two sites will be the target of a series of low-altitude reconnaissance observations. After selection of the primary site, the mission will enter the Sample Acquisition Phase. The mission has adopted a sampling strategy referred to as Touch-And-Go, or TAG.

TAG uses the momentum of a slow, descending spacecraft trajectory to maintain contact with the surface for a few seconds, just long enough to obtain a sample, followed by a controlled back-away burn. The spacecraft will leave Bennu in 2021 and return the sample to the Utah Test and Training Range (UTTR) on September 24, 2023.

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B1.1-0039-18 MICRO-IR AND SEM/EDS ANALYSIS OF CARBONACEOUS CHONDRITE METEORITES IN SUPPORT TO NEXT ASTEROIDAL SAMPLES RETURNED CHARACTERIZATION

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Multiple analytical techniques are generally applied to characterize returned asteroidal and cometary samples, and meteorites [1,2,3]. Waiting for samples that will be returned from primitive asteroids by Hayabusa 2 and Osiris Rex missions [4,5], we applied Infrared µ-spectroscopy (µ-IR), Scanning Electron Microscopy and Energy Dispersive Spectroscopy (SEM/EDS) on three Carbonaceous Chondrite (CC) meteorites. The analysed CCs are: 1) Murchison (CM2 group); 2) NWA8267 (CM2 group) [6]; and 3) NWA2086 (CV3 group) [7]. These can be considered as possible analogues of space mission asteroid targets, i.e. Bennu (B-type) and Ryugu (C-type). A preliminary analysis was performed by using a Stereo Microscope (Leica M205c), equipped with a digital camera, in order to select sample regions characterized by a significant mineralogical heterogeneity. Successively, the same areas have been analysed by means of a µ-IR Microscope in the spectral range 8-14 µm, and by SEM/EDS. Christiansen features and Reststrahlen bands of the main minerals were identified by means of µ-IR technique while chemical information and high-resolution images of the inclusions were identified by using the SEM/EDS. Combining the results obtained applying these two techniques allowed us to determine the mineralogy of the selected regions. The matrix and chondrules of NWA2086 (CV3) meteorite are composed of olivine and Mg-rich pyroxene The Murchison inclusions composition can be ascribed to olivine, hydrates silicates with low amount of sulphides and iron oxide. The NWA8267 analysed region is composed of low-Ca pyroxene and sulphides. In order to have a comprehensive mineralogical framework of meteorite samples, which will support the returned asteroidal samples characterization, we planned to: 1) analyze additional CCs regions of interest by means of the combined analytical techniques; and 2) compare the CCs spectra from 2 to 4.2 µm with C-type asteroids spectra, e.g. 1 Ceres, 10 Hygeia, to find similar spectral features.

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B1.1-0040-18 COMETS - HOW LABORATORY EXPERIMENTS CAN HELP TO UNDERSTAND THEIR FORMATION AND ACTIVITY

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In the past years, very successful space missions have significantly improved our knowledge of the origin and activity of comets. These space missions have been supported by a variety of different theoretical models and intensive observational campaigns. However, the support from ground-based laboratory experiments has been limited, although they can provide deeper insights into the physics processes driving the activity of comets.

Comets are believed to have formed in the young Solar System by the gentle gravitational collapse of dust clouds, typically consisting of mmto cm-sized aggregates. Due to the nature of this formation scenario, the nucleus is composed mainly of non-volatile dust (the dustto-ice mass ratio is 4-9), with only minor contributions (in mass) by volatiles. The nucleus apparently consists of intact dust aggregates, which have survived the comet formation process, owing to the small impact velocities during the collapse. For most of their lifetime, comets have orbited the Sun at large heliocentric distances so that they remained almost unaffected by solar radiation. However, gravitational disturbances by the giant planets can change their orbital parameters over time and, thus, comets can get closer to the Sun.

In this case, solar illumination leads to the evaporation of water ice and other volatile species and, thus, a volatile-free dust layer forms, covering the water ice. This desiccated dust layer possesses a low thermal conductivity, a low gas permeability and a very low tensile strength (Pa). As a result, the evaporation of the volatile constituents can lead to the ejection of dust aggregates from the surface. These aggregates are composed of micrometric particles.

Laboratory experiments performed so far were very useful to understand the nature of ice-dust samples under come-tarylike conditions. However, since we have now data from several fly-by missions and more than two years of escorting a comet from the onset of activity throughout the perihelion (activity maximum) and beyond, the picture of gas and dust production has changed. The major changes are 1) that comets can show activity anywhere on their surface,

2) that comets possess a very high dust-to-ice ratio and 3) that cometary surfaces consist of millimeterto centimeter-sized aggregates.

These new insights have changed the requirements needed to carry out state-of-the art comet simulation experiments with realistic sample materials. Thus, a new generation of ground-based laboratory experiments is required to interpret the data gathered by previous space missions (especially by the Rosetta mission) and to support future space missions to comets, or to other icy bodies in the Solar System.

The objective of our laboratory investigations is to investigate the fundamentals of cometary activity, by performing experiments with appropriate comet analogue materials, such as aggregates composed of silicate particles, granular H2O ice and CO2 ice. In order to study the activity of comets in laboratories on Earth, one has to create optimised analogue materials and ensure realistic environmental conditions, in which the samples are studied. In particular, a setup must be designed in which gravity is rendered unimportant. This can be achieved by choosing appropriate aggregate sizes (e.g., smaller than 200 µm in radius) and correspondingly higher gas-production rates (by adapting the temperature of the samples). The ratio between tensile strength of the dust and sub-surface gas pressure can be adjusted to cometary conditions.

B1.1-0041-18 THE DOUBLE ASTEROID REDIRECTION TEST (DART): OVERVIEW AND INVESTIGATIONS

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The Double Asteroid Redirection Test (DART) will be the first space experiment to demonstrate asteroid impact hazard mitigation by using a kinetic impactor. At this writing DART is currently in Preliminary Design Phase (“Phase B”), and is part of the Asteroid Impact and Deflection Assessment (AIDA), a joint ESA-NASA cooperative project. The mission is scheduled for its Preliminary Design Review in April 2018, with a transition to Final Design and Fabrication (“Phase C”) afterward.

The AIDA target is the near-Earth binary asteroid 65803 Didymos, an S-class system that will make a close approach to Earth in fall 2022. The DART spacecraft is designed to impact the Didymos secondary at 6 km/s and demonstrate the ability to modify its trajectory through momentum transfer. The primary goals of DART are (1) perform a full-scale demonstration of the spacecraft kinetic impact technique for deflection of an asteroid; (2) measure the resulting asteroid deflection, by targeting the secondary member of a binary NEO and measuring the resulting changes of the binary orbit; and (3) study hyper-velocity collision effects on an asteroid, validating models for momentum transfer in asteroid impacts. The DART Team has identified five broad “investigations” to be addressed by the project: Modeling and Simulation of Impact Outcomes, Remote Observations, Dynamical and Physical Properties, Science Proximity Operations, and Ejecta Dynamics and Evolution.

The DART impact on the Didymos secondary will change the orbital period of the binary by at least 73 seconds, which can be measured by Earth-based optical and radar observations in the post-impact period. The baseline DART mission launches in 2021 to impact the Didymos secondary in 2022 near the time of its close pass of Earth, which enables an array of groundand space-based observatories to participate in gathering data. The AIDA project will provide the first measurements of momentum transfer efficiency from hyper-velocity kinetic impact at full scale on an asteroid, where the impact conditions of the projectile are known, and physical properties of the target asteroid are also characterized. The DART kinetic impact is predicted to make a crater of order 10 meters diameter, depending on target physical properties, but will also release a large volume of particulate ejecta that may be directly observable from Earth or even resolvable as a coma or an ejecta tail by ground-based telescopes.

We will discuss the plans for the DART mission and its investigations.

B1.1-0042-18 THE HERA MISSION: EUROPEAN COMPONENT OF THE ESA-NASA AIDA MISSION TO A BINARY ASTEROID

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The European component of the joint ESA-NASA Asteroid Impact and Deflection Assessment (AIDA) mission has been redesigned from the original version called Asteroid Impact Mission (AIM), and is now called Hera. The main objectives of AIDA are twofold: (1) to perform an asteroid deflection test by means of a kinetic impactor under detailed study at NASA (called DART, for Double Asteroid Redirection Test); and (2) to investigate with Hera the changes in geophysical and dynamical properties of the target binary asteroid after the DART impact.

This joint mission will allow extrapolating the results of the kinetic impact to other asteroids and therefore fully validate such asteroid deflection techniques. Hera leverages technology and payload pre-developments of the previous AIM, and focuses on key measurements to validate impact models such as the detailed characterisation of the impact crater. As such, AIDA will be the first documented deflection experiment and binary asteroid investigation. In particular, it will be the first mission to investigate a binary asteroid, and return new scientific knowledge with important implications for our understanding of asteroid formation and solar system history.

The baseline target is the binary near-Earth asteroid (NEA) (65803) Didymos. In particular, its secondary component, called hereafter Didymoon (163 ± 18 m diameter), is the target of the DART mission.

The baseline payload of Hera includes a Framing Camera, a miniaturized LIDAR and for the first time a 6U CubeSat dedicated to asteroid characterization carrying two additional instruments. The spacecraft design allows for 40 kg of additional payload mass. Current options under investigation include the Small Carry-on Impactor proposed by JAXA (a replica of the one on-board the Hayabusa2 mission) and a high-frequency radar for the measurement of subsurface properties. Other options, such as a small lander, can also be considered. A Radio Science Experiment (RSE) will also be performed, which does not involve any additional on-board hardware but only complex on-ground data processing.

Finally, a mission like Hera will certainly fire the imagination of young people and adults, as the science is accessible and understandable to those audiences and is associated with fascinating challenges and goals of planetary defense. The status of the study and payloads will be presented.

B1.1-0043-18 AN OVERVIEW OF THE DESTINY+ MISSION: FLYBY OF GEMINIDS PARENT (3200) PHAETHON AND IN-SITU DUST ANALYSES

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DESTINY+ (Demonstration and Experiment of Space Technology for INterplanetary voYage, Phaethon fLyby and dUst Science) is a mission proposed for JAXA/ISAS Epsilon class small program, currently in the pre-project phase (Phase-A) with a launch targeted for 2022. DESTINY+ is a joint mission of technology demonstration and scientific observation. DESTINY+ will conduct a high-speed (33 km/sec), close flyby of Geminids parent asteroid (3200) Phaethon and in-situ dust analyses of interplanetary dust and interstellar dust around 1 a.u. The science goal is to understand the nature and origin of cosmic dust brought to the Earth, in the context of exogenous contribution of organics to the origin of terrestrial life. The mission objectives are two folded: (1) to measure physical properties (velocity, orbit, mass) and chemical composition of dust around 1 au, and (2) to conduct geological observation of Phaethon upon flyby and analyze dust nearby Phaethon. The science observation is conducted with a panchromatic telescopic camera (TCAP), a UV-VIS-NIR multiband camera (MCAP) and a dust analyzer (DDA).

B1.1-0044-18 VISIBLE-INFRARED SPECTRAL CHARACTERIZATION OF 3200 PHAETHON AT ITS CLOSEST APPROACH TO EARTH

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The asteroid 3200 Phaethon is a peculiar object with a very eccentric orbit with a perihelion located at only 0.14 AU and it has been dynamically associated with the Geminid meteor stream (Gustafson 1989; Williams Wu 1993; Jenniskens 2006, and references therein). Phaethon is a B-class asteroid and it is linked with carbonaceous species and hydrated silicates such as phyllosilicates. Good match of the Phaeton spectra are the aqueously altered CI/CM meteorites (Licandro, 2007) and the CK meteorites (Clark et al. 2010). The asteroid 3200 Phaethon is the target of the Destiny + Space mission, managed by Japanese Space Agency (Jaxa), which will perform a close rendevouz with this asteroid, with the scientific objectives of studying its surface properties and assessing its cometary activity in terms of release of dust and volatiles. The December 2017 Phaethon Earth approach have been a very important event since it was about 10 times closer than any other future approach predicted at least for the next 20 years. In that occasion, we observed the asteroid at the 3.5 mt Telescopio Nazionale Galileo in the spectral interval (0.4-2-5 µm).We obtained three spectra in the Visible from 0.4 to 0.8 µmm, with a strong fringing longward of 0.8 µmm which doesn't allow to use the data between 0.8 and 1 µmm. The spectra are featureless, however, the slope of two spectra agrees well with many previous observations of Phaeton (see e.g. Licandro et al, 2006). One spectra show, instead, a bluer behaviour, similarly to the unique previous observation by Luu and Jewitt (1993). The IR spectrum is almost featureless, with very weak features at the limit of the S/N which at present are under investigation.

B1.1-0045-18 OKEANOS - JUPITER TROJAN ASTEROID RENDEZVOUS AND LANDING MISSION USING THE SOLAR POWER SAIL

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OKEANOS (Oversize Kite-craft for Exploration and AstroNautics in the Outer Solar system) is the future mission under study to cruise to the outer solar system using a large-area solar power sail, and to rendezvous with and land on a Jupiter Trojan asteroid for in-depth study there. Jupiter Trojans are the key targets to be explored, because they are mainly volatilerich D/P type asteroids, located beyond the water ice snow line, and possibly originated from the EKBO scattered due to planetary migration. The conditions and materials that were lost in the inner solar system should be preserved there. This mission aims at investigating the origin and evolution of Jupiter Trojans and their materials by direct microscopy and mass spectroscopy of the collected samples. Geologic context of the landing site and the surrounding area will be observed with imaging, NIR and X-ray spectroscopy, and radiometry. The landing site will be selected by global mapping of imagery, NIR and TIR imaging spectroscopy, and ground penetrating radar to understand the global shape, surface geology, mineralogy, degree of hydration, thermo-physical properties, and so on. Gravity (or porosity) and magnetic property of the bulk asteroid to study the interior structure will be also measured by Doppler shifts and magnetic field measurements. Current activity of dust ejection and volatile eruption will be also measured. The details of the mission and instrumentation will be presented.

B1.1-0046-18 LABORATORY ANALOG EXPERIMENTS TO UNDERSTAND THE POSTCOLLECTION ALTERATION OF COMET SURFACE MATERIALS FOR CAESAR

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Comet Astrobiology Exploration SAmple Return Mission proposed for New Frontiers 4

The primary goal of the Comet Astrobiology Exploration SAmple Return (CAESAR) mission (Squyres et al. 2018; Hayes et al. 2018) proposed for NASA's New Frontiers 4 program is to bring the first cometary surface materials (dust, organics, and ice) back to Earth for study. This requires storage of the collected solids at temperatures above that of the comet itself during the return voyage and capturing sublimating gases in a separate, cooled container. Warming of the cometary materials in order to drive sublimation could induce changes that are both physical (such as structural changes in the cometary dust grains) and chemical (such as the breakdown or formation of organics or the aqueous alteration of minerals). To prevent such alterations and to interpret the state of the comet surface sample upon retrieval after delivery to Earth, a thorough understanding of the effects on the sample caused by sublimation and exposure to evolved gases is necessary. To this end, we have studied the behavior of H2O transfer under varied conditions of sublimation and collection temperature in an experimental breadboard set-up at NASA GSFC. We have also studied the same process in the presence of a cometary dust analog (fumed silica) in order to determine if any alteration occurs during the exposure to H2O vapor during sublimation. Particles exposed to sublimating H2O were analyzed using scanning electron microscopy (SEM), electron diffraction (EDX), and infrared (IR) spectroscopy. No evidence for alteration was observed. These results will be discussed in terms of their implications for comet surface sample return missions.

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B1.1-0047-18 COMET SIMULATION EXPERIMENTS TO MEASURE THERMO-MECHANICAL PROPERTIES OF NUCLEI UNDER SOLAR ILLUMINATION

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Although comet nuclei appear weak at large scales, the Philae lander first bounced off the surface of 67P, then the MUPUS penetrometer was unable to make its way inside the surface. Both observations suggest the presence of a layer of hard materials at depth. To better understand what this hard layer consists of and how it develops over time, we are developing a new simulation chamber to examine explore correlations between the composition of starting icy comet nucleus analog materials (dust-to-ice ratio, in particular), their thermal properties, their mechanical properties, and their evolution over depth and time. The primary approach is to synthesize porous cometary analogs with a wide range of dust-to-ice ratios, and simulate the variations in insolation they would be subject to along typical Jupiter-Family Comets orbits (scaled to timescales accessible in the laboratory) under high-vacuum conditions using a custom-built lamp with illumination modulation. In this context, "dust" refers to the refractory components of comet nuclei (e.g. silicates, large organic molecules), and "ice" to their volatile components (mostly H2O and CO2 ice in Jupiter-Family Comets). Temperature profiles are measured continuously using a custom-built thermal probe, and 2D time-dependent thermal modeling retrieves the thermal properties and their evolution as function of depth and time.

A custom-built cone penetrometer apparatus measures the strength (resistance to penetration) of the comet analogs at various locations of the sample over the course of each experiment. We will report on the status of development of this new simulation chamber and preliminary results obtained to date.

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B1.1-0048-18 DETECTION OF COMETARY ACTIVITY DURING 67P/CHURYUMOV-GERASIMENK PRE-PERIHELION BY MEANS OF GIADA-VIRTIS DATA FUSION

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Previous works based on data provided by the Rosetta/VIRTIS imaging spectrometer demonstrated the occurrence of a water diurnal cycle (De Sanctis et al., 2015) and the occurrence of recently exposed water ice outfalls (Filacchione et al. 2016) on the nucleus of the comet 67P/Churyumov-Gerasimenko well before the perihelion passage. Longobardo et al. (2017) found a systematic 3.2 um absorption band center (shortward) shift following an increase in surface temperature, interpreted as due to cometary activity: high temperatures lead to underlying water ice exposure. In this work, pre-perihelion cometary activity has been further investigated, combining the VIRTIS data with those by GIADA, the dust detector onboard Rosetta. In particular, we considered the measurements performed, from August to December 2014, by two of the three GIADA sub-systems: the Grain Detector System (GDS) and the Impact Sensor (IS). Following Della Corte et al. (2015) we separated the particles in "compact", i.e. high-density particles (IS and GDS-IS detections and GDS isolated detections), and "fluffy" detected as "dust showers" (GDS dust showers), i.e. particles detected only by the GDS and clustered in time (Della Corte et al. 2015; Fulle et al., 2015). A third category is a mixture of the two, detected by GIADA as a compact particle immediately followed by a dust shower (Fulle et al., 2016). For particles detected by both subsystems, velocity, momentum and mass are determined. For particles detected only by the IS, the velocity is inferred by applying an empirical relation (Della Corte et al., 2016). For the third category we assigned a unique velocity given by the compact particle velocity associated with the shower. We retrieved the source region for individual compact particles and for the dust showers coupled with compact particles, assuming a radial trajectory along which the particle: 1) is uniformly accelerated in the first 11 km from the nucleus (i.e. acceleration region, Ivanovski et al. 2017); 2) has a constant speed out of the acceleration region. Our analysis provides the following main results:

1) Good correlation between the two studied categories of particles source regions, i.e. the source of the two different types of particles is likely the same. 2) Correlation between number of particles detected by GIADA and the 3.2 um band shift magnitude observed by VIRTIS in each comet region observed during the considered period, corroborating that the band center shift with temperature is due to the diurnal pre-perihelion cometary activity.

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B1.1-0049-18 GRAVITY, INTERNAL STRUCTURE AND NUCLEUS COMPOSITION OF 67P/ CHURYUMOV-GERASIMENKO AS MEASURED BY THE ROSETTA RADIO SCIENCE EXPERIMENT RSI

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When Rosetta arrived at its target comet 67P/Churyumov-Gerasimenko it first performed a series of distant flybys (100-30 km). During this mission phase the mass of the comets nucleus could be determined by analyzing the RSI radio tracking data. In combination with the volume from images of the OSIRIS camera this resulted in a precise bulk density determination. That already gave first insights into the comets interior structure. The nucleus appears to be a low-density, highly porous dusty body. From bound orbits with distances below 30 km the low degree and order gravity field coefficients could be derived. The gravity field coefficients strongly depend on the nucleus irregular shape and on the interior mass distribution. The shape is very well reconstructed from of the OSIRIS camera images. Various models of the interior nucleus structure and density distributions are used to compute simulated values of the gravity field coefficients. A comparison with the observed coefficients yields the feasibility of the theoretical interior structure. Thus, the gravity field helps constraining models of the internal structure, the composition and also of the origin and formation of the comets nucleus.

B1.1-0050-18 MASS ESTIMATION OF COMET 67P/CHURYUMOV-GERASIMENKO AND UPDATED PHILAE REST COORDINATES FROM CONSERT RANGING DATA

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The Philae lander on the surface of comet 67P/C-G was finally imaged by the OSIRIS camera onboard the Rosetta spacecraft on September 2, 2016. In this study, we derive an estimate of the mass of the comet from the three CONSERT measurement sequences taken in direct visibility from the lander to the orbiter, and compare it with the mass estimate derived from radio-tracking data of the Rosetta spacecraft from the Earth[1][2]. We also derive updated 3D coordinates for the lander, by taking into account the shape of the comet as a constraint and the 2D a priori coordinates from the OSIRIS images[3].

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B1.1-0051-18 IMPLICATIONS OF ROSETTA DATA ON COMETARY DUST STREAM DYNAMICS AND THEIR RISK FOR INTERPLANETARY SPACE CRAFTS

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From August 2014 to September 2016 ESA's Rosetta spacecraft escorted comet 67P/Churyumov-Gerasimenko (hereafter 67P) on its journey into the inner solar system and out again. The mission provides, via various dust and gas instruments, unprecedented data on the nature of cometary activity.

By using state of the art models for the inner gas and dust comae dynamics for the interpretations of Rosetta data sets (e.g. Bieler et al. (2015), Fougere et al. (2016), and Marschall et al. (2016)) we are now able to extend our understanding of the dust emission direction and speed distribution of cometary dust particles. Furthermore the in-situ dust experiments provide data point to determine the dust size distribution (e.g. Fulle et al. (2016), and Merouane et al. (2017)). This expands our knowledge of the dust size distribution we have from other comets (e.g. McDonnell et al. (1987) for 1P/Halley). These results are the basis to determine the trajectories of dust streams within the solar system (e.g. Soja et al. (2015)). Such models can predict the number densities of interplanetary dust particles originating from comets. In this work we will present the effects of our updated input parameters which are informed by

Rosetta measurements on the dynamics of these dust stream. Understanding the dynamics of dust streams is of great importance for our assessment of the risk for interplanetary space craft posed by cometary dust particles. The results of or model can be directly used to estimate this risk by calculating dust impact probabilities.

Acknowledgement

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B1.1-0052-18 IN-SITU NEGATIVELY-CHARGED NANOGRAINS AND ENERGETIC PARTICLES FROM COMET 67P/CHURYUMOV-GERASIMENKO AS SEEN BY ROSETTA IES ON 07 JUNE 2016

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On 07 June 2016 the Rosetta Ion and Electron Sensor (IES) instrument observed both negatively and positively charged particles approximately 28 km away from comet 67P/ChuryumovGerasimenko. The local He++ energy peak of 1430 eV/e corresponds to the mass-loaded solar wind speed of 371 km/s. At this velocity, the energy-time spectrograms observed negative pickup particles with mass per charge ratios of 1.16 (H-) and 4.12 (He-) between 06:03 and 11:36 UT while the electrons are accelerated to 100s of eV with an energy peak around 200 eV. The IES electron analyzer also indicated charged nanograins a few hours prior to the electron enhancements. A cometary outburst would support the highly localized and temporal nature of these negative particle signatures. Prior to the electron signatures, we found a few probable lower hybrid waves (2 s wave packets) beginning at 5:33 UT. We will investigate whether the lower hybrid waves present

B1.1-0053-18 GRAINS: A NEW NUMERICAL METHOD FOR THE STUDY OF GRAVITATIONAL AGGREGATES

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The study of small bodies addresses a number of questions relevant for space engineers, planetary scientists and physicists. Near Earth Asteroids (NEA) are a great opportunity for technological and human exploration missions. NEAs can also represent a threat for the planet. The scientific and technological exploitation and the implementation of mitigation actions for hazardous asteroids rely upon our knowledge of their properties. Remote surveys play a fundamental role to estimate asteroid properties, but they can provide very limited information about their internal structure. GRAINS addresses such problem through N-body numerical simulations of gravitational aggregation. This method is suitable to estimate the internal properties of rubble-pile asteroids: gravitational aggregates with very low tensile strength and high level of porosity. The study of aggregation phenomena currently relies on codes optimized for a large number of mutually interacting particles, regardless of their individual shape and rigid body motion. Although not relevant for many applications, this limitation could be relevant for the case of asteroids, as suggested by results of granular dynamics in terrestrial engineering applications. The latter are commonly studied using multi-body codes, able to simulate contact interactions between a large number of complex-shaped bodies, but not suitable for gravitational dynamics. GRAINS is able to joint the advantages of both classes of codes into a single implementation, to reproduce N-body gravitational dynamics between a large number of complex-shaped rigid bodies. In this work, aggregation simulations are presented: favorable conditions leading to the formation of an asteroid are investigated, when starting from a cloud of boulders. The analysis is performed under many degrees of freedom, to include different geometries, physical and dynamical properties of the boulders and final aggregate. The problem to be investigated is twofold: (a) the study of gravitational aggregation dynamics, and

(b) the study of the physical and dynamical properties of the final aggregate. The first aspect includes the analysis and numerical simulation of typical scenarios, for small and medium sized (hundreds of meters) asteroid aggregation, to identify the conditions that lead to the formation of a single or multiple aggregate, or to the dispersion of the particle cloud. The second aspect analyzes the properties of the final aggregate, as a result of the dynamical simulation, which are then studied and classified depending on the initial parameters and simulation scenario.

Preliminary results show good agreement between theory and observation, and confirm the capability of the numerical code to predict natural aggregation phenomena.

B1.1-0054-18 OBSERVATIONS OF H2O EMISSION LINES AT 22235 MHZ OF THE COMET 96P/ MACHHOLZ

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The 22-meter radio telescope of Crimean Astrophysical Observatory has implemented the possibility of carrying out studies of almost all space masers (OH masers, H2O masers, methanol masers, SiO masers), as well as spectral observations in the frequency range from 85 GHz to 115 GHz. These innovations made it possible to begin the study of weaker sources of cosmic maser radio emission including in cometary atmospheres. The observations of H2O emission lines at 22235 MHz of the comet 96P/ Machholz were performed during October 24-31, November 1-5, 2017 with usage of 22-m radio telescope CrAO. Water production rates estimated from intensities of radio and optical lines are compared.

B1.1-0055-18 THE COMPOSITIONAL BEHAVIOR OF THE JUPITER FAMILY COMETS

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The Jupiter family comets 41P/Honda-Mrkos-Pajdušáková and 45P/Tuttle-Giacobini-Kresák were observed using the 0.5m and 1.2m telescopes at the Mount Abu Infra-red observatory(MIRO) during the period of December 2016 to May 2017. The optical spectra of these comets were obtained using the low resolution spectrograph LISA mounted on the telescpoes at MIRO. As expected in the optical region,the comets exhibited a lot of molecular emission bands including CN,C2,C3,CH and NH2. The spatial profiles of some of these molecules were studied using the traditional theoretical model given by Haser. Although, these molecular emission bands are daughter and grand-daughter products, the behavior of their production rates and scale lengths strongly depends on the parent molecules. The parent molecules originate in the subsurface layers of the cometary nuclei. They are influenced by many of the orbital parameters like perihelion and aphelion distances and orbital period, inclination, etc. Both of these low inclination Jupiter family comets have close resemblance (in terms of the above mentioned orbital parameters) to the short-period comet 67P/Churyumov-Gerasimenko studied in detail by Rosetta (few results in MNRAS, Vol. 462, Issue 1, November 2016). Therefore, their study can give vital confirmation on the similarity or otherwise of the Jupiter family comets.

Similar study (Kumar V et al., MNRAS, 2016, 463(2), 2137) has also been done on some of the long period comets like C/2014 Q2(Lovejoy) which had an extremely high orbital inclination of 80 deg (with the ecliptic). Behavior of the different classes of comets gives us an idea of their relative source of origin in the proto planetary disk. Therefore detailed study of the different families of comets will provide information on the homogeneity or heterogeneity of the proto-planetary disk at the early stages of its formation.

This work describes the observations and results from the optical spectrum of the two Jupiter family comets as compared to the longer period Oort cloud comets.

B1.1-0056-18 NEW GENERATION OF COMPACT COMETARY D/H SURVEY MISSION

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There are numerous debates and models about the source of water and organic compounds on Earth and other terrestrial planets without converging to an agreement. One of the best ways to study this problem is by determining the deuterium-to-hydrogen (D/H) ratios in comets and across the Solar System because there is a gradient in D/H in the solar nebula due to the temperature gradient. The OD/OH in interstellar space measurements is usually around 2×10-5, slightly higher than the Earth's 1.5×10-4 value. The previous notion was that Jupiter family comets (JFC) are formed further away from the Sun, close to Neptune, whereas Oort cloud comets have formed closer in, outside of Saturn. If that proposition is correct, then we should see a trend of higher D/H ratio in JFCs then the Oort cloud comets. This hypothesis, however, is under debate due to mixing values of D/H measurements in JFCs. Our very few cometary D/H measurements suggest a wide range of D/H ratios in the water within Jupiter family objects and preclude the idea that this reservoir is solely composed of Earth ocean-like water. We need not one, or two but several measurements of many comets, as well as observations of many comets over the period of their orbit around the sun and preferably data from the same comets over multiple orbits before we can apply statistics and improve our ability to distinguish between different scenarios. It is not possible to get such statistics using in situ measurements, such as mass spectrometers, and the current remote sensing high spectral resolution spectrometers require large aperture space-born telescopes that can't be solely dedicated to cometary studies. We are proposing to take advantage of a novel technique, Spatial Heterodyne Spectrometer (SHS), to survey cometary D/H at 308 nm. SHS is a high throughput, a reflective two-beam cyclical interferometer that can obtain high spectral resolution spectra (R 100,000) from a narrow bandpass in VIS to UV in a miniaturized format using small aperture telescopes. A key advantage comes in achieving high sensitivity observations using small (<0.5m) aperture telescopes in a dedicated SmallSat. Using SHS in a low cost

(<50M)Small Satina polar orbit around the Earth, SHS will enable us to survey cometary D/Hratiosinmany

B1.1-0057-18 ON THE EXISTENCE OF GROUPS OF METEORITES AND METEORITEPRODUCING METEOROIDS IN ORBITS OF JUPITER FAMILY COMETS

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The possibility of existence of groups of meteorite-producing meteoroids which associate with six known ordinary chondrite meteorites was analyzed. The IAU Meteor Database of Photographic orbits and the other published sources have been used to search for possible groups of related known meteorites and meteorite-producing bolides for which can believe that any bolides survived the atmospheric encounter. A comparison of the orbits of meteorite-producing fireballs with each other and with orbit of known meteorite was carried out. Three criterions of orbital similarity known as DSH criterion Southworth and Hawkins, DDr criterion Drummond and DN criterion Jopek have been used to suggest that this is the group of related bodies. In result six identified groups comprising a total of 95 meteorite-producing meteoroids associated with six known ordinary chondrites were found. The geocentric radiants and orbital elements of meteoroids confirmed sporadic nature and orbits of Jupiter family comets (Tj 3.1) of these events. On the calculated value of the aerodynamic pressure at the height of maximal brightness the bulk densities of studied meteoroids were estimated. As result a value of bulk densities of meteoroids about 1070-1250 kg m-3 were obtained and suggested the carbonaceous composition of meteoroids in these groups. Gravitational perturbations as well as the rotational instability, the impact ejection and thermal fracture of parent bodies of groups of meteorite-producing meteoroids cause to shatter into numerous fragments of different sizes. The resulting fragments form a group of bodies with almost identical heliocentric orbits, which then gradually move towards to Earth-crossing orbit due to orbital resonance with major planets, especially with Jupiter. In groups still can contain potential meteorite-producing meteoroids and this must lend some support to purposeful monitoring of potential members of groups in the identified periods of increased fireballs and meteorites activity by means of both of land fireball network and space tools established on orbital satellites is important for the prevention of danger to the Earth.

B1.1-0058-18 DEVELOPING A GENERAL UNDERSTANDING OF THE EVOLUTION OF COMETARY LANDSCAPES THROUGH NUMERICAL SIMULATIONS

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Comets, remnants of the formation of our solar system, typify the remnant, unprocessed materials from which all the larger planets were constructed. Consequently, they represent a window into the initial conditions that proved favorable for the formation of the Earth and life as we know it. With Rosetta's rendez-vous of comet 67P/Churyumov-Gerasimenko (67P) in the summer of 2014, we now have a dataset that permits access to the spatial scales where the processes relevant to small body evolution can be directly observed. These observations have allowed for detailed analyses of morphologies down to the meter scale across the entire nucleus, and have provided a long temporal data set with which to search for changes on the surface, important observations that have given us the opportunity to watch how a comet erodes.

Changes on the surface are driven by outgassing from sublimation of near-surface volatiles, and are expressed on the surface in two forms: large-scale changes to the bulk nucleus via cliff collapse, and small-scale changes contained within the smooth terrain regions that blanket much of the northern hemisphere. Large-scale failure of cliffs generates low thermal inertia, volatile-depleted regolith that acts to slow further bedrock sublimation, allowing for the surface of 67P to retain its relatively primitive topographic form to the current day. Yet, despite their brittle appearance in Rosetta images, with boulder deposits at their base suggestive of mass wasting, there is little evidence of substantial topographic evolution of the cliffs after 67P's perihelion passage. Most changes were within the smooth plains deposits, with only a few observations of cliff failures. As such, we have no knowledge, of the frequency of mass wasting events and how much material may be expected to be removed in any given event.

Numerical landscape evolution modeling offers the possibility to tie Rosetta's many observations to the fundamental physics that drives these processes, and ultimately determine whether 67P evolves gradually, through its jets, or stochastically through large outburst events. Specifically, we utilized the MARSSIM landscape evolution model, which accounts for the thermophysical weathering of a bedrock composed of both volatile and non-volatile materials on a low, variable gravity environment like on 67P. Unlike for other planetary bodies, our simulations use realistic inputs as to the volatility and strength of the bedrock, and insolation rates and initial topography as measured by Rosetta.

Our simulations are designed to test over what time scale(s) 67P's topography evolves, and in what manner (i.e. does the surface erode gradually through its jets, or are sudden, chaotic events the dominant means by which the topography is formed)? These simulations, therefore, allow us to constrain the rates of landscape evolution and the total erosional exhumation on 67P, to directly answer the question as to how its surface evolved despite the current apparent low levels of observed activity. Accordingly, we assess the question of whether 67P's northern hemisphere terrains are primitive or not, and compare directly the erosional processes observed on both 67P, but also erosional processes observed on comets 81P/Wild 2, 9P/Tempel 1 and 103P/Hartley 2. Further, we combine a robust study of transient changes in the smooth regolith terrains, which are expressed as pits, to better constrain both the evolution of this vast smooth regolith cover, and of the volatiles embedded within the near-surface of 67P.

B1.1-0059-18 PLASMA WAVES IN COMETS

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Plasma waves are a unique feature of space plasmas and have a universal presence in our solar system - planets, some of their satellites and interplanetary medium (IPM) where electrostatic and electromagnetic plasma waves are observed. The plasma environment of Sun also supports the generation of some plasma waves such as Alfven waves which travels a long distance in heliosphere. Plasma waves are predicted to exist in interstellar medium (ISM) and are also believed to exist in many other natural plasma systems such as pulsars, quasars and galaxies.

The plasma environment around a comet is also capable of sustaining plasma waves. Some of these waves are observed in comets Giacobini-Zinner, Halley, Grigg-Skjellerup and Borrelly. Some other comets such as Hyakutake and 67P/ Churyumov-Gerasimenko are also supposed to sustain plasma waves but are yet to be observed. This paper presents a brief review on the plasma wave observations in cometary plasma environment carried out so far and some of its unresolved issues.

B1.1-0060-18 RELATIONSHIP BETWEEN THE FORMATION OF THE ANOMALOUS TAIL OF COMETS WITH METEOROID SWARMS

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Of the 80 comets having anomalous tail, it detected 24 comets, which is associated with meteor showers. About 20 comets, observed a significant transient nuclei activity, are able to generate meteoroid swarms that do not intersect the Earth's orbit. It determines the minimum time of formation of the closed meteoroid swarm of comet 6P/d'Arrest, 10P/Tempel 2, 19P/Borrelly, 34D/Gale, 67P/Ch-G and D/1894 F1. It turned out that the most rapidly meteoroid swarm formed from comets 19P/Borrelly, 34D/Gale, 67P/Ch-G, 6P/d'Arrest, D/1894 F1 and 10P/Tempel 2. Time meteoroid swarm formation depends on the velocity of ejection of dust particles comet. This must be taken into account in the preparation of space missions beyond Earth orbit.

B1.1-0061-18 DYNAMICS OF LANDSLIDES ON AN ASYMMETRIC COMET

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The phenomenon of landslide is a form of the gravity movement. They play important role in the overall process of erosion on terrestrial planets. Comets and other small celestial bodies have very weak gravity field, so it is believed that probability of such motion is very low. However, data from space missions to comets 9P/Tempe 1 and 67P/Churyumov-Gerasimenko revealed existence of landslides. The causes of landslides are usually related to instabilities of slopes. It is often possible to indicate a few causes of the landslide. Causes are the factors responsible for making the slope unstable. Usually only one factor is a trigger. For terrestrial landslides several causes are usually considered, e.g.: (1) the pressure of water in pores acts usually to destabilize the slope, (2) acceleration of ground motion resulting from earthquakes or impacts, (3) liquefaction of saturated soil, whereby the soil loses its strength in response to an applied stress.

Some of these factors could also trigger the motion [1]. Note that on comets, instead of liquefaction, one can expect fluidization when gas and solid particles form a mixture [2]. On the small bodies of spherical shape the total area of the regions with large slope is limited. The different situation is observed on highly asymmetric bodies [3]. In the present paper we consider comet 67P/Churyumov-Gerasimenko. It is found that the most of the surface (75%) has the slope in the range 0< <40o. The slope in the range 40o < <70o is found on 17% of the surface and on 6% of the surface the slope is 70o< <90o. On 1.6% of the total area of the comet there are overhanging surfaces. Here, we consider slow ejecta as material for the possible landslides. This ejecta could be a result of an internal activity [4, 5] or of impacts. We find that for the velocity 0.3 m s-1 or lower, the ejecta land usually close to the starting point. Ejecta faster than 0.5 m s-1 have complicated trajectories and could land very far from the starting point.

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B1.1-0062-18 THE SHIFTING SANDS OF PHOBOS: SPACE WEATHERING AND MASS WASTING ON MARS' MOON

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Visibleto near-infrared imaging and spectroscopy (e.g. Mars Express OMEGA HRSC; Mars Odyssey CRISM HiRISE) of Phobos reveal two major geologic units: the majority of the surface is covered by a "red" unit, a low-albedo, nearly spectrally featureless unit with a red continuum slope; while a "blue" unit, defined by its slightly higher UVVIS albedo and relatively flatter continuum slope, is more locally distributed and associated in particular with Stickney crater. The red unit may be derived from the blue unit as a result of darkening and reddening by space weathering (e.g. Pieters et al., 2014); however, limited spatial resolution of measurements, the unique orbital environment at Phobos, and its unknown composition are challenges to understanding the true relationship of these two units.

The Phobos gravitational environment presents a set of unique conditions that can inform our understanding of regolith development and maturation for this enigmatic body. Due to its proximity to Mars and its slightly eccentric orbit (e = 0.0151), Phobos experiences librations that lead to local variations in surface gravity slopes. These slopes can vary by up to 2 degrees for every orbital period (7hr 39 min). Using direct numerical simulations of Phobos' regolith, we show that these variations can lead to a small amount of mass-wasting in high-slope regions during every orbit. We find that high-slope regions that experience moderate-to-high variations in surface slopes are correlated with blue geological units on the moon's surface. In particular, we find that this may explain the mass-wasting features that appear on Stickney's eastern ridge and extends eastward towards the sub-Martian point. Our findings suggest a continual shifting of regolith on the surface of Phobos that transforms its surface by exposing fresh sub-surface material.

Using OMEGA observations of blue and red regions of Phobos, we quantify typical slope differences between the units. Leveraging space weathering rates derived from observations of several asteroid families (e.g. Kaluna et al. 2015) that could be compositional analogs to Phobos, we analyze the spectral slope differences between the blue and red units on Phobos and find that blue material would weather to red in 104-108 years. This timescale agrees with our predicted quick refreshing rate due to eccentricity-driven mass-wasting. If blue material on Phobos represents relatively pristine, unweathered regolith, it is difficult to explain the observed absence of mafic absorptions in the context of in-situ formation or the capture of an inner solar system body, which predict the presence of olivine and pyroxene. Rather, Phobos is likely a captured main-belt or outer solar system body.

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B1.1-0063-18 TELESCOPIC CAMERA FOR PHAETHON (TCAP) AND MULTIBAND CAMERA FOR PHAETHON (MCAP) TO BE INSTALLED ON THE DESTINY+ SPACECRAFT

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DESTINY+ (Demonstration and Experiment of Space Technology for INterplanetary voYage, Phaethon fLy-by and dUst Science) is a mission proposed for JAXA/ISAS Epsilon class small program, currently in the pre-project phase (Phase-A) with a launch targeted for 2022. DESTINY+ is a joint mission of technology demonstration and scientific observation. The science mission objectives are (1) to measure physical and chemical properties of cosmic dusts around 1 au and (2) to conduct geological observation of Phaethon upon flyby and analyze dusts nearby Phaethon. Phaethon is known as a parent body of the Geminid meteor shower, the size of which is approximately 6 km in diameter. Phaethon is important as a known source for cosmic dust delivered to the Earth. During the flyby of Phaethon spatially resolved images of Phaethon will be taken by two onboard cameras, the Telescopic CAmera for Phaethon (TCAP) and the Multiband CAmera for Phaethon (MCAP). The relative flyby speed is as high as 33

km/s and the distance at the closest approach is approximately 500 km. The main purposes of the DESTINY+ flyby observation of Phaethon is to understand the geology of a parent body of a meteor shower, and in particular constrain the dust ejection mechanisms from active (i.e., dust-ejecting) asteroids. The specific objectives of the camera observation are taking images for

(1) obtaining the light curve of Phaethon in order to estimate the rotational period, (2) measuring the outline shape of Phaeton, (3) making a 3D shape model of Phaethon, (4) observing the surface geological features of Phaethon including dust ejection features, and (5) observing the surface material distribution of Phaethon. The observations (1) to (4) will be conducted by TCAP, and (5) by MCAP. We will explain the flyby imaging sequence of DESTINY+, and show the conceptual designs of TCAP and MCAP.

B1.1-0064-18 FURTHER ANALYSIS OF TRANSIENT DUST CLOUDS AT L4 AND L5 OF THE EARTH-MOON SYSTEM

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Dust clouds at the L4 and L5 libration points of the Earth-Moon system as first observed by Kordylewski (1967), continue to provide Earth-based, space-based and in-situ observational challenges. With the last comprehensive study concluded in 2002 (Moeed, 2003), this paper provides an update on the positive and negative observations since. So far, positive observations have shown that the infra-red might offer the best opportunities for detection (specifically in bands between 1.5μm and 8μm). Further study has therefore suggested focusing on ground and space-based infra-red surveys which have serendipitously observed these regions. An analysis of such mission data yields over 8,500 further observations of L4 and L5 (which we take to incorporate a 0.5° region around both points). Some preliminary results from the COBE

(DIRBE) dataset (negative observations) are presented demonstrating an upper limit of 6.31 MJy/sr (Moeed, 2003). The methodology used however is repeatable across all other scans of the area and analysis of all 8,500 scans should yield improved results. The "now-you-see-menow-you-don't" phenomenology of these clouds is also correlated against possible interplanetary dust collisional events (e.g. cometary tails) which could regularly feed these areas.

B1.1-0065-18 INVESTIGATION OF THE SOLAR SYSTEM STRUCTURE USING THE SOLAR POWER SAIL: OKEANOS

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The solar power sail mission: OKEANOS (Oversize Kite-craft for Exploration and AstroNautics in the Outer Solar system) is a Japanese candidate deep-space probe that will be powered by hybrid propulsion of solar photon acceleration and ion engines. The main scientific objectives are studies of Trojan asteroids in the Jovian L4 or L5 regions. The long distance and period from the launch to the swing-by at Jupiter will give us a good opportunity to explore the solar system between the Earth and the Jupiter to elucidate the solar system disc structure. We define the cruising-phase sciences of the OKEANOS mission as the scientific theme that will be explored or observed from the launch to the swing-by at Jupiter. Candidates of instruments for the cruising phase are: the EXo-Zodiacal Infrared Telescope (EXZIT), the Arrayed Largearea Dust detectors in INterplanetary space (ALADDIN)-2, the MaGnetic Field experiment (MGF)-2, and the GAmma-ray burst Polarimeter (GAP)-2. In this paper, we report scientific purpose and observation plans of them. Zodiacal light observed at visible and near-infrared wavelengths is thought to be sunlight scattered by interplanetary dust. The two-dimensional distribution of zodiacal light reflects the three-dimensional structure of interplanetary dust. However, it is still controversial that how the ratio of asteroid-origin to comet-origin changes by the heliocentric distance. Therefore, the comparison of the radial distribution of zodiacal light and the in-situ dust observation will help clarify the distribution and components of solid particles in our solar system. These results are expected to provide precise distribution of the interplanetary dust in our solar-system discs. The temperature of the solar wind, which depends on the heliocentric distance, has been observed to be greater than that predicted by the adiabatic model. Therefore, the existence of heating processes, such as plasma turbulence or magnetic reconnection, could be predicted. The observation of the magnetic field by the devices separated in the scale of the membrane of the Solar Power Sail provides the resolution of the plasma turbulence on the electron scale. Thus, the intermittent observation of the magnetic field between the Earth and Jupiter would determine the heating mechanism of the solar wind. The synergy of the magnetic field and dust observation may show the interaction between interplanetary dust and solar wind. By analyzing the environments on the dust surface, the chemical evolutions of molecules caused by solar wind and cosmic radiation can be investigated. We are investigating the possibilities to detect gamma-rays and particles from the solar-system shocks.

B1.1-0066-18 INVESTIGATING CERES' SUBSURFACE PROPERTIES THROUGH INTERMEDIATE LANDSLIDES

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Ceres, the largest body in the asteroid belt, is a primary focus of NASA's Dawn mission, partially due to evidence for ice in Ceres' surface and interior. Here we use Dawn Framing Camera data and build on earlier work using landslides to estimate ice content. Previously, three landslide types were identified using morphological criteria: type 1 (T1) have a thick, lobate toe, type 2 (T2) are thin and have a larger run out length than T1 landslides, and type 3 (T3) are more comparable to fluidized ejecta. However, landslides that do not fall cleanly into these groups, termed intermediate (IM), span a continuum between T1 and T2. Looking at these IM landslides allows us to better understand the relationship and progression between T1 and T2 and to identify any unique behaviors.

Our current analysis of IM landslides estimates the friction coefficient of Ceres' near-surface material as the landslide deposit is emplaced via the ratio of landslide drop height to run-out length (H/L). We include both the conventional maximum (max) and our in-progress center of mass (CoM) approximation. To obtain HMax/LMax, we produce a profile graph to attain the max lengths and heights of the feature. HCoM/LCoM measurements are obtained using a profile by estimating the center of mass of the projected preexisting surface and the deposit. We have found some H/L values to be lower than those of mobile clays, suggesting these landslides require friction reduction most likely from ice. Further, the overlapping range of H/L ratios for T1 and T2 flows is reinforced by the continuous range of H/L values for IM landslides. This implies emplacement conditions are not uniquely linked to morphology, and may suggest temperature-dependent behavior. We have also used a volume-area measurement of the scar to describe the flows. This relationship can be used to describe the type of material flowing in the landslide and can help distinguish between the different types using the depths to which the flows fall. This, along with an investigation of physical properties, has been done among the landslides to fill the continuum between T1 and T2. Overall, the major conclusions drawn from IM landslide analyses are 1) the idea that transportation is loosely tied to morphology, 2) that landslides on Ceres progress across a continuum where the distinction of T1 and T2 represent the end member states, and 3) the observation of potential fluidization in the landslides.

B1.1-0067-18 THERMAL ANALYSIS OF CERES' SURFACE

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Thermal inertia is a fundamental parameter that controls surface temperature variations of airless bodies; being sensitive to the presence of dust, regolith or rock, it can be considered as an indicator of the physical structure and type of the surface material. Ceres and Vesta, the two largest bodies of the main asteroid belt, are important to understand the early stages of solar system and the formation of terrestrial planets; the Visible and InfraRed mapping spectrometer (VIR) onboard the NASA DAWN mission has allowed to measure the surface temperature of these bodies, and a thermal analysis has been done for Vesta's surface, obtaining a map of its thermal inertia. A similar analysis has now been done for Ceres. The thermal inertia is derived by comparing the observed temperatures with the theoretical temperatures calculated with a thermophysical model. The code can simulate different types of material with different thermal conductivity, corresponding to different kind of material (from lunar dust to regolith, in ascending order of thermal inertia); the temperatures are calculated iteratively by varying the values of roughness (a term characterizing topography at subpixel scale) and thermal conductivity class, until observed temperatures are reproduced. Our analysis indicates a low value of the average thermal inertia (up to 20 Jm−2K−1s−1/2), thus confirming again the inversely proportional trend of the thermal inertia as a function of the diameter, observed for many asteroids of the main belt. Much higher thermal inertia values than the average have instead been derived for two small areas, the faculae of the Occator crater and the Haulani crater. The possible causes of these differences will be discussed.

B1.1-0068-18 GEOPHYSICAL MODELING OF CEREAN FRACTURED TERRAIN: INSIGHTS INTO THE STRUCTURE AND H2O CONTENT OF THE SOLAR SYSTEM'S SMALLEST DWARF PLANET

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Nar Sulcus is located in the southwest quadrant of Yalode crater on Ceres' southern hemisphere. Geological mapping of the fractured terrain revealed it is composed of two sets of mutually perpendicular fractures.

We test the hypothesis that the topography and morphology of the Nar Sulcus normal faults are controlled primarily by a thin ice-rich elastic layer. We do this by mapping the structures in Nar Sulcus from spacecraft images, comparing their profiles to a single layer flexural-cantilever model for normal faulting similar to the one developed by [1], and analyzing their displacement:length (D/L) ratios using a method similar to the technique described in [2]. This analysis, which is similar to the one conducted on the europan ice shell by [3], estimates the elastic thickness, elastic moduli, and remote stress acting on the faults at Nar Sulcus.

Initial results from the flexural-cantilever model indicate that the elastic thickness of the cerean 'crust' is 700 m, and that its tensile strength is higher than that of pure water ice but much lower than that of even weakly lithified silicate material. The D/L analysis suggests that the remote stress on the Nar Sulcus normal faults is on the order of a few tens of MPa. This remote stress is incompatible with a genesis from static loading, and suggests an active source of uplift [4]. This could plausibly be solid-state diapirism, or laccolith formation due to cryomagma accumulation sourced from either impact melt or endogenic reservoirs [5].

The incorporation of higher resolution terrain models before the COSPAR meeting will provide for more thorough and insightful results.

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B1.1-0069-18 VOLATILES ON VESTA AND CERES INVESTIGATED BY GEOMORPHOLOGICAL AND EXPERIMENTAL ANALYSES

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The two most massive objects in the asteroid belt were explored by the Dawn mission: Vesta (diameter 526 km) was visited from 2011-2012 and Ceres (diameter 940 km) was visited from 2015-2018. Both objects are protoplanets that have likely existed since the beginnings of our solar system. Thus, they can provide valuable inputs into our understanding of the evolution of the solar system. Prior to Dawn's arrival, Vesta was thought to be depleted in volatiles while, in contrast, Ceres was predicted to be volatile rich (e.g. Russell and Raymond, 2011, SSR). However, the discovery of pitted terrain (Denevi et al., 2012, Science) and curvilinear gullies and lobate deposits in impact craters on Vesta (Scully et al., 2015, EPSL) indicated that Vesta, at least locally, might not be as depleted in volatiles as originally thought. Scully et al. (2015) hypothesized that localized deposits of subsurface water ice were heated by impacts, releasing liquid water onto the walls of newly formed impact craters. Under impact-induced transient atmospheric conditions, this short-lived liquid water was proposed to form curvilinear gullies and lobate deposits via a debris-flow-like process. The vaporization of this short-lived liquid water, at the ends of the curvilinear gullies and lobate deposits, was further suggested to contribute to the formation of the pitted terrain. Similar geomorphological features have been observed on Ceres (e.g. Sizemore et al., 2017, GRL), and there is abundant evidence for water ice within Ceres' crust (e.g. Buczkowski et al., 2016, Science; Combe et al., 2016, Science; Schmidt et al., 2017, Nature Geoscience). Here we evaluate the hypothesis of Scully et al. (2015), using both geomorphological analyses and laboratory experiments about the behavior of liquid water under low-pressure conditions. We will present initial results of our geomorphological analyses of curvilinear gullies, lobate deposits and pitted terrain in specific Vestan impact craters, and compare these features to those within Cerean impact craters. In addition, we will discuss our experimental set-up, and present the results of our initial experiments, in which water and brine were exposed to pressures of 10-4-10-5 torr. This work is being carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract to NASA. Government sponsorship acknowledged.

B1.1-0070-18 BREAK-UP NEAR-EARTH ASTEROID FAMILY 1566 ICARUS AND 2007 MK6

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Many asteroid families have been identified in the main belt while none in the near-Earth asteroids population due to frequent planetary perturbations. Apollo type NEA 2007 MK6 has been suggested to be a fragment of near-sun asteroid (1566) Icarus. In order to examine surface heterogeneity, rotational lightcurve and spectroscopic observations were carried out using US-Japan telescopes and 4.3-m DCT at Lowell observatory for Icarus and 2007 MK6 during 2015-2016 Earth encounters. The visible spectrum of 2007 MK6 was defined as O-type taxonomy. Meanwhile Icarus also has O-type features among average Sq-type surface. This paper will discuss physical evidences for the break-up NEA candidate.

B1.1-0071-18 DEVELOPMENT OF A DUST IMPACT DETECTOR AT LOW-MID VELOCITY RANGES FOR A RENDEZVOUS MISSION TO SMALL BODIES

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Since the dawn of solar system exploration, cosmic dust measurement by spacecraft has been mainly focused on hypervelocity impacts in cruising phases, fast flybys to target bodies and incoming sporadic dust flux to orbits around planets/satellites. Recently mission opportunities are expanding to rendezvous to small bodies like comets and activated asteroids and other celestial bodies emitting local dust components such as icy plumes of Ceres, Europa, and Enceladus. In such rendezvous missions including Rosetta/Philae to a comet nucleus, spacecraft receives impacts by local dust at much lower velocities than the hypervelocity regime, i.e., well below 1 km/s order. In order to detect impact signals and to derive physical properties of these local dust grains, we must develop a new type of dust detector sensitive enough to lower momentum (i.e., smaller and slower impacting particles) than previous hypervelocity dust detectors. In this study, we started to develop such a new detector by redesigning electronics and data processing programs of the ALADDIN Poly-vinylidene Fluoride (PVDF) film sensor array onboard the solar sail spacecraft IKAROS launched in 2010. The IKAROS-ALADDIN was originally designed for detecting hypervelocity impact signals of as large meteoroids as 10 microns order during the interplanetary cruising between the Earth and Venus orbits. We first added an amplifier circuit just after the IKAROS/ALADDIN data processing unit and conducted single particle impact experiments of 10 to 50 micron glass beads, 20 micron aluminum particles, 30 micron iron particles, 100 micron alumina particles onto the IKAROS-type PVDF film sensors at low to medium velocity ranges, namely 1 to 600 m/s. With the 4 cm^2 effective area of the PVDF sensor, we obtained an empirical relationship between impact momentum and signal profiles. The second step of our development is to distinguish the amplified signals of lower momentum cases from integrated noise signals by reducing multiple noises generated from the sensors, the electronics, and the impact experiment apparatus and by re-arranging an array of amplifiers and noise filters for the data processing unit in order to allow the PVDF sensors to have larger effective areas like the IKAROS-ALADDIN.

B1.1-0072-18 ALL-SKY SPACE INSTRUMENT FOR EARLY DETECTION OF DANGEROUS BODIES IN THE NEAR EARTH SPACE

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The Chelyabinsk meteorite of 2013 attracts interest to small Solar system bodies that can be seen only very close to the Earth. Such objects can reach the Earth only a few hours later their possible detection, so a survey of early warning of dangerous space objects must be based outside of the Earth surface. We propose a simple device that will consist of wide-angle optoelectronic cameras which fields of view cover all sky. If the satellite with such device will be launched to the solar-synchronized orbit and use 3-axis stabilization, any star in sky images will be stable and point-like. Though any moving object will produce moving image, and it can be easily detected. As cameras observe the stable sky, it is possible to use long expositions for increasing limiting power. If we use high-speed lens "CANON EF85mm f/1,8" and full matrix camera like SONY-7Alpha, we can use 100-sec exposition to have 17.5m limiting magnitude. So deem will be comet nucleus with diameter 20 meters at a distance 2 million kilometers. Having velocity 20 km/s it can reach Earth in 30 hours. To avoid the hindering illumination from the Sun, the whole instrument must be placed in the shadow of its solar batteries. Batteries will cover only 10% of the whole sky in the direction, from where less than 1% of natural Solar system objects can appear. From solar-synchronized orbit, the Earth will cover nearly 10% of the sky too, but due to the orbital motion of the satellite maximal duration of invisibility of any coverable point will be just 1/6 of revolution period. So the proposed space instrument will be continuously observing the whole sky without any risk of missing or mixing up the objects of interest.

B1.1-0073-18 DETECTION OF SMALL TRANS-NEPTUNIAN OBJECTS WITH STELLAR OCCULTATIONS AND MIOSOTYS.

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Miosotys

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We present here a 4 years campaign of search for TransNeptunian Objects by a dedicated ground-based instrument MIOSOTYS (Multi-object Instrument for Occultations in the SOlar system and TransitorY Systems). MIOSOTYS is a fibre-based, high speed photometer which is designed mainly for serendipitously monitoring the occultation events caused by small (D around 1 km) Trans-Neptunian Objects (TNOs) located in the so-called Kuiper Belt. Such occultations reveal the density of small TNOs as far as 40 AU and beyond. Also, they provide information on the size distribution down to hectometer-sized objects. This is a key parameter for better understanding formation processes in this remote region of the solar system. We will describe the instrument and the telescopes as well as the observations conditions, the data reduction and the quality of the data set. We will present the method of search for potentials occultation events and how these events are fitted with synthetic profiles using diffraction patterns. This method, applied to the data set, gives occultation profiles which number is used to deduce the density of TNOs in the sky plane.

B1.1-0074-18 DUST LEVITATION DYNAMICS ON SMALL AIRLESS BODIES

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Increased interest in the exploration of small bodies in the solar system has led to a number of intriguing scientific objectives and mission architectures to these destinations. However, not much is known about the natural surface environment that exist on such bodies, nor what kind of effects our presence near the small body surfaces will have on the dynamics of the dusty regolith there. Thus a model of the small body environment which is able to predict surface conditions is needed for future mission planning and operations. Furthermore, this kind of model can be used concurrently with missions such as OSIRIS-REx and Hayabusa2 to match our predictions with observations in nature.

Using an updated version of the small body environment simulation developed by Nichols and Scheeres (2017) complete with polyhedron gravity model, solar radiation pressure, an electrostatic charging model, and consideration to the cohesive properties of the regolith material, the initial conditions required for particles to separate off the surface of a small body are examined. Such initial conditions provide insights into the charging characteristics and sizes of dust particles that are and are not able to escape from the surface; thereby providing a prediction on the types of charged particles which would remain on the surface and expect to be encountered on exploration missions. Additionally, examination of the charging rate of a dust particle due to currents to and from the grain by the surrounding plasma sheath can be coupled with the rotation rate of the small body and the grain's location on the body to determine if charged dust transport is a primary means of surface development and dynamics on the small body. The electrostatic model used in this simulation employs plasma sheath charging rates by Colwell et al. (2005), while leveraging new experimental and theoretical patched charging model results by Wang et al. (2016) and Zimmerman et al. (2016). Overall this work focuses on modeling the small body surface environment and providing predictions of the fine dust grain population expected to exist on the surface of such bodies, with simulations of how this dust population changes with the natural evolution of the body.

B1.1-0076-18 AUTOMATING ASTEROID SHAPE MODELING FROM RADAR IMAGES

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Characterizing the shapes and spin states of near-Earth asteroids (NEAs) is essential both for ruling out potential future Earth impacts and for planning spacecraft missions. Delay-Doppler radar imaging is a powerful technique to characterize NEAs. Radar observations using the Arecibo Observatory and the Goldstone Solar System Radar have provided detailed images of many near-Earth asteroids.

Reconstructing objects' shapes and spins from delay-Doppler data is a computationally intensive inversion problem. Since the 1990s, delay-Doppler data has been analyzed using the SHAPE software (Hudson 1993, Magri et al. 2007), providing shape models of a few dozen NEAs out of the hundreds observed with radar.

SHAPE performs sequential single-parameter fitting and requires considerable computer runtime and human supervision. Multiple-parameter fitting algorithms can more efficiently invert delay-Doppler datasets (Greenberg Margot 2015) and decrease runtime, but extensive human oversight of the shape modeling process is still required. Producing a single NEA shape model typically takes weeks to months. We have explored the application of two techniques to accelerate and better automate delay-Doppler shape modeling: Bayesian optimization and deep neural networks.

One of the most time-intensive steps of the radar shape modeling process is to perform a grid search to constrain the target's spin state. We have implemented a Bayesian optimization routine that uses SHAPE to autonomously search the full space of spin-state parameters. Bayesian optimization yields spin-state constraints with more than a factor of 3 less computer runtime than a grid search and with minimal human supervision. These routines are now being incorporated into radar data processing pipelines at Arecibo.

The shape modeling process could be further accelerated using a deep neural network to replace iterative fitting, quickly providing a good approximation of an asteroid's shape and spin state. However, neural network approaches require training with thousands of known asteroid shapes and corresponding sets of delay-Doppler images - far more than the current radar sample. To overcome this limitation, we have produced a database of simulated radar observations. The current database includes 10,000 artificial shape models mimicking the distribution of known asteroid shapes and simulated delay-Doppler data sets produced using a wide range of spin states and orbits for each of the artificial shapes. The database can be further expanded as needed.

We are now experimenting with training different neural network architectures, with the goal of eventually having a software routine that can produce an approximate shape and spin state model from a delay-Doppler radar dataset almost instantaneously.

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B1.1-0077-18 DYNAMICAL CHARACTERISTICS OF THE SURFACE AND THE ENVIRONMENT AROUND THE ASTEROID 16 PSYCHE

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The asteroid 16 Psyche, localized in the main belt and having a diameter of approximately 250 km, is thought to be the most massive among the M type asteroids. Observations made from Earth indicated an Iron-Nickel composition. It is believed that this body may be what was left from a metallic core of a protoplanet that would have had a catastrophic collision. Last year, a space mission with the same name, Psyche, was selected by NASA within the Discovery Program. The mission goal is to study the origin of planetary cores based on the exploration of asteroid 16 Psyche. The launch of the mission is planned for 2022 and, after a 4 years journey, it will explore the target for about 20 months. Therefore, a previous good knowledge of the target might be very useful for its planning. In the present work is studied a variety of dynamical aspects related to the surface, as well as, the environment around this asteroid. In our studies was adopted the shape of the asteroid determined by radar observations. The shape is given by a polyhedron of 2292 triangular faces and 1148 vertices. Assuming constant values for its density and rotational period. We used computational tools to explore the gravitational field generated by this asteroid. It was determined a set of physical and dynamical characteristics over the whole surface of the asteroid. Among them were computed and analyzed the altitude, tilt, slope, potential height, potential speed and escape speed. Beyond that, the equivalent spherical harmonics that define its gravitational field were computed and compared with the gravity field obtained via the polyhedron model. In order to explore the neighborhood close to asteroid 16 Psyche, the location and linear stability of the equilibrium points were found. The system has four external equilibrium points and an internal one. Two of the external points are unstable and the other two stable. A set of numerical simulations of massless particles around the asteroid confirmed the stability of these points, and also showed an asymmetry in the size of the stable regions. That information is also relevant in order to estimate regions on the surface of 16 Psyche that might have a higher amount of accumulated particles.

B1.1-0078-18 FREEZING OF AMMONIUM-SODIUM-CARBONATE-CHLORIDE BRINES: IMPLICATIONS FOR THE ORIGIN OF CERES' BRIGHT SPOTS

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Subsurface brines on Ceres containing natrite (Na2CO3) and smaller amounts of NH4Cl or NH4HCO3 have been proposed to reach the dwarf planet's surface from an internal reservoir, where the brines freeze and result in bright spots across Ceres. Kinetically frozen solutions containing the likely constituents of Ceres' subsurface brines (ammonium, sodium, carbonate, and chloride ions) were studied via infrared and micro-Raman spectroscopy, where the flash-frozen mixtures were found to preferentially form ammonium chloride and ammonium bicarbonate, even in sodium-dominated solutions. Additionally, sodium chloride only formed when sodium or chloride (or both) were present in excess in the brine solutions. Raman spectroscopy was further employed to analyze the effect of vacuum exposure on these frozen brines over longer periods of time to simulate the surface conditions of Ceres.

B1.1-0079-18 ASTEROIDS OBSERVATION FROM THE SOUTHERN HEMISPHERE USING PLANETARY RADAR

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Radar observations can provide unique information on the rotation period, size, structure, rotational state, and surface and near-surface characteristics and roughness of Near-Earth Objects (NEOs) such as asteroids. Via measurements of the range

(distance along the line of sight) and velocity along the line of sight, radar observations complement optical measurements of the plane-of-sky motion and enable precise knowledge of the orbits of asteroids. Multiple, sufficiently precise observations can allow orbits to be obtained to the extent that the mass and bulk density of an object can be inferred due to the presence of non-gravitational forces. Further, the orbits of asteroids can be used to assist with mission planning for spacecraft (e.g., as for the OSIRIS-REx and Psyche missions).

Although tons of interplanetary dust and small objects hit the earth every day, asteroids and comets can cause significant damage. Therefore, monitoring these asteroids is very important as it enables the prediction of collision orbits, and consequently, it becomes potentially possible to perturb the object away from the collision trajectory. Moreover, as these objects represent remnant debris from the formation of the solar system formation, studying them is also of scientific interest.

Approximately 5% of asteroid passes are only observable from the southern hemisphere, while suitable transmitters and receivers are almost exclusively located in the northern hemisphere. To extend asteroid radar coverage to the southern hemisphere, three stations in Australia have recently been configured to provide a radar capability to observe asteroids and study their trajectories and physical properties. These stations are the Tidbinbilla Deep Space Network station, and the Parkes and Narrabri stations of the Australia Telescope National Facility.

In this paper, we report on three asteroids, namely 2012 TC4, 1981 ET3 (Florence), and 2017 VR12. 2012 TC4 is of special interest, since the southern hemisphere location allowed observation during closest approach, only 40,000km from Tasmania. The provided results will be based on data collected in Australia using a bi-static radar setting. Data are subsequently processed using a software package created by UNSW Canberra, in contrast to the bulky and specialized receiver/recorders traditionally used for this purpose. We conclude with a discussion of future plans for the Southern Hemisphere Asteroid Radar consortium including more asteroids observable mainly from the Southern Hemisphere to complement the information obtained via DSN in the Northern Hemisphere. We also discuss plans to use multi-static radar and investigate the use of new coded waves to provide enhanced images of the target asteroids.

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B1.1-0080-18 GOLDSTONE RADAR OBSERVATIONS OF TRIPLE NEAR-EARTH ASTEROID 3122 FLORENCE

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We report Goldstone radar observations of near-Earth asteroid (NEA) 3122 Florence obtained in 2017. We observed Florence on 14 days between August 29-September 13, dates that straddled the asteroid's closest approach within 0.047 au. With an estimated diameter of about 4.4 km (Mainzer et al. 2011), Florence is among the largest near-Earth asteroids. The radar data reveal that Florence is a triple system that consists of a large primary body and two small moons that revolve around it. The observations yielded an extensive set of delay-Doppler images achieving range resolutions as fine as 75 m/pixel that placed hundreds of pixels on the primary asteroid. At least one large crater, several hundred meters in diameter, is visible in images obtained on Sep. 1, the day of the closest approach. Tracking of features visible in the images confirms the 2.36 h rotation period estimated from lightcurves by Wisniewski et al. (1997). The images suggest the primary has equatorial and polar dimensions of 4.6 and 4.1 km and a low elongation. The shape is sloped in both hemispheres and resembles the primary of the 1999 KW4 binary system reported by Ostro et al. (2006). The dimensions inferred from the radar images are consistent with those estimated from thermal infrared observations reported by Mainzer et al. (2011). Florence is only the third known triple system in the near-Earth asteroid population (after 2001 SN263 and 1994 CC) and it is by far the largest. Preliminary estimates for the diameters of the satellites are 0.2 and 0.3 km, and they orbit the primary with periods of about 7 and 22 hours. The inner moon of Florence has the most rapid orbital period among all satellites of the known binary and triple systems in both NEA and main belt populations. We observed two radar eclipses of the inner moon on Aug. 31 and Sep. 1. We used the measurements of delayDoppler positions of the satellites to estimate the orbital parameters, mass, and bulk density of the system. Due to the three-body nature of the system, we integrated the full equations of motion of the system to fit the radar astrometry estimated from Goldstone and Arecibo images. The orbital fit suggests that the pole of the primary is within 10 deg of the ecliptic longitude and latitude of (78 deg, -85 deg), although we cannot exclude a prograde pole 180 degrees from this point. We obtain a system mass of (7.9 ±

0.2) 1013 kg and a J2 value to 0.092 0.013, where J2 is the second degree zonal harmonic of the gravity field. If we adopt an equivalent diameter of 4.2 km for the primary, then the system mass implies a bulk density of 2 g/cm3, which, for plausible S-class meteorite analogues, is consistent with a porosity of at least a few tens of percent. The J2 value is consistent with the theoretical value calculated for a uniform density oblate object. The radar data were obtained as the asteroid moved 90 degrees on the sky, covered a wide range of subradar latitudes, and are ideal for estimation of a detailed 3-D shape model of the primary.

B1.1-0081-18 KIDNAPPING SMALL SIZE (POSSIBLY ICY) ASTEROID TO DEFLECT THEM AND BUID SAFE HUMAN CURRIER AND MULTI STATION LIFE-RAFT FOR SPACE ENTERPRISE.

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We know that any inter-planetary flight for human being is under a severe danger because of the lethal solar flares and their consequent radioactive solar ray showers. The screening for the astronauts by any huge superconducting magnets is too heavy, costly and fragile by many reasons. On the contrary the ability to reach any nearby icy small size (few meter up to a few tens meter size) asteroids, to harbour (by robotic tractors) there a complete undergound screened rooms where to host ecological life systems is the simplest opportunity we face today. This goal may guarantee a natural and safe currier net for future life (and human) stations and or enterprise. The need to deflect such a small size (a few hundreds to several thousands of tons objects) may be achieved by micro robotic nuclear engines tractors, located on the asteroid surfaces, able to dig the asteroid icy surface and to propel it by effective a mass momentum by a few element fountain jet array: the mini asteroids skin (ice, dust) ejections and their consequent bending might drive the asteroid easely to any trajectories, possibly enhanced by planet gravity sling shot. The need for such a wide array of icy asteroid stations, mostly in a robotic ibernated state, it will offer a safe and solid multi station life-raft in our (planetary) wide space sea. Such array will be able to collect material and to guarantee energy stations for future (step by step) short and long human (and living systems) planetary travels. References:

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B1.1-0082-18 GENERATING PERIODIC ORBITS FOR EXPLORATIONS OF ELONGATED ASTEROIDS

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Searching for periodic orbits around those minor bodies suffers from the trade-off: inefficient calculation by using the accurate polyhedral model or partial loss of essential characteristics with over-simplified models. Here a practical method is proposed to overcome the above problem in terms of elongated asteroids. The method is to obtain required initial variables of periodic orbits by using the rotating mass dipole with appropriate parameters, and then local iterations are implemented to obtain the real orbits over an asteroid in the polyhedral model. After introducing the dipole and polyhedral models, detailed procedures of the searching method are listed with five steps. A planar single lobe orbit is then presented to evaluate the effectiveness of the method, regarding the asteroid 216 Kleopatra of the triple asteroid system as a representative elongated body. By applying the above method, ten families of periodic orbits around Kleopatra are identified and discussed with respect to their orbital stabilities and periods. One sample of the sombrero orbit is checked by calculating 1000 hours to examine its orbital behavior. Besides the above orbits, the intriguing head-surrounding orbit is also analyzed even with an unexpected converged solution.

B1.1-0083-18 THE SEMI-ANALYTICAL ANALYSIS OF ORBITAL MOTION AROUND AN ASTEROID WITH THE JOINT EFFECTS OF THE C_20 TERM AND THE SOLAR RADIATION PRESSURE

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This study develops a semi-analytical method of propagating orbital motion near the equatorial plane of an asteroid, taking into account the joint effects of the asteroid's oblateness (the C20 term), the solar radiation pressure (SRP) and the asteroid's orbital eccentricity around the Sun. In the asteroid-centered frame, the Hamiltonian of the orbital motion is derived with Poincaré variables. It is firstly averaged over the orbital motion around the asteroid, and time-explicit formulas of the evolution of orbital eccentricity are obtained. The second average is performed over the asteroid's eccentric orbital motion around the Sun, and timeexplicit formulas of the evolution of orbital inclination are obtained. Then, the eliminated oscillating terms of the inclination during the second average are recovered by applying the Lie transformation. Compared with numerical integrations, the validity of these solutions for different semi-major axes and different values of area-to-mass ratios is analyzed. This study improves the knowledge of secular orbital evolution around an asteroid. It can be applied to fast prediction of long-term orbital evolutions around near Earth asteroids (NEAs), e.g. characterizing the fate of the orbiting dust/ejecta or the spacecraft especially with large solar sails.

B1.1-0084-18 ON THE SPIN-ORBIT-SPIN COUPLING IN THE BINARY ASTEROID SYSTEMS

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The well-known spin-orbit coupling usually assumes an invariant mutual orbit between the satellite and the planet (or the planet and the Sun) and usually only considers the second order term of the satellite's (or the planet's) non-spherical gravity and assumes a spherical shape for the planet (or the Sun). Different from this scenario, the two asteroids in the binary asteroid system are usually highly irregular. It may be no longer valid to assume an invariant orbit and only consider the second order term of one single asteroid. Considering higher order non-spherical terms of both asteroids and a varying mutual orbit, a more generous concept — the spin-orbit-spin resonance — was proposed by some researchers. In a general spin-orbitspin resonance, the orbital motion and both asteroids' rotational motions are involved. In the absence of one asteroid's rotational motion, the resonance is reduced to the traditional spinorbit resonance. In the absence of the orbital motion, the resonance is reduced to the spin-spin resonance.

When the two asteroids are close to each other (which is often the case in the current binary asteroid population) and move one eccentric orbits, the strength of the spin-orbit-spin resonances may be so strong that they overlap with each other. This overlap allows the binary asteroid system to transfer between different resonances via the Arnold diffusion. This process provides an efficient way for the orbital energy and the two asteroids' rotational energy to transfer between each other. In this contribution, using tri-axial ellipsoid shape models for the two asteroids and the mutual potential truncated at the 4th order, the spin-orbit-spin resonances are investigated. Their possible implications on the long-term dynamics of binary asteroid systems when combined with the YORP effect are also briefly addressed.

B1.1-0085-18 MOTION IN THE VICINITY OF ZERO-VELOCITY SURFACES ABOUT IRREGULARLY SHAPED BODIES

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There is increasing interest for the exploration of the small bodies of the solar system which has recently resulted in number of space missions devoted to these bodies. Also, significant effort has been invested in theoretical analysis of their dynamical environment. This is primarily referred to the development of novel methods for the modeling of gravity field, such as muscons and polyhedral models, which are significantly advantageous comparing to the traditional methods based on the spherical and ellipsoidal harmonic series. Although motion of the particle in such complex dynamic environment cannot be defined in closed form, there is the integral of motion which defines the so-called zero-velocity surfaces (ZVS) which separate the regions in which the motion is possible from those in which it is not (forbidden regions), similarly as in the threebody problem. In this research, we analyze the motion of the particle in the vicinity of these surfaces from the differential geometry point of view, by observing the connection between local geometrical characteristics of the orbit and ZVS when the particle is very close to them. We notice the relations between the curvature and torsion of the orbit and local main curvatures of the ZVS and dependence of these relations on the proximity of the particle to the ZVS. We performed this analysis for the asteroids Bennu and Castalia, for which the accurate shape models are available, and which are also good representatives of oblate and prolate bodies.

SPACE STUDIES OF THE EARTH-MOON SYSTEM, PLANETS, AND SMALL BODIES OF THE SOLAR SYSTEM (B)

PLUTO AND CHARON: THE NEW HORIZONS MISSION RESULTS (B1.2)

B1.2-0001-18 TO PLUTO AND BEYOND: OVERVIEW OF NASA'S NEW HORIZONS MISSION

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The New Horizons mission was selected by NASA in November 2001 to conduct the first in situ reconnaissance of Pluto and the Kuiper belt. The spacecraft was launched on 2006 January 19, received a gravity assist from Jupiter during closest approach on 2007 February 28, and flew 12,500 km above Pluto's surface on 2015 July 14. New Horizons carries a sophisticated suite of seven scientific instruments, altogether weighing less than 30 kg and drawing less than 30 W of power, that includes panchromatic and color imagers, ultraviolet and infrared spectral imagers, a radio science package, plasma and charged particle sensors, and a dust counting experiment. The flyby of Jupiter at 32 RJ in early 2007 provided a 20% boost in spacecraft speed, which cut more than 3 years off the travel time to Pluto and provided an excellent practice planetary encounter, as well as unique science data. The New Horizons flyby of the Pluto system in 2015 provided unprecedented detail on the Pluto-Charon binary and Pluto's four small moons (Styx, Nix, Kerberos, and Hydra, in order of their orbital distance from Pluto). Pluto's surface displays diverse landforms, terrain ages, albedos, colors, and composition gradients. Measurements of Pluto's atmosphere revealed many surprises, including 20 separate haze layers and smaller than expected N2 escape rates. Charon displays evidence of ancient tectonic activity and a giant hood of dark, red material covering its poles. All the small satellites have highly elongated shapes, surprisingly high albedos, and unusual rotational properties. The New Horizons plasma and dust instruments have provided a record of solar wind activity, high energy ions, and dust density along its trajectory from 1.5 AU to 43 AU. The first New Horizons Kuiper Extended Mission (KEM) was approved by NASA in 2016, and the spacecraft is now headed toward a close flyby on 2019 January 1 of the cold, classical Kuiper belt object 2014 MU69, which may be the most primitive object ever visited by a spacecraft. In this paper, we review the journey of the New Horizons spacecraft across the solar system, highlighting both its technical achievements and its unique scientific findings.

B1.2-0002-18 THE GEOLOGY OF THE PLUTO SYSTEM

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NASA's New Horizons mission acquired a large set of images and other data making possible thorough geological analysis of landscapes in the Pluto System. Pluto and Charon exhibit strikingly different surface appearances, despite their similar densities and presumed bulk compositions. Systematic investigation, modelling and mapping revealed that much of Pluto's surface is attributed to surface-atmosphere interactions and the mobilization of volatile ices by insolation. Many valley systems appear to be the consequence of glaciation involving nitrogen ice. Other geological activity requires or required long periods of internal heating, such as Pluto's extensive tectonic fabric. The convection and advection of volatile ices in Sputnik Planitia are thought to be powered by present-day radiogenic heat loss. The prominent mountains at the western margin of Sputnik Planitia, and the strange, multi-km-high mound features to the south, probably composed of H_2O, are young geologically as inferred by light cratering and superposition relationships. These multi-km-high mound features might be cryo-volcanoes. Their origin, and what drove their formation so late in Solar System history, is under investigation. East of Sputnik Planitia are large belts of sub-parallel sharp-crested ridges found only at high altitude that are apparently composed of massive deposits of sublimation-sculpted CH_4 ice, referred to as Bladed Terrain. New Horizons found evidence that Bladed Terrain may cover much of Pluto's low latitudes and may have originally formed there in part as a consequence of Pluto's very high obliquity. Currently Bladed Terrain is undergoing net erosion. This observation, along with evidence for formally more extensive nitrogen glaciation, implies that Pluto has undergone significant climate evolution. The dynamic remolding of landscapes by volatile transport seen on Pluto is not apparently evident on Charon's surface. Charon does, however, display a large resurfaced plain and globally engirdling extensional tectonic network attesting to its early endogenic vigor.

B1.2-0003-18 PLUTO'S GLACIERS, GLACIATION, AND IT'S RELATED MYSTERIES

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The New Horizons flyby of Pluto revealed an active low temperature physics laboratory involving volatile ices like N_2 and CH_4 and showcasing geologic features indicative of both present and past glaciation including dendritic networks, U-shaped and alpine valleys, as well as features resembling medial moraines and debris deposition. This talk will review these observations as well as our theoretical understanding of the ability of both N_2 and CH_4 ices to flow on Pluto's surface based on published laboratory assessed rheological properties of these volatiles. We will show some simulations of N_2-ice glacial flow based on the predicted past precipitation of N_2 using global circulation modeling of Pluto's past million year climate. We examine one of several outstanding issues: the puzzle of what processes and scenarios may be responsible landscape erosion on Pluto. We review the leading candidate mechanisms we think may be responsible for erosion of Pluto's surface and, further, shine light on how Pluto's low gravity and relatively low N_2 ice inventory make it difficult to reconcile how these mechanisms can carve km deep valley systems over the course of Pluto's geologic history. We shall discuss one hypothetical solution to this dilemma, namely, that Pluto's surface possibly harbored a far deeper inventory of CH_4 ice deep in its past and that this volume of ice, while present, provided the requisite overburden pressure to drive glacial erosion of Pluto's surface.

B1.2-0004-18 CONVECTION OF VOLATILE ICES ON PLUTO

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The 2.5-km deep, volatile-ice-filled basin named Sputnik Planitia (SP) is central to Pluto's geological, glaciological, and climatological activity. Composed of nitrogen, methane, and carbon monoxide ices, but dominated volumetrically by N2-ice, this ice sheet is organized over much of its extent into cells, typically 10-40 km across, that strongly resemble the surface manifestation of solid state convection. We have previously shown that solid layers of N2 ice >1 km or so thick should convect for Pluto's estimated present-day, steady state radiogenic heat flow (even considering a wide range of uncertainty for the latter). We have also shown that convective overturn in a several-km-thick layer of solid N2(-CH4-CO) can explain the great lateral width of the cells. We have argued that the temperature dependence of N2-ice viscosity implies that the SP ice layer convects in the sluggish lid regime, a unique convective mode heretofore not definitively observed in the Solar System. In this talk we will describe ongoing efforts to understand this convection and its implications, focusing on the questions of the aspect ratio and planform of the convective cells and the implications for the thickness of the ice sheet (depth to the water ice basement), Pluto's heat flow, and the potential for N2-ice melting at the base of the ice sheet.

We perform CITCOM convection calculations in 2-D and 3-D to constrain the depth of this N2 and thus the depth of the Sputnik impact basin and related properties and conditions. For an extended but plausible range of Rayleigh numbers and viscosity contrasts for solid nitrogen, convection can occur in all possible regimes: small viscosity-contrast, sluggish lid, or stagnant lid, or the layer could be purely conducting. Convective dynamics are complicated at the vicinity of regime transitions, thus we conduct a systematic analysis of convection regimes using 2-D convection simulations. Moreover, the conditions at the base of the nitrogen ice sheet are uncertain. It may be directly in touch with the water ice bedrock, or nitrogen-rich melts may be present if the base reaches the melting temperature of nitrogen (63 K). This bottom boundary condition affects the dynamics of the convection system and thus the surface manifestation, which is more prominent in 3-D models.

Sputnik Planitia is a deep, 1150 km x 900 km elliptical basin likely formed by the impact of an 200-km-wide ancestral Kuiper belt object more than 4 billion years ago. Based on depths of smaller, fresher craters formed in Pluto's water-ice bedrock, SP was likely originally no deeper than 10 km, which implies an upper limit of 7 km for the N2-ice sheet today. Preliminary topography determined by photoclinometry on the highest resolution New Horizons LORRI transects indicates the cells themselves are broad domes 100 m high. These topographic profiles are more consistent with greater as opposed to lesser viscosity contrast across the convecting layer. The vertical scale is also indicative of the integrated thermal anomaly (which provides the buoyancy that drives the convection). For N2-ice thermal expansion (which is large), 100 m of uplift is consistent with a temperature contrast of 10 K over a depth of 5 km, and greater thermal anomalies are required as the viscosity contrast increases. It is hard to reconcile these requirements with solely top-down cooling due to climactic temperature variations (small temperature changes), which has been proposed for SP.

B1.2-0005-18 CRYOVOLCANISM ON PLUTO AND COMPARISON TO FEATURES ACROSS THE SOLAR SYSTEM

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Pluto's surface has experienced considerable endogenic and exogenic resurfacing (Moore et al., 2016). The terrains on Pluto represent a variety of ages, from seemingly ancient to surprisingly young. Some of the very young terrains are the result of the volatile ices on Pluto's surface (e.g., the convecting nitrogen-ice-rich plains of Sputnik Planitia). But Pluto also has several examples of more recent activity (terrains with few-to-no superimposed craters), that appear to be primarily made out of non-volatile water ice.

The most prominent examples of potential cryovolcanism are two enormous domes with deep central depressions (Singer et al., 2016). The informally named Wright Mons stands 4 km high and the main mound spans 150 km. The informally named Piccard Mons is approximately 7 km high and 225 km wide. Only a few potential distinct flow features are evident, but the morphology of the areas surrounding Wright and Piccard indicates there may have been multiple episodes of terrain emplacement. There is also an extensive plateau to the west of Wright Mons with a relatively flat surface. This plateau exhibits many large depressions with various morphologies, most of which do not appear to have an impact origin.

Each potential example of cryovolcanism found in the outer solar system is unique, and Pluto and Charon's features expand the information we have to understand this enigmatic process. We will present image, topographic, and composition data for these feature along with geologic mapping results. We will discuss potential formation mechanisms in light of available empirical and model constraints.

Please note some geologic features names used here are informal.

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B1.2-0006-18 NUMERICAL MODELING OF PLUTO'S GLACIERS, FROSTS AND ATMOSPHERE TO INTERPRET NEW HORIZONS OBSERVATIONS

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On the basis of our experience on the other terrestrial climates of the solar system (Mars, Earth, Titan, Venus), we have developed a hierarchy of models to simulate the climatic processes at work on Pluto: a Global Climate Model to represent the evolution of the 3D atmospheric circulation and surface ices (N2, CH4 and CO) over up to several Earth years, complemented by a 2D volatile transport model able to simulate the evolution of the N2, CH4 and CO reservoirs over several millions years. Such tools are based on universal equations, with the minimum of ad-hoc hypothesis. Yet we found that the modelled Pluto climate system and the evolution of its volatile reservoirs are surprisingly sensitive to a few model parameters such as the ice albedos and deep subsurface thermal inertia. Nevertheless, by choosing selected values we could reproduce many characteristics of the planet observed by New Horizons in 2015, such as the distribution of nitrogen and methane glaciers and frost, the evolution of pressure, many aspects of the Sputnik Planitia ice cap, or the thermal structure of the near surface atmosphere. In this talk we will review what we have learned from these simulations, but also put forward the observations that remains enigmatic and difficult to understand and predict with our physical models.

B1.2-0007-18 COMPOSITION OF PLUTO, CHARON AND THE SMALL SATELLITES

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NASA's New Horizons spacecraft provided the first high-resolution imaging of the surface of Pluto and its moons. The Ralph instrument provides 4-color images (Blue 400-500 nm, Red 540-700 nm, NIR 780-975 nm, CH4 860-910 nm) and near-infrared spectral imaging from 1.25 to 2.5 microns. These data allow us to map the composition of volatiles, like N2, CH4 and CO, across the surface of Pluto as well as non-volatiles like water ice and the tholins. We find that the large basin, Sputnik Planitia, is filled with volatile ices and there is a general latitudinal pattern of composition on Pluto (that is interrupted by the basin of Sputnik Planitia). The north pole

of Pluto is dominated by methane rich ice relative to the more volatile N2 ice, mid-latitudes are dominated by N2 ice, and the equatorial region is dominated by tholins.

Pluto's large moon Charon generally has a more uniform surface composition compared to Pluto. The surface composition is dominated by crystalline water ice. Also seen on the surface of Charon is a feature near 2.2 microns attributed to an ammonia-containing species. Intriguingly, Charon has a dark, red north pole that can be explained by methane escape from Pluto and becoming cold trapped on Charon's pole until it photolyzes during the long artic winter. Two small satellites of Pluto, Hydra and Nix, also show a surface composition of water ice and hydrated ammonia.

These results and their implications will be addressed.

B1.2-0008-18 THOLIN-LIKE MATERIAL ACROSS THE SURFACE OF PLUTO

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Inferring the composition of Pluto's surface and atmosphere is critical to further understand the origin and evolution of this icy dwarf planet and by extension other trans-Neptunian objects with similar size or smaller. Laboratory experiments suggest that the dark red to yellow color of Pluto is due to the presence on the surface of tholin-like material, which are organic compounds produced through photolysis and radiolysis of native material found on the surface and atmosphere of the dwarf planet. We present a characterization of the tholin material across Pluto's surface through a pixel-by-pixel Hapke modeling of the New Horizons Ralph/LEISA and MVIC data (Reuter et al., 2008). The ultimate goal is to understand whether one or more colored agents are present across the surface and to possibly identify their optical characteristics. This will be of great importance as an input for future laboratory measurements and for understanding the nature of the dark material inside and outside the Pluto forming zone.

B1.2-0009-18 PLUTO'S ATMOSPHERE AS SEEN BY NEW HORIZONS

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Observations of Pluto's atmosphere by NASA's New Horizons spacecraft during its July, 2015 flyby [1] included a REX radio uplink occultation [2]; Alice ultraviolet airglow, solar occultation, and stellar occultations and appulses [3]; LORRI and MVIC images and LEISA infrared spectral-images of the haze [4]; and SWAP and PEPSSI in-situ observations [5]. Concurrent ground-based observations included stellar occultations [6] and ALMA measurements [7]. Together, these paint a picture of an N2-dominated atmosphere with numerous trace constituents, including CO, CH4, HCN, simple hydrocarbons, and more processed hazes. The atmosphere has a spatially variable lower atmosphere/planetary boundary layer that is strongly influenced by the surface temperature and the daily sublimation/condensation cycle [8]; a middle and upper atmosphere with Titan-like haze formation and chemistry [9]; and a cold, loosely bound upper atmosphere with CH4 and N2 escaping by enhanced Jeans escape [10].

[1] Gladstone et al., 2016, Science 351, aad8866. [2] Hinson et al., 2017, Icarus 290, 96-111.

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B1.2-0010-18 SOME PROBLEMS IN INTERPRETATION OF THE NEW HORIZONS OBSERVATIONS OF PLUTO'S ATMOSPHERE

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Here I will briefly discuss the following problems related to Pluto's atmosphere: (1) restrictions to LTE in the rotational lines of H2O and HCN above 700 km that affect thermal balance of the atmosphere; (2) contradictions in the estimates of H2O influx from ablation of the interplanetary dust; (3) great difference between the haze volume surface area in the LORRI and MVIC observations and that in the UV solar occultations and the models, including significant corrections to sticking coefficients of C2H2, C2H4, C2H6, and HCN in condensation, and (4) Triton's thermosphere during the Voyager 2 flyby.

B1.2-0011-18 PLUTO'S HAZE PROPERTIES FROM DISK INTEGRATED NEW HORIZONS MVIC OBSERVATIONS

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New Horizons flew by Pluto in July of 2015, revealing a geologically active world [1] with a complex atmosphere [2]. While Pluto has long been known to have a seasonal atmosphere [3-5], this flyby allowed us to image the atmosphere for the first time at resolutions less than 1

km/pixel and large phase angles up to 170°, revealing distinct haze layers in Pluto's atmosphere [6]. Like Pluto, both Titan and Triton are large icy worlds with complex hazy atmospheres and have been observed at high phase and resolution [7,8]. Herein, we apply a simple radiative transfer model to phase curves from disk-integrated observations of Pluto, Titan, and Triton, at phase angles from 15-170° to determine the single scattering albedo and the Henyey-Greenstein scattering phase function of Pluto's haze particles. From these two parameters and comparison between the three bodies we determine the size and spectral nature of Pluto's haze [9]. We generated phase curves from full disk images of Pluto taken by the Multispectral Visible Imaging Camera (MVIC) in its four color filters. MVIC began observing the Pluto system on April 9th 2015, 96 days before closest approach on July 14th 2015. We limit ourselves to data taken 6.7 days before and after closest approach as images taken before this time show Pluto as only appears as a few pixels on the disk which can exacerbate pointing errors. As MVIC observed the same faces of Pluto multiple times in those 96 days these images are redundant and can be ignored. We perform aperture photometry within the images to find the mean brightness of the atmospheric pixels, <I/F>, by summing all the pixels in the annular aperture, removing the mean dark current, and dividing by the number of pixels on the disk. To determine viewing and phase angles we use the MICE toolkit from JPL's Navigation and Ancillary Information Facility [10]. We similarly determine the phase curves of Titan and Triton using observations from the Imaging Science Subsystems aboard Cassini and Voyager 2 respectively. In addition to disk integrated phase curves, we also generate resolved phase curves for several areas of Pluto. We chose areas with seemingly contiguous compositions and morphologies, and subregions within them were completely illuminated through multiple observations during the flyby. Unsurprisingly Sputnik Planitia is brighter than Cthulhu Regio and the disk integrated value at low phase. However, Cthulhu Regio shows a massive increase in brightness at high phase angles, even brighter than the whole disk. This could be an increase in haze opacity over Cthulhu Regio or inadvertently including pixels off the disk due to pointing errors. Future work will interrogate these two hypotheses.

[1] Stern et al., 2015 The Pluto system: Initial results from its exploration by New Horizons [2] Gladstone et al., 2016 The atmosphere of Pluto as observed by New Horizons [3] Cruikshank et al., 1976 Pluto - Evidence for methane frost [4] Brosch et al., 1985 Occultation by Pluto on 1985 August 19 [5] Hubbard et al., 1988 Occultation evidence for an atmosphere on Pluto [6] Cheng et al., 2017 Haze in Pluto's atmosphere [7] Muñoz et al., 2017 Titan brighter at twilight than in daylight [8] Buratti et al., 2011 Photometry of Triton 1992-2004: Surface volatile transport and

. [9] Rages et al., 1983 Size estimates of Titan's aerosols based on Voyager high-phase-angle images [10] Acton et al., 2017 A look toward the future in the handling of space science mission geometry

B1.2-0012-18 RADIOMETRY AT 4.2 CM DURING THE NEW HORIZONS PLUTO ENCOUNTER

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During the New Horizons encounter of the Pluto system on July 14, 2015, the radio brightness temperatures of Pluto and Charon were measured from three unique perspectives: (1) the dayside on approach, (2) near closest approach to Pluto, and (3) the nightside on departure. The measurements were made using the New Horizons 2.1 m High Gain Antenna (HGA), the spacecraft's X-band receiver at 4.2 cm wavelength, and the on-board Radio Science Experiment

(REX). Pluto and Charon were unresolved by the HGA for the dayside measurements, but the measurements near closest approach scanned two chords across the Pluto disk with a resolution of about 12% of Pluto's diameter. The nightside measurements were recorded in two phases:

a scan across the Pluto nightside, at a resolution close to 50% of Pluto's diameter, during the REX radio occultation experiment (with the HGA pointed toward Earth), and (ii), later in departure, separate full-disk observations of Pluto and Charon. These measurements constitute an ensemble of radio brightness temperatures of Pluto and Charon from both the sunlit and dark hemispheres, and over a variety of surface materials, topography and emission phase angles. Placing these measurements in physical context necessarily involves understanding the emissivity, not only of the surface materials, but also the composition and structure of the subsurface, given the low absorptivity of the materials on Pluto and Charon at 4.2 cm wavelength. Fortunately, the surface material composition on Pluto's dayside was imaged independently at high resolution by the New Horizons on-board infrared imaging spectrometers [1,2], but only to a depth of the order of 0.1 cm. Even so, the emissivity of materials such as tholins and the ices of nitrogen and methane at temperatures in the range 30-40 K is poorly known, and further confounded by the lack of knowledge of the subsurface. With these uncertainties in mind, possible physical temperatures for Pluto and Charon are presented using models of emissivity derived from sparse laboratory experiments and extended via numerical computation. Choices of surface and subsurface composition and structure are further discussed that fit the observations within the constraints of emissivity and physical plausibility. [1] Stern

S. A., et al., The Pluto System: Initial Results from its exploration by New Horizons, Science 350, id.aad1815 (2015). [2] Protopapa S., et al., Pluto's global surface composition through pixel-by-pixel Hapke modeling of New Horizons Ralph/LEISA data. Icarus 287, 218-228 (2017).

B1.2-0013-18 THE SOLAR WIND INTERACTION WITH PLUTO'S ATMOSPHERE AS OBSERVED BY NEW HORIZONS

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The scientific objectives of NASA's New Horizons mission include quantifying the rate at which atmospheric gases are escaping Pluto and describing its interaction with the surrounding space environment. The two New Horizons instruments that measure charged particles are the Solar Wind Around Pluto (SWAP) instrument and the Pluto Energetic Particle Spectrometer Science Investigation (PEPSSI) instrument. This presentation describes results from these instruments when New Horizons flew past Pluto in July 2015 at a distance of 32.9 AU from the Sun.

Particle instruments on New Horizons revealed an interaction region confined sunward of Pluto to within 6 Pluto radii with an upstream solar wind stand-off distance of only 2.5 Pluto radii. The surprisingly small size is consistent with an atmospheric escape rate of 4-8 x 1025 CH4

molecules s–1 (considerably less that predicted before the flyby) as well as a particularly high solar wind flux due to a passing compression region. This region is similar in scale to the solar wind interaction with Mars's escaping atmosphere. Beyond Pluto, the disturbance persists to distances greater than 400 Pluto radii downstream.

B1.2-0014-18 NEW HORIZONS OBSERVATIONS OF DISTANT KBOS IN 2016 AND 2017

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NASA's New Horizons spacecraft flew past Pluto in July 2015 and will encounter the cold classical Kuiper Belt Object (KBO) 2014 MU69 on January 1, 2019. During the cruise between these two encounters, New Horizons has observed several KBOs and dwarf planets at uniquely high phase angles, as well as Centaurs at extremely high phase angles to search for forwardscattering rings or dust. We will report on the observations obtained with the LORRI framing camera from the start of 2016 to the end of 2017. These cover dwarf planets, classical KBOs, Centaurs, and the previously-reported 3:2 resonant KBO (15810) Arawn (Porter et al. 2016). We will present astrometry and photometry for these objects, in addition to a high-phase rotational lightcurve for 2012 HE85. We also describe and report on the ground-based observations with Subaru Hyper Suprime-Cam (HSC) that enabled these spacecraft observations. These observations are the prototypes for the continuing exploration of the classical Kuiper Belt that New Horizons will resume in August 2018.

B1.2-0015-18 THE NEW HORIZONS KUIPER EXTENDED MISSION: PLANS AND GOALS

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NASA's New Horizons spacecraft is conducting a first exploration of the Kuiper Belt in its current, approved Extended Mission, which will last through 2021 when the spacecraft reaches 50 AU. The centerpiece of this extended mission is a flyby of the cold classical Kuiper Belt Object (KBO) 2014 MU69 (MU69) on 1 January 2019 UT. This KBO orbits the Sun with a low eccentricity; it will be encountered at a heliocentric distance of 43.2 AU. This will be the first (and only, for the foreseeable future) close look at a cold classical KBO, and the most distant close encounter with any object in history. The nominal close approach distance for the flyby trajectory is 3,500 km, 3 times closer than the 2015 flyby of Pluto by New Horizons. Expected spatial resolutions will be as high as 35 m/pixel for panchromatic imaging, 320 m/pixel for color imaging, and 1.8 km/pixel for 1.25-2.5 μm near-IR spectroscopy. All of these resolutions considerably improve on those achieved at Pluto and its system of satellites. We also plan extensive rotational coverage on approach to MU69, deep imaging searches for satellites and rings, and measurements of microwave thermal emission from the day and night sides. Though neither coma nor activity is expected in such a cold, small body (D 30 km), we will also conduct extensive searches to constrain any such phenomena in visible scattered light, via UV absorption and emission techniques, and using the spacecraft's in situ plasma and dust instruments. We will summarize knowledge of MU69, the scientific objectives of the flyby, as well as the other heliospheric and KBO/Dwarf Planet science New Horizons is performing in this extended mission. We will also outline the exciting planetary science New Horizons can perform in a second extended mission.

B1.2-0016-18 PRESENTING THE NEW HORIZONS MISSION RESULTS TO THE FRENCHSPEAKING WORLD ON JAN 1ST, 2019

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The results of the mission to Pluto, Charon and MU69 that have been obtained or will be soon obtained with the equipment of the New Horizons spacecraft and the remarkable work of the team of scientists need to be communicated to the science community at large, to the decision makers who support such mission. The story needs also to be told to the public at large, to bring education about the world in which we live, and to foster new vocations and investment in space research. Reunion Island, a French/European state that may compare with Hawaii, located on the opposite side of the world with respect to Pasadena where the mission was initiated, played a minor but yet important role during launch operations in 2006, and a full scale model of the spacecraft is on permanent display for visitors in the city of Sainte-Rose where the Nasa tracking station was hosted. On the occasion of the 1st January 2019 fly-by of New-Horizons over object MU69, educational teams in Reunion Island, in cooperation with global French-speaking media, have plans to extend knowledge about the New Horizons mission and its achievements to the 300 million people of the French-speaking community world-wide.

B1.2-0017-18 SPECTROSCOPIC MEASUREMENTS OF RADICALS IN OUTER SOLAR SYSTEM ICE ANALOGS

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New Horizons instruments are pushing our understanding of outer solar system bodies. LEISA and Alice instruments in particular, are providing and will provide a wealth of spectral information to determine chemical compositions. Pluto and most KBOs surfaces are dominated by N2-ices and smaller amount of CH4, and CO. Based on the laboratory irradiation of outer Solar System ice analogs by photons or energetic particles, CH- and N-bearing radicals are expected to be present and trapped in these icy surfaces due to N2 ice low reactivity. The (non-)detection of radicals would put constraints on the processing history of these icy bodies.

To identify radicals in KBO surface spectra, the electronic and vibrational transitions of these species frozen in N2 matrices at low temperatures (25-45K) need to be measured over a large wavelength range.

In this work, we show the first results from an experimental setup capable of measuring radical spectra in outer Solar System ice analogs from the VUV to the mid-IR. Radicals are produced in a supersonic pyrolysis nozzle by thermally cracking specific reactants in an N2 flow. The radical-N2 beam is further expanded into a vacuum chamber and condensed onto a temperature controlled cryogenically-cooled window. The isolation of radicals by the N2 matrix allows us to perform spectroscopic measurements and derive radical frequencies as well as band strengths. The methyl radical (CH3) has been chosen as proof of concept here and future measurements will be extended to ethyl (CH3CH2), cyano (CN), and methylene (CH2) radicals. These spectroscopic data will allow us to derive local abundances of radicals from observed spectra and understand the specific energetic processing and history of Pluto and other KBOs.

SPACE STUDIES OF THE EARTH-MOON SYSTEM, PLANETS, AND SMALL BODIES OF THE SOLAR SYSTEM (B)

GROWING UP: THE LONG JOURNEY OF PLANETARY SYSTEMS FROM INTERSTELLAR VOLATILES AND REFRACTORIES TO ASTEROIDS, COMETS, AND PLANETS (B1.3)

B1.3-0001-18 INTRODUCTION BY MSOS+DOS AND TWO 5-MIN POSTER PRESENTATIONS

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Introduction by MSOs+DOs and two 5-min poster presentations

B1.3-0002-18 PROTOPLANETARY DISKS AND THEIR EVOLUTION

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The formation of planetary systems takes place in the gaseous dusty disks that surround young stars during their epoch of formation, known as protoplanetary disks. With the advent of sensitive observations and together with developments in theory, our field is making rapid progress in understanding how planet formation proceeds. In this review, I will describe how the evolution of protoplanetary disks is traced by observations of their dust and gas components, and I will present recent observational results that elucidate key aspects of the planet formation process, particularly focusing on observations at the sub-mm, millimeter, and centimeter-wave regime. This wavelength range is already providing a plethora of new results, thanks to improvements in sensitivity brought forward by VLA and ALMA. Finally, I will discuss different features observed in protoplanetary disks (gaps, asymmetries, spiral structure, etc.) at high angular resolution, and the role these substructures may play during the process of disk evolution and planetary formation.

B1.3-0003-18 NATURE OR NURTURE? THE EFFECT OF RADIATION ENVIRONMENT ON PROTOPLANETARY DISC EVOLUTION

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FRIED (Fuv-Radiation Induced Evaporation of Discs) is a project dedicated to studying the effect of radiation environment on the evolution of protoplanetary discs and any planet formation within them. Do discs subject to strong UV radiation in high mass star forming regions produce different planets to those in quiescent environments? What about in the intermediate regime?

The loss of matter from such discs is set by thermochemistry in the photodissociation (PDR) regime. State of the art photochemical-hydrodynamics is therefore required to model this process, which we have at our disposal using the TORUS-3DPDR code (e.g. Bisbas et al. 2015, Haworth et al. 2016).

In an externally evaporating disc, our models find a competition between the growth and radial drift of grains into small radii (where they might produce planets) and the evaporation of grains from the outer disc. This limits the available mass reservoir for planet formation, but also quickly sees the global solids-to-gas mass ratio rise as grains grow to a size at which they are resilient to stripping by photoevaporation.

I'll illustrate this with our recent work in which we studied the evolution of discs that would have been precursors to the famous Trappist-1 planetary system in different radiation environments (Haworth et al. 2018). Our models imply that photoevaporation requires much higher initial disc masses than canonically expected in order to facilitate formation of the observed 4 Earth masses of planets in this system. I'll also highlight our first evidence of an evaporating disc in a low mass star forming region in the case of IM Lup (Haworth et al. 2017).

Finally, I'll give a preview of upcoming results, including a large publicly available grid of mass loss rates for a range of stellar, disc and UV field parameters. This will permit theorists to include external photoevaporation in disc models, and for observers to make quick instantaneous mass loss rate estimates.

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(10.1093/mnras/sty168)

B1.3-0004-18 MAGNETICALLY INDUCED DISK WINDS AND TRANSPORT IN THE HL TAU DISK

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The mechanism of angular momentum transport in protoplanetary disks is fundamental to understanding the distributions of gas and dust in the disks. The unprecedented ALMA observations taken toward HL Tau at high spatial resolution and subsequent radiative transfer modeling reveal that a high degree of dust settling is currently achieved in the outer part of the HL Tau disk. Previous observations, however, suggest a high disk accretion rate onto the central star. This configuration is not necessarily intuitive in the framework of the conventional viscous disk model, since efficient accretion generally requires a high level of turbulence, which can suppress dust settling considerably. We develop a simplified, semi-analytical disk model to examine under what condition these two properties can be realized in a single model. Recent, non-ideal MHD simulations are utilized to realistically model the angular momentum transport both radially via MHD turbulence and vertically via magnetically induced disk winds. We find that the HL Tau disk configuration can be reproduced well when disk winds are properly taken into account. While the resulting disk properties are likely consistent with other observational results, such an ideal situation can be established only if the plasma β at the disk midplane is β0 = 2 104 under the assumption of steady accretion. Equivalently, the vertical magnetic flux at 100 au is about 0.2 mG. More detailed modeling is needed to fully identify the origin of the disk accretion and quantitatively examine plausible mechanisms behind the observed gap structures in the HL Tau disk.

B1.3-0005-18 VOLATILES FROM THE PRESTELLAR PHASE TO PROTOPLANETARY DISKS

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In this presentation, I will overview the theoretical and observational studies of volatiles from interstellar gas to protoplanetary disks.

Interstellar space is filled with diffuse gases, which are repeatedly swept by supersonic flows around sources such as expanding HII region and supernova remnants. Molecular clouds are formed in the post-shock region, when the converging flows make the shock wave propagating perpendicular to the magnetic field. While a significant fraction of carbon and oxygen is already depleted in the solid phase (dust grains) in diffuse clouds, the dust grains are coated by the ice mantle, when the visual extinction of molecular gas reaches a few magnitude (i.e. hydrogen column of several 1021cm−2).

As a self-gravitating core is formed, and the molecular gas becomes dense, the collisional timescale of gas and dust, and thus the freeze-out timescale of molecules onto ice mantle become shorter. Prestellar cores are characterized by dense (>105 cm−3) cold (sim 10 K) gas and the freeze out of heavy-element species, including CO, at the core center. Despite the low temperature, the ice mantle is not chemically inert; H atoms can diffuse and hydrogenate atoms and molecules. CO is hydrogenated to form CH3OH, as well as radicals, for example. Observations find vapors of water and various complex organic molecules (COMs), which could be non-thermally desorbed from ice mantle and/or formed via gas-phase reactions of sublimates. The cores eventually become gravitationally unstable and collapse to form stars.

The central region of the core is heated by the contraction and irradiation from the newly formed protostar. Various COMs are formed by radical-radical reactions in the ice mantle in the luke-warm ice mantle and by the gas-phase reactions of sublimates. Emission lines of water, COMs, and other organic molecules are intensively observed towards protostellar cores and a forming protoplanetary disk at the core center.

In the protoplanetary disks, volatiles are again frozen onto grains in the outer cold midplane, while they are in the gas phase in the warm upper layers and inside their snow lines. Emission lines of relatively abundant species are spatially resolved; some lines show ring-like structures, which are interpreted in terms of snow lines, evolutions of dust grains, and the spatial and temporal variations of C/O ratio caused by the cold finger effect. Emission lines of COMs, such as CH3OH, are also detected.

B1.3-0006-18 CONSTRAINTS ON EMBEDDED DISK STRUCTURES AND MASSES AS SEEN BY CARMA AND ALMA

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Class 0 I protostars are thought to represent early stages in the lifetime of protostellar disks, when they are still embedded in their natal envelope. As such, they provide an opportunity to study the initial conditions of protostellar disks, before any significant disk evolution or planet formation has occurred. We have conducted a survey of Class I protostars, initially with CARMA but now continuing with ALMA, to study the structure of their disks and measure their masses. We fit detailed radiative transfer models to our sample and find that Class I disks have similar structure to Class II disks, including several Class I disks with gaps, cavities, and other interesting features. Our measurements show that Class I disks are, on average, more massive than the older Class II disks. As such, Class I disks may be a better representation of the initial masses present in protostellar disks. These samples are, however, still small, so we have begun an effort to model all 330 Class 0 I protostars from the Herschel Orion Protostar Survey that were observed with ALMA as part of the VANDAM Survey. When completed, this study will produce a comprehensive picture of the youngest protostellar disks. We will finish by presenting early results from this effort.

B1.3-0007-18 CHARACTERIZING THE YOUNGEST DISKS USING CHEMICAL TRACERS.

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Disks around young stars are the birthplace of planets. The first steps of planet formation, that is, grain growth and maybe even the formation of larger bodies, already occur when the disk is still deeply embedded in its natal envelope. Thus, these young disks, rather than the more evolved protoplanetary disks, likely provide the initial conditions for planet formation. However, the physical and chemical structure of embedded disks is poorly characterized. We therefore aim to analyze the temperature profile of these youngest disks. The temperature is a critical unknown, since it directly influences the volatile composition of the planet-forming material. Reversing this argument means that certain molecules are good tracers of the disk temperature. An example is N2D+, which can only be abundant when CO is frozen out (T < 20 K). The non-detection of N2D+ in L1527, together with analysis of the optically thick 13CO and C18O emission, suggests that this embedded disk is likely warm enough to prevent CO freeze-out. These results are in contrast with more evolved protoplanetary disk observations that show large cold (T < 20 K) gas reservoirs in the outer disk. Higher temperature regions (> 100 K) can be probed with complex organic molecules such as methanol, because their volatility is expected to be similar to that of water. This means that methanol ice evaporates around the water snowline. Our ALMA observations toward the V883 Ori disk therefore provide a way to validate the water snowline location that Cieza et al. (2016) postulated based on the continuum optical depth. Finally, the high spatial resolution and large frequency coverage of the PILS survey toward IRAS 16293 allows us to probe the temperature structure at different radii using multiple H2CO lines. These measurements provide the first observational constraints on the temperature in embedded disks, allowing us to test model predictions that they are warmer than their more evolved counterparts.

B1.3-0008-18 CO DESTRUCTION IN PROTO-PLANETARY DISK MIDPLANES

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CO has long been thought to be the best mass tracer for proto-planetary disks as it can be easily detected with ALMA in many disks. However, the inferred gas masses from CO in recent ALMA observations seem to be inconsistent with their inferred dust masses, with inferred gasto-dust ratios between 0.1 and 10, rather than the canonical value of 100. Moreover, those few disks that have Herschel HD detections have gas masses inferred from HD that can be orders of magnitude higher than those inferred from CO. This suggests that at least one additional mechanism, next to freeze-out and photodissociation, is removing CO from the gas-phase. One suggestion is that the bulk of the CO is chemically processed, and the carbon sequestered into other less volatile species such as, CO2, CH3OH and CH4, in the dense, shielded midplane regions of the disk.

We have studied this option by carrying out a parameter exploration with our gas-grain chemical code. We investigated the CO abundance evolution over a range of conditions representative of disk mid-planes. The impact of the assumed chemical parameters, especially the efficiency of tunnelling and diffusion was also studied. A reduction of the total CO abundance by a factor of 10-50 is found at high densities between 15 and 30 K on timescales of 3 Myr assuming an ionisation rate of 10−17 s−1. Main reactions are identified. Varying the tunnelling barrier and the diffusion to binding energy ratio shows that the order of magnitude destruction of CO is robust between 20 and 30 K, but that there is a very strong dependence on the tunnelling efficiency of H below 20 K.

The finding that CO is efficiently destroyed between 20 and 30 K on a 3 Myr timescale is encouraging since most of the 13CO and C18O emission is expected to come from parts of the disk with temperatures within this range.

B1.3-0009-18 EXPLORING DCO+ AS A TRACER OF DUST EVOLUTION IN PLANETFORMING DISKS

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In planet-forming disks, deuterated species like DCO+ often show up in rings. Two chemical formation routes contribute: cold deuteration at temperatures below 30 K and warm deuteration at temperatures up to 80 K. In this work we reproduce the DCO+ emission in the disk around HD163296 using a simple 2D chemical model for the formation of DCO+ through the cold deuteration channel and a parametric treatment of the warm deuteration channel. We use data from ALMA in band 6 to obtain a resolved spectral imaging data cube of the DCO+ J=3- 2 line in HD163296 with a synthesized beam of 0.″53× 0.″42. The observed DCO+ emission is reproduced by a model with cold deuteration producing abundances up to 1.6e11. Warm deuteration, at a constant abundance of 3.2e12, becomes fully effective below 32 K and tapers off at higher temperatures, reproducing the lack of DCO+ inside 90 AU. Throughout the DCO+ emitting zone a CO abundance of 2e107 is found, with 99% of it frozen out below 19 K. At radii where both cold and warm deuteration are active, warm deuteration contributes up to 20% of DCO+, consistent with detailed chemical models. The decrease of DCO+ at large radii is attributed to a temperature inversion at 250 AU, which raises temperatures above values where cold deuteration operates. This return of the DCO+ layer to the midplane reproduces the local DCO+ emission maximum at 260 AU. We can use the morphology of DCO+ emission to trace the temperature substructures of disks produced by dust evolution processes. Outer disk temperature inversions, expected when grains decouple from the gas and drift inward, can lead to secondary maxima in DCO+ emission and a reduction of its radial extent. This can appear as an outer emission 'ring', and can be used to identify a second CO desorption front.

B1.3-0010-18 A SURVEY OF CH3CN AND HC3N IN PROTOPLANETARY DISKS

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The organic content of protoplanetary disks sets the initial compositions of planets and comets, thereby influencing the subsequent chemistry that is possible in nascent planetary systems. The complex nitrile-bearing species CH3CN and HC3N are, along with CH3OH, the only large organic molecules detected towards protoplanetary disks to date and therefore provide crucial constraints on the growth of organic complexity in disks. We present observations of CH3CN and HC3N towards the disks around the T Tauri stars AS 209, IM Lup, LkCa 15, and V4046 Sgr, as well as the Herbig Ae stars MWC 480 and HD 163296. In this sample, HC3N and CH3CN are detected towards five and three disks respectively. For disks with multiple detections, we constrain the emission origin of these complex nitriles using the rotational diagram method to obtain emission temperatures. We also explore connections between the observed nitrile emission strength and the physical environment of the disk. The relative abundances of different nitrile molecules are consistent in protostars, disks, and comets, demonstrating a robust nitrile chemistry at play in different circumstellar environments. In contrast, nitrile abundances relative to oxygen-bearing molecules appear systematically higher in disks compared to protostars and comets; the origin of this distinct, nitrile-rich organic chemistry in disks is at present not fully resolved, pointing to a need to explore other potential chemical pathways in disk models.

B1.3-0011-18 RESOLVED OBSERVATIONS OF 12C/13C AND 14N/15N IN PROTOPLANETARY DISKS

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Isotopic ratios are commonly used to trace the origin of Solar System bodies. This is a fundamental but still highly debated topic. It is still unclear whether most of the organics are inherited from the protosolar nebula or if they are the result of an active chemistry in the protoplanetary disk phase.

Disk-averaged 15N enrichments that are similar to comets have been observed in disks, assuming a standard isotopic ratio 12C/13C= 70. However, spatially resolved observations of N isotopic ratios are needed to elucidate the origin of these 15N enrichments, and ultimately the origins of organics, across the Solar System: a constant 14N/15N ratio across disks would favor a scenario where disks inherit their organics from the natal cloud, while a gradient would strongly suggest that the chemistry is modified during the disk phase.

I will present high-angular resolution (0.2” = 15 au) ALMA observations of the HCN isotopologues in a protoplanetary disk. We derive the radial dependence of both the 12C/13C and 14N/15N isotopic ratios within the planet and comet forming region. I will discuss how these results compare with observed values in the ISM and in Solar System bodies, and how we can disentangle between the inheritance and disk chemical processing scenarios.

B1.3-0012-18 COMETS AND THEIR RELATIONSHIP TO THE EARLY SOLAR SYSTEM: INSIGHTS FROM SPACE MISSIONS AND EARTH-BASED OBSERVATIONS

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Comets and small primitive bodies were witness to the solar system's formative processes. During the earliest epochs of our solar system's formation, temperature gradients led to a variety of compositional and isotopic chemical gradients within the protoplanetary disk. This disk chemistry left it's chemical fingerprints on the planetesimals that are preserved as today's comets. A goal of comet studies has been to use the chemistry of comet ices understand the disk chemistry and formation location of comets. The story is incomplete, however, without considering the dynamical movement of these small icy bodies as the giant planets formed. A legacy of several decades of dedicated surveys to characterize the orbits, chemistry and physical properties of comets has resulted in a picture of comets that is quite different from the initial models developed in the 1950s. Today there are three cometary reservoirs: the Oort cloud, the Kuiper belt and scattered disk, and the main asteroid belt. Our definition of what distinguishes a comet form an asteroid is blurring, and there is likely a continuum of compositions between volatile rich and volatile poor. There is increasing evidence that in contrast to the distinct dynamical reservoirs we see today that comet formation regions strongly overlapped in the protoplanetary disk [1].

Comet missions have shown that there was wide-scale migration of disk material and comets incorporated dust from a variety of temperature regimes. Some of the refractory comet dust component experienced high temperatures near the sun, while in other cases there was evidence of aqueous alteration. In contrast, results from missions, in particular from the Rosetta mission have shown that the volatile component is likely primordial, possibly preserving signatures from the interstellar cloud. Comet nuclei are now known to be very low-density highly porous bodies, with very low thermal inertia, which likely contributes to the preservation of primordial material. In contrast comet sizes suggest that they have undergone collisional evolution.

Both groundand space-mission data have shown that comets are not chemically homogeneous and that comets show different chemical taxonomies that are not correlated with their dynamical class. Isotopic information is known for a subset of these comets, however a detailed comparison between disk chemical models and solar system dynamical models will need to be made before the data can be interpreted in terms of formation location and delivery of volatiles to the terrestrial planets. Recent dynamical models are reproducing key characteristics of today's solar system; some of these require significant giant planet migration, while others do not. A key difference between these two classes of models is that the former models expel rocky material from the inner solar system into the Oort cloud while the latter do not [2]. This talk will present our understanding of comets and their relation to the early solar system and protoplanetary disk, and discuss how newly discovered objects may contribute to our understanding of the planet formation process in other solar systems [3].

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B1.3-0013-18 THE COMPOSITION OF COMETS - 30 YEARS OF INVESTIGATIONS

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The study of comets is important for understanding the origin of our solar system and as such ultimately for identifying the prerequisites for the development of life. As comets are considered remnants of the early solar system formation and spent most of their lifetime at temperatures below 50 K, their chemical composition, particularly in view to organic compounds, is very important for understanding whether the complex organics, from which life might have developed, were formed from simpler molecules on the surface of the primitive Earth or were supplied as ready by impacting comets. The latter would mean that such complex molecules were already present 4.6 billion years ago. Also the intimate mixture between minerals and organic molecules is an essential aspect for the origin of life. Different grain surfaces provide different catalytic properties, and can locally lead to a decrease of entropy on the expense of the entropy elsewhere in the closed system of multigrain dust, once it is in water.

The first major breakthrough in identifying the organic composition of a comet nucleus dates back to 1986, when three spacecraft (VEGA 1, 2 and Giotto) passed through the inner coma of comet Halley and obtained in-situ measurements of its gas and dust composition. A number of small organic molecules, known to be present in the interstellar medium were detected in the gas coma, and the presence of organic macromolecules was discovered in the comet dust. About 10 years later (1996-1997) the apparition of the extraordinary bright comet Hale-Bopp in combination with the availability of new sophisticated observing facilities at sub-mm wavelengths, led to a quantum leap in our understanding of the evolution of the gas coma composition as a function of heliocentric distance. In 2006, after another decade, the Stardust mission returned a sample of dust particles collected in the coma of comet Wild-2 which permitted the detailed analysis of the returned material in laboratories available on the Earth; and in 2016, again about 10 years later, the Rosetta mission concluded its 2-year rendezvous-mission with comet Churyumov-Gerasimenko. In these 30 years of comet compositional investigations important progress was made in identifying the composition and chemistry of comets. An overview will be given of the most important milestones with special emphasis to organic material.

B1.3-0014-18 THE INVENTORY OF PREBIOTIC BUILDING BLOCKS AROUND A YOUNG, SUN-LIKE PROTOSTAR

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Small molecules such as methanimine (CH2NH), methylamine (CH3NH2), hydroxylamine (NH2OH) and methyl isocyanate (CH3NCO) belong to a select group of so-called prebiotic molecules that are thought to be at the basis of amino-acid and peptide-bond formation. On Earth, amino- acids are important building blocks of life, which through peptide bonds link with each other to form proteins. Recent ALMA observations have shown for the first time that CH2NH and CH3NCO are present around the low-mass, sun-like, protostar IRAS 16293-2422, showing that prebiotic building blocks could already have been present at the earliest formational stages of our own Solar System. [1][2]

This work is conducted as part of the protostellar interferometric line survey, a broad band ALMA survey of the protostellar binary IRAS 16293-2422. The detections of CH2NH and CH3NCO rotational transitions are presented and integrated emission maps show their presence at Solar System scales (60 AU) around the protostar. Supporting solid-state laboratory data shows that CH3NCO has its origin in the ice mantles of interstellar dust grains. Non-detections of NH2OH and CH3NH2 are used to constrain chemical pathways to interstellar amino-acid formation. Specifically, the abundance comparison of CH3NH2 between this low-mass protostar and the galactic centre source Sgr B2 shows that CH3NH2 is depleted by

at least 1-2 orders of magnitude in IRAS 16293-2422. This shows that around low-mass protostars CH2NH might be a more relevant precursor to amino-acid formation than CH3NH2.

N.F.W. Ligterink et al., Month. Not. Roy. Astron. Soc. 469 (2017) 2219

N.F.W. Ligterink et al., Astronomy Astrophysics, subm. (2018)

B1.3-0015-18 THE CHEMICAL LINK BETWEEN COMET 67P/C-G AND LOW MASS PROTOSTAR IRAS 16293-2422: INTEGRATIVE STUDIES IN OBSERVATIONAL ASTRONOMY AND CHEMICAL-DYNAMICAL MODELING

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Organic molecules are the building blocks of life and this is why the search for amino acids and their complex organic precursors at different stages of star and planet formation is one of the exciting topics in modern astronomy. Understanding how, when and where organics (simple as well as complex including potentially prebiotic molecules) are formed is one of the most important questions for Astrochemistry/Astrobiology. Complex organics have been detected in prestellar cores, protostars, and protoplanetary disks. Can a part of the organic content observed in these regions be preserved during the protostellar stages and incorporated into asteroids and comets, that can deliver it to planetary embryos through impacts? By looking at the cometary compositions, observations of solar-type protostars can help to address this critical question.

In this context, here we will present our observations towards the solar-type protostar IRAS 16293-2422 in the 3mm band of the IRAM 30m telescope along with existing ALMA observations. We will also describe how the chemo-dynamical simulations using the state-of-the-art gas-grain-bulk chemical-kinetic model can help us to understand the chemical composition of comet 67P observed by Rosetta.

For the first time, we will also shed light on to the possibility of protostellar inheritance of glycine (king of the ROSETTA Zoo) on to the comet 67P.

B1.3-0016-18 HOST ICES FOR VOLATILE SPECIES IN SOLAR SYSTEM PLANETESIMALS: THE CASE FOR CLATHRATES

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The identity of the host material for volatile species present in comets, KBO's, icy moons and giant planet atmospheres is a key question in tying conditions in the outer solar system to the composition of these observable bodies. Planetesimals may contain crystalline water ice and/or amorphous water ice as host material, within which volatiles may be trapped, or the volatiles may condense out directly as ices. These processes depend on conditions within the protoplanetary disk and the history of the grains as they fall into, and then move within, the disk itself. Beginning with data from Comet Halley in 1986, and culminating with the observations of Comet 67/P Churyumov-Gerasimenko, comets have proved to be key in constraining the phases within which volatiles are trapped. Measurements of abundances of small species of similar volatility (Ar, N2, CO) provide a basis for testing different trapping patterns, and suggest clathrate hydrate as the preferred carrier phase (Mousis et al. Ap.J 819, L33, 2016). Subsequent analyses of other species such as O2 support this inference. Furthermore, returning to the Halley data-now three decades old-suggests consistency with the clathrate hypothesis but with an elevated C/O ratio in the gaseous disk.

B1.3-0017-18 BINDING ENERGY A KEY TO DEFINING INTERSTELLAR VOLATILE SPECIES

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Icy grain mantles are the main repository of the complex organic molecule (COM) in the interstellar medium (ISM). Such icy mantles constitute the main reservoir of volatiles in clouds, protostellar envelopes, comets, and protoplanetary disks. Ices form by a condensation of atoms and molecules from the gas-phase and subsequent grain surface chemistry. Hydrogenation reactions initiate the complexity of interstellar grain mantle in molecular clouds (10 K). Since the chemical composition of interstellar grain mantle is mostly dependent on adsorption energies (also known as binding energy) of the surface species, it is a key to study the formation of more complex molecules on interstellar grain surfaces. H2 is believed to be a precursor of the COM. Since hydrogen is widespread either in atomic or in molecular form, our aim in this work is to review the variation of the adsorption energies of H and H2 and other important elements e.g., C, N, O, S, and P depending on the nature of the adsorbents. Choice of absorbents was based on relative abundances of interstellar material. Dust particles in the interstellar medium are composed mainly of silica (SiO2), magnesium and iron silicates (e.g., olivine, forsterite), amorphous carbon or water ice. Benzene is employed as a carbonaceous material and for silicate grain, a simple cluster of silicon dioxide (silica) (SiO2)3 is used (Sil et al. 2017). Around dense cloud regions, water is the major constituent of a grain mantle, therefore, usage of binding energies with bare grains is immaterial. To mimic the water as the adsorbents, we use watercluster.The outcome of our calculations is implemented in a large gas-grain chemical model to predict the abundances of various complex interstellar species.

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B1.3-0018-18 LINK BETWEEN INTERSTELLAR AND COMETARY COMPOSITIONS

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How life emerged on Earth is a long-standing mystery. Comets are the reservoirs of primitive material, amino acids, organic compounds etc. It is thought that heavy bombardment of these comets in the early Earth could lead to the synthesis of Earth's prebiotic inventory (Chyba 1990). The recent observation of organohalogens in protostar IRAS 16293 and comet found CH3Cl to CH3OH ratio is consistent between comets and the Interstellar Medium (Fayolle et al. 2017). We will use gas-grain chemical modeling to determine the abundance of some simple and complex molecule and check their consistency with cometary observations. Monte Carlo simulation will also be employed to study the chemical composition under Interstellar environments on the interstellar dust surface to mimic the cometary grain surface compositions.

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B1.3-0019-18 FROM ORGANIC INTERSTELLAR MATERIAL OF DIFFUSE INTERSTELLAR BANDS TO COMET NUCLEI: SURVIVING THE ACCRETION PROCESS.

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The analysis of dust grains collected by Rosetta spacecraft from comet 67/P ChuryumovGerasimenko has shown that they are constituted of about the same amount of minerals and large organic molecules (in mass 45% organic, 55% mineral, Bardyn et al. 2017). We suggest that they are the same organic molecules that produce, in the Interstellar Medium (ISM), diffuse absorption features imprinted on stellar spectra (DIBs, Diffuse Interstellar Bands). The large molecules forming the DIBs are not yet identified, except for fullerene C60+, but are thought to constitute ". the largest reservoir of organic material in the Universe" (Snow, 2014). They were certainly present in the parcel of ISM which condensed into our proto-solar nebula. They were conserved during the formation of the solid comet nucleus, within the scenario established by Davidsson et al. (2016) based on many arguments collected by Rosetta: a hierarchical scenario of gentle accretion of small interstellar grains to the final size of the nucleus. We back up our suggestion from both qualitative and quantitative arguments. A statistical analysis of DIBs suggests that in the ISM, the ratio organic/mineral is at least RISM=0.32, to be compared to RC= 0.8 for the comet. On the other hand, the sounding of some interstellar nebulae show that, when the line-of-sight approaches the centre, the DIBs depths are levelling off while the dust extinction is still increasing, suggesting an accretion process for the DIB molecules. These organic molecules would agglomerate to form interstellar grains that will end up in the proto-solar nebula, then in comet nuclei. This conclusion implies that a comet return-sample mission would not need to be much cooled to keep the double interest for comets and for Interstellar Medium studies.

B1.3-0020-18 THE CHEMICAL STRUCTURE OF THE ASTEROID BELT

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The asteroid main belt between Mars and Jupiter holds evidences from the early Solar System history. Built from the originally thin and stratified accretion disk, it has been scrambled by planetary migrations, resulting in a dynamical excitement and radial mixing of compositions.

Since the 1970s, spectral surveys have characterized the surface compositions of the largest members first, then of smaller bodies, slowly progressing through the size distribution. These surveys led to major discoveries, including the succession of dominating compositional classes along heliocentric distances, and the presence of interlopers in this over-arching structure.

In the 2000s, these results have sustained the emergence of the current paradigm of Solar System formation in which planets migrated from their formation locations to their current orbits (the Nice model). Since then, the Sloan Digital Sky Survey and the NASA WISE mission have observed over a hundred thousands of asteroids in the visible and mid-infrared, characterizing their surface composition and providing their diameter. Simultaneously, our knowledge on asteroid density presented a tenfold increase.

This dataset allowed to push the description of asteroid compositions to smaller sizes and to study the distribution of material in the main belt by mass, rather than by numbers. The resulting picture go back over the previous view, and the few interlopers seem to be rule. The large scale structure discovered in the 1980s seen on the largest bodies holds, but mixing increases at smaller sizes. This detailed picture supports the main results from recent dynamical models of planetary migration and radial mixing of smaller bodies, albeit several observed structures remain yet to be explained: numerous primitive D-type in the inner belt, apparently missing mantle counterpart (A-types) to the crustal and iron core-like (Vand M-types) material.

In this talk, observational evidences from past decade will be reviewed, current picture of the compositional distribution of material in the main belt presented; open questions, inherited from past spectral surveys, summarized; and prospectives drawn.

B1.3-0021-18 LINKING THE NITROGEN ISOTOPIC COMPOSITION OF STAR-FORMING REGIONS WITH COMET 67P

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There are large variations in the stable isotope composition of the volatile elements hydrogen, nitrogen, and oxygen among the solar system bodies. The solar system solids are typically enriched in the rare heavy isotopes (D, 15N, 17O, 18O) compared to the Sun and Jupiter. To understand the origin of these isotopic anomalies, a cross-disciplinary link between the fields of astronomy, cosmochemistry, and solar system science is indispensable. However, establishing such as link is not straightforward, as astronomical observations mainly target the gas in starforming regions, whereas the most pristine solar system materials are present in the form of meteorites and cometary ices.

The ratio of the two stable nitrogen isotopes, 14N/15N, is a promising tool for linking results across the fields, as the nitrogen isotopic composition can be measured in star-forming regions and solar system bodies. The 14N/15N ratio should also be less prone to secondary alteration than the deuterium-to-hydrogen ratio.

In this contribution, we will present spatially resolved measurements of the 14N/15N ratio around embedded protostars from IRAM observations and the Protostellar Interferometric Line Survey (PILS) with ALMA. First results on the nitrogen isotopic composition of comet 67P/Churyumov-Gerasimenko by Rosetta-ROSINA will also be presented, and we will explain how we are trying to link these data sets to gain insights into the origin of nitrogen in our solar system and beyond.

B1.3-0022-18 CHEMICAL EVOLUTION OF COMPLEX ORGANICS IN ICES FROM INTERSTELLAR ICE TO COMETS

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Comets contain a wealth of information, as they preserve the earliest record of material from the formation of our solar system. Recently, after a 10 year journey, Rosetta visited the comet 67P/Churyumov-Gerasimenko. This mission unveiled the presence of significant organic material including the amino acid glycine.1 Although we cannot yet directly compare cometary ice to interstellar ice, this detection does support the hypothesis about the origin of life on Earth, e.g., that complex organic molecules may have been delivered from space.

In the Ice Spectroscopy Laboratory at NASA's Jet Propulsion Laboratory, we are in the process of upgrading the existing two-color Laser Ablation Ionization Mass Spectrometer system to enable spectroscopy of specific mass-filtered radiation products.2,3 This high vacuum system has a cryostat, enabling substrate temperatures down to 5 Kelvin. On top of this substrate, we can deposit an astrochemically-relevant mixture,. This ice can subsequently be processed using high-energy electrons, resembling the cosmic rays present in the interstellar medium. Radicals will be created in this ice, which can subsequently react and form complex organic molecules. We have previously demonstrated that we can directly study these radiation products at low temperature, using IR laser desorption combined with multi photon ionization mass spectrometry.

To enhance the existing capabilities of the system, we will incorporate a Quadruple Mass Filter; this allows us to spectroscopically study individual complex organic species (each with a specific mass over charge, m/z). With ion optics, a selected molecular ion will be guided toward a second cold substrate for re-deposition, where it can be subsequently studied using spectroscopic means. This powerful combination of mass spectrometry and spectroscopy will enable us to not only (1) better identify individual mass signals generated by radiation experiments, but to also (2) obtain clear spectral profiles of these products (which may be reactive and/or difficult to isolate by other means). The ultimate goal of this system is to better understand the low-temperature radiation processing of astrophysical ices, and to bridge our understanding of interstellar ices and cometary bodies.

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B1.3-0023-18 NEW INTERSTELLAR DETECTIONS TO TEST AND REFINE ASTROCHEMICAL MODELS

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We present the detections of three new oxygen-bearing molecules in the ISM: HC5O, HC7O, and methoxymethanol (CH3OCH2OH) that are found at the earliest (TMC-1: HC5O and HC7O) and latest (NGC 6334I: CH3OCH2OH) stages of star formation. TMC-1 is a cold, dense dark cloud at the stage just before star formation begins; it represents the t=0 chemical inventory, an inventory that is processed as soon as stars turn on. Observations at early stages offer the ability to benchmark our astrochemical models under relatively quiescent conditions. Conversely, NGC 6334I is an active, massive hot core region with extreme chemical and physical conditions that have processed this early inventory into that which will be incorporated into a forming solar system. We will discuss our results, including additionally the surprising first detection of the aromatic benzonitrile (c-C6H5CN) molecule in TMC-1, in these contexts, and examine the laboratory and observational studies that can address these issues.

B1.3-0024-18 PRIMITIVE LITHOLOGIES IN PRIMITIVE CARBONACEOUS CHONDRITE.

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Chondritic-porous interplanetary dust particles (CP IDPs) composed of amorphous silicates (GEMS: glass with embedded metal and sulfide), organics and silicate mineral grains at subμm scales are believed to be of cometary origins and represent samples of the building blocks of the solar system (e.g., [1]). Less aqueously-altered carbonaceous chondrites (CCs) have finegrained matrix of amorphous silicate (GEMS-like material), silicate mineral grains and organics and called primitive CCs. However, most of them are more or less oxidized (absence of metal) and aqueously altered (presence of hydrous minerals) (e.g., [2]). We found more primitive lithologies in two primitive CCs; Acfer 094 (C ungrouped) and MIL 090657 (CR2.7).

By using X-ray nanotomography, an ultra-porous lithology (UPL) having large porosity comparable with CP IDP was found in a matrix of Acfer 094 [3]. UPL is composed of GEMS-like materials, where hydrous layer silicate and metal are absent, silicate minerals and organics at sub-μm scales. The isotopic compositions are solar. After this founding, we found many UPLs 10 μm in typical size using SEM. Distinct UPL-matrix boundary without deformed texture suggests the presence of ice in void space for preserving UPLs during accretion with matrix.

Less porous lithology having GEMS-like materials with metal as well as sulfide and organics were found in a matrix of MIL 090657 [4,5]. This lithology is recognized only in microtomed sections. By using X-ray nanotomoraphy, similar lithology with slight aqueous alteration and others with relatively high aqueous alteration were found. The Texture of lithology boundary suggests that the primitive lithology was poorly lithified during their accretion.

The two primitive lithologies have different features with each other and also different from CP-IDPs. A primitive lithology in Paris (CM) [6] has different features as well. Nanoparticles similar to GEMS were formed by condensation experiments in the system Mg-Si-Fe-S-O, where a variety of mineralogy were formed in different redox conditions [7], suggesting that GEMS and GEMS-like materials were formed by condensation probably in different locations of the primitive solar nebula, and CP IDPs and the primitive lithologies in CCs may represent samples of the building blocks of the solar system in different locations.

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B1.3-0025-18 NON-SPHERICAL DUST DYNAMICS IN PROTOPLANETARY DISKS: SIMULATIONS IN THE EPSTEIN REGIME OF SECOND GENERATION DUST DURING FORMATION OF GIANT PLANETS IN CIRCUMSTELLAR DISCS.

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Recent high-resolution ALMA observations of protoplanetary disks (e.g. Isella et al. 2016, PRL, 117; ALMA Partnership et al. 2015, ApJ Lett. 808:L3,10pp) triggered interest on studying solid bodies in discs at different scales. The dynamics of small (from sub-micron grains up to solid bodies of sizes of hundreds of meters) dust particles is governed by the interaction of the gas with the gravity of the star in the disk. Consequently, the dust dynamics are subject to the vertical settlement of dust particles (see e.g. Armitage, P., Lect. Notes, 2017, arXiv:astro ph/0701485v6).

In the case of planetesimals (tens of kilometers in size) the interaction is governed mainly by gravity. Turrini et al. 2018 (AA, submitted, arXiv:1802.04361) investigated the dynamical and collisional response of the planetesimal population to the formation of HD163296's three giant planets. The resulting high impact velocities increase the collisional dust production and release gas species, like H_2O, due to the ice sublimation during impacts. Such high impact velocities would transform the gas flow into supersonic and could lead to transition from the Epstein regime to the continuum Stokes regime.

Here, we focus on applying of our code, developed for dynamics of non-spherical particles in cometary environment (Ivanovski et al. 2017, Icarus 282, 333-350), to the dynamics of secondgeneration dust collisionally produced in HD163296. We study: 1) the vertical settlement of the high speed dust and 2) its motion before the Epstein-to-Stokes regime transition occurs. We present results on how the dust non-sphericity affects the timescales of vertical settling of small dust, what are the dust rotational frequencies and a mechanism of accumulation of non-spherical dust particles in the disk gaps.

B1.3-0026-18 CHONDRULE FORMATION THROUGH COLLISIONS OF ROCKY AND ICY PLANETESIMALS

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Chondrule formation is one of the most important issues to be solved in planetary science. Although many models have been proposed, a consensus has not been reached. Heating by 26Al causes internal melting of rocky planetesimal. When such plantesimals collide, silicate melt can splash out from inside and may lead to formation of chondrules (e.g. Asphaug et al. 2011, EPSL 308 369, Sanders and Scott 2012, MAPS 47 2170). However, the size of a droplet should be much larger than the chondrule size in this model. Here I propose a new model based on collisions between a melting rocky planetesimal formed inside the snow line and a planetesimal formed outside the snow line. I determined a range of water content which is suitable for chondrule formation. Collision simulation is conducted to determine the efficiency of chondrule formation using iSALE hydrocode. If the inside of rocky planetesimal is totally melted, the total volume of chondrule is larger than that of a projectile object. This would be the origin of chondrules in ordinary chondrites. On the other hand, collisions involving cool rocky object leads to less efficiency of chondrule formation. Chondrules in carbonaceous chondrite can be formed in this process.

B1.3-0027-18 EARLY ACCRETION OF CHONDRULE DUST RIMS

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Fine-grained dust rims (FGRs) surrounding chondrules could have acted as the “glue” that allowed chondrules to stick and form centimeter-sized agglomerates. The porous structure of FGRs would have allowed inter-chondrule collisional energy to dissipate. Eventually, FGRs would have been compacted by these collisions.

We performed molecular dynamics simulations of FGR accretion to elucidate the initial structure of FGRs (i.e., before compaction) under different solar nebula conditions at a heliocentric radius of 1 AU. The disk model employed was the minimum-mass solar nebula. Our coagulation code takes into account the physics of collisions between micron-sized dust and submillimetersized chondrules. Both types of solids are assumed to be spherical. The relative velocities between dust and chondrules were taken to be due to Brownian motion and turbulence. The latter contribution was parameterized by the dimensionless turbulent viscosity α number of accretion disk theory. The collisional outcomes that we modeled are sticking, restructuring and bouncing. For computational expediency, we restricted dust particles to accumulate on a small circular patch on the chondrule surface.

Our simulations used α values of 10−k, k=1,. ,6. Dust grains had radii between 0.5 and 10 microns, distributed as a power law with exponent -3.5. We also varied the chondrule radius from 500 microns to 1000 microns, in 100 micron increments. In some cases, we modeled accretion of dust aggregates (cluster aggregation, CA), in addition to accretion of dust monomers (particle aggregation, PA). Rims were built to a total thickness of up to 400 microns. The time required to accumulate the rim was tracked for the duration of the simulations, which modeled up to 100 years of evolution.

For PA, we find that the porosity of FGRs is typically very high (> 60%), and that it increases with distance from the chondrule surface. The porosity radial profile of FGRs is qualitatively similar among different α’s and chondrule radii. This profile has a relatively small slope within 120 microns of the chondrule surface, with porosities between 55% and 70%. The slope increases markedly at a distance between 120 and 250 microns. As FGR thickness increases with time, the mean porosity of FGRs decreases from about 85% to between 66% and 70%,

depending on the chondrule radius.

The radial porosity profiles of FGRs formed by CA are qualitatively and quantitatively different from those formed by PA. The former accretion mode produces FGRs that are more porous than those obtained by PA by 30%, at least within 250 microns of the chondrule surface. The CA porosity profiles are flatter than the PA profiles.

Future work will need to take into account fragmentation of FGRs, non-sphericity of grains and chondrules, and the effect of electrical charges on the surfaces of both dust grains and chondrules.

B1.3-0028-18 DUST AND GAS IN DEBRIS DISKS AROUND NEARBY STARS

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Debris disks are signposts of mature planetary systems, with dust generated by collisions bodies that have grown to at least the size of Pluto-like planetesimals. While the origin of dust in most debris disks is reasonably well understood, the origin of gas in some systems is less clear. I will review our current understanding of the origin and nature of gas in debris disks, including whether the gas is primarily second-generation in nature like the dust, or whether it may be a remnant of the protoplanetary disk in some systems. I will also discuss recent high-resolution ALMA observations that allow us to dynamically measure the total mass inventory of the nearby debris disk around AU Mic, by resolving its vertical structure at millimeter wavelengths for the first time. Resolved observations at two widely separated radio frequencies (ALMA Band 6 and Band 9) also allow us to probe the strengths of bodies in the collisional cascade for the first time outside our Solar System.

B1.3-0029-18 ACHONDRITE METEORITES - INSIGHTS INTO SOLAR SYSTEM AND PLANETARY PROCESSES FROM 'OLD' AND 'YOUNG' ROCKS

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As of February 2018 there are approximately 57400 officially classified meteorites [1]. Of these approximately 4000 are classified as achondritic meteorites [1], based on their chemical, mineralogical and textural features. The classification system for the achondrite meteorites is complex and, in some cases remains contentious, with different characteristics seemingly contradicting the models of formation and evolution and the traditionally understood genetic links between different types of meteorite. Recent advances in isotope cosmochemistry, owing to improvements in both instrumentation and sample processing techniques, have helped to solve some outstanding issues but have also raised new questions [e.g. 2,3]. Despite this complexity, the non-chondritic meteorite samples represent a highly diverse set of Solar System materials and provide a wealth of information in the chemical and physical evolution of the early Solar System e.g. first few millions of years and, in the case of martian and lunar meteorites subsequent planetary processes.

Primitive achondrites: Primitive achondrites are made up of the stony meteorite acapulcoites, brachinites, lodranites, winonaites, ureilites and brachinites and also the iron meteorite IAB-complex and IIEs [4]. It is generally understood that the primitive achondrite meteorites experienced at least some partial melting or formed from material that was molten but had not experienced large-scale differentiation (i.e. segregation of metal from silicate) processes, thus they retain 'primitive' chemical signatures such as chondritic O isotope signatures [4]. Primitive achondrites provide information on the chemical and physical processes occurring early in the Solar System during planetesimal formation and prior to magma ocean formation.

Achondrites: Achondrites comprise both stony meteorites and stony-iron meteorites. The majority of the achondrites (angrites, aubrites, HED clan (howardite, eucrite, diogenite), pallasites and mesosiderites) are derived from asteroidal parent bodies, whereas the Martian and lunar meteorites and from 'planetary' bodies i.e. the planet Mars and the Moon. The asteroidal achondrites show evidence of igneous textures i.e. they formed from molten precursor material and chemical signatures indicative of derivation from a differentiated source. The stony-iron pallasites show complex textures and show some chemical affinities with the IIIAB irons [4], although other evidence, such as the cooling rates of metal indicates a genetic link is unlikely [5]. The traditional view of pallasite formation was that these samples represented the core-mantle boundary of a differentiated proto-planet(s) [e.g. 6], however more recent studies suggest that the pallasites may have formed by impact processes during a 'hit and run' collision [5]. Lunar meteorites provide additional insights as to the formation and evolution of Earth's moon given that they show more extensive variation than the Moon rocks collected during the Apollo missions. Martian meteorites are of great value given they are the only samples of Mars available to study in laboratories on Earth and thus provide some 'ground-truth' to compare with data generated from robotic remote sensing and lander missions. Indeed, the first conclusive evidence of liquid water on Mars was found during the study of the Martian meteorite Nakhla [7].

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B1.3-0030-18 EXPLORING THE CHEMICAL DIVERSITY OF OUR SOLAR SYSTEM

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Interplanetary and interstellar dust particles (IDP and ISD) continually bombard the Earth. They ablate in the atmosphere, and their trajectories change due to drag forces by the time ground based optical and/or radar observations could fully characterize them. These particles carry valuable information about their parent bodies that can now be fully harvested by in situ dust measurements, using newly developed instrumentation. Placing a dust instrument onboard a near-Earth spacecraft will revolutionize our understanding of the composition of interstellar and interplanetary dust, contributing to our fundamental understanding of the evolution of our solar system, and will improve our dust hazard models for the safety of crewed and robotic missions to Mars and other destinations.

This talk will summarize the capabilities of a new in situ dust instrument capable of measuring the mass, charge, composition, and velocity vector of impacting dust particles. By deriving the orbital elements of dust particles their source regions can be identified. We will summarize the scientific rationales for a mission concept to carry a dust impact ionization mass spectrometer instrument onboard a near Earth spacecraft. The setup will enable future missions to explore the diversity of the chemical makeup of a broad range of bodies in our solar system and beyond, offering a powerful approach to testing the genetic relationships between small body reservoirs.

B1.3-0031-18 ORIGINS OF VESTA AND CERES AND IMPLICATIONS FOR PLANETESIMAL DIVERSITY

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Prior to the Dawn mission, it was already known from telescopic observations that Vesta and Ceres, the two most massive bodies in the main belt, had divergent histories. Vesta's surface was very similar to basaltic achondrite meteorites [1], and Ceres' had affinity to primitive carbonaceous chondrites [2, 3]. Ceres mass and size provided a density of about 2.1 g/cm3, indicating a significant water content (25% by mass), and thermodynamic modeling [4, 5] showed heating, ice melting and silicate hydrothermal alteration with mass differentiation. Vesta was known to be much denser (3.46 g/cm3), suggesting a dry and hot history [6]. Prior to the Nice [7] and Grand Tack [8] models, Ceres and Vesta were thought to have formed in the same part of the protoplanetary disk near their current location [9], and their differences were ascribed to a delay in the formation of Ceres with respect to Vesta. The Dawn mission's exploration of Vesta and Ceres [10] has advanced our knowledge of their internal evolution and surface geology and composition, which elucidates their early histories and adds constraints on early solar system processes. These bodies offer remarkable examples where differentiation state can help constrain accretional environments. Dawn confirmed that Vesta experienced extensive silicate melting and differentiation, resulting from a hot, dry evolution [11]. On the other hand, Ceres exhibits a much milder thermal history, resulting in only partial differentiation and retention of volatiles [12-15]. This contrast can be primarily attributed to the abundance of water in Ceres that helped moderate internal temperature via latent heat and hydrothermal circulation [5, 16]. It has been suggested that Vesta and Ceres accreted from similar chondritic feedstocks but at different times, i.e., with different short-lived radioisotope budgets [4, 9]. Abundance of Al-26 could lead to rapid devolatilization of volatiles in Vesta, accreted earlier, while Ceres could preserve the bulk of its volatiles. However, it seems likely that the starting composition of Vesta and Ceres was very different, especially in terms of ice abundance. The remarkable discovery of ammoniated clays at the surface of Ceres [17] is a primary clue. Multiple models have been suggested to explain the origin of volatiles in the asteroid belt, and several distinct episodes of volatile migration have been suggested. The first one is that planetesimals in the 100-meter size range migrated from the outer Solar system via gas drag and could gently accrete with growing asteroids in the main belt [18]. However, migration of planetesimals across the gap opened by Jupiter in the solar nebula likely lead to de-volatilization and loss of most of the ammonia [19]. An alternative is that larger planetesimals (1-10s km) migrated following destabilization of feeding zones by the growing giant planets [20]. While this may have favored preservation of volatiles, the accretion of that material at velocities of 10s km/sec with growing asteroids is not well understood. Ceres' formation in, and subsequent migration from the Kuiper Belt [21] is challenged by dynamical and geophysical considerations [22]. The Grand Tack model or similar models tracking early planetary growth and migration may provide the best compromise, where Ceres came from the region between the giant planets [8]. Recent accretion models support the idea that planetesimals that large could form between Jupiter and Neptune [23].

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B1.3-0032-18 EVOLUTION OF PROTOPLANETS FROM DETAILED ANALYSES OF THE SURFACES OF VESTA AND CERES BY DAWN

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The Dawn spacecraft orbited Vesta (2011-2012), is now orbiting Ceres (2015-2018), and has provided the first detailed evaluation of large planetary building blocks that reside in the asteroid belt. Analyses of these protoplanets involve integrating data from Dawn instruments to assess mineralogy and morphology in geologic context, quantify topography globally at high spatial resolution, and document global elemental composition, all coupled with coherent Doppler tracking that enables assessment of internal mass distribution from gravity measurements. These two protoplanets are quite dissimilar: Vesta (near 2.4 AU) exhibits affinities to the terrestrial planets as an anhydrous silicate body that differentiated early into a rocky crust, mantle, and core whereas Ceres (near 2.8 AU) exhibits affinities more associated with an 'ocean world' and represents an ice-rich partially-differentiated body. Although both bodies exhibit an extensive subsequent cratering history across their surfaces, they each capture different aspects of early Solar System history. The average surface of Vesta is relatively bright, reflecting its pyroxene-rich product of differentiation, whereas that of Ceres is quite dark, reflecting a regolith containing pervasive Fe and C opaque compounds. The mineralogy of Vesta

is now directly tied to Howardite-Eucrite-Diogenite achondrite meteorites (HEDs) in patterns on the surface associated with major impact events that excavated primary Vesta lithologies and mixed and redistributed them globally. Minor amounts of foreign materials that were delivered later contaminate the surface and exhibit carbonaceous chondrite affinities, including hydrous components. Such exogenic materials are identified and mapped in spatial context. In contrast, Ceres exhibits a globally dark aqueously altered surface mineralogy including ammoniated components. Small exposures of water-ice are detected at a few recent craters, while sub-surface ice in regolith pores increases toward the poles. Local areas enriched in sodium-carbonate are identified and mapped, including the prominent relatively recent and very bright deposits in Occator crater. Localized exposures of aliphatic organics have been mapped across an elongate 200 km region in the northern hemisphere. We explore how the very distinct compositional and geologic properties of these protoplanets, the two most massive bodies found in the asteroid belt, result from differences in their starting materials, location, and evolution during the subsequent 4.5 Ga.

B1.3-0033-18 THE CARBON CONTINUUM IN THE SOLAR SYSTEM

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Carbonaceous species evolve from hydrocarbons and organics to amorphous and glassy carbons to graphites with increasing levels of thermal processing and irradiation. Because of this evolution, a “carbon continuum” is present throughout the solar system, with overall less-processed organics more present in the outer solar system and overall more-processed carbonized materials in the inner solar system. Spectral signatures of carbonaceous species - in the ultraviolet as well as at infrared wavelengths - mark the amount of processing experienced by a solar system object’s surface.

With exposure and processing (thermal, irradiation), carbons and organics tend to lose their hydrogen component, ultimately leading to carbonization and graphitization. In the outer solar system, complex organics can exhibit diagnostic spectral features in the UV and infrared (e.g. at Pluto, Iapetus, comets 67P and Halley, outer main belt asteroid Themis and at dwarf planet Ceres). With more maturity, organics are expected to evolve from aliphatic (linear molecular chains) to aromatic (molecular rings). On this continuum, diagnostic features are expected to appear, especially in the UV (<300 nm). As processing of carbon species occurs and H is lost, a UV absorption feature at 220 nm forms. As more H is lost, the UV absorption narrows and shifts toward longer wavelengths, and is accompanied by an increasing brightness toward shorter wavelengths, the FUV rise, such as is seen at Ceres (Hendrix et al., 2016). The more evolved carbonaceous surfaces in the inner solar system are more likely to display evidence of graphite or graphitized carbon and exhibit a stronger UV absorption feature and associated far-UV rise.

We present spectra of the diagnostic spectral shapes and examples from throughout the solar system.

B1.3-0034-18 THE REFLECTANCE OF ICE/DUST ASSOCIATIONS.

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Association and segregation of volatiles and refractories are among the most important processes in the scenarios of formation and evolution of planets. In this scenario, the H2O molecule plays a unique role because its abundance and unique properties. Also, the H2O molecule interacts with the electromagnetic field over most of the spectrum, making it possible to identify and characterize water -mostly its solid formon planetary surfaces using different and complementary remote-sensing techniques. Because of the complexity of the interactions between light and the particulate layer (regolith) that covers most planetary objects in the Solar System, the physical models necessary for the quantitative inversion of remote-sensing data must be thoroughly tested to assess the accuracy of the retrieved values of various properties. This is particularly critical in the optical domain where a multitude of physical and chemical parameters influence the reflectance of the surface. Laboratory experiments with macroscopic analogues that reproduce part of the complexity of natural surfaces, but are nevertheless wellcharacterized quantitatively, are key for the assessment of the qualities and limitations of models. Libraries of reflectance data collected with series of well-characterized samples can also be used for direct comparisons with spacecraft data when model cannot be used. Working with well-characterized icy samples to be used as references is particularly complicated as the samples tend to be prone to fast metamorphism and caution must be taken at all times to keep them pristine. The Laboratory for Outflow Studies of Sublimating icy materials (LOSSy) has been developed for this purpose at the University of Bern since 2010 [1,2]. We have built machines and developed protocols to produce various types of icy analogues in reproducible ways. This includes intimate mixtures of ice and dust, grains of ice with dust embedded into the ice or frost grown onto a dust substrate [3,4]. In addition to H2O ice, we have also started experimenting with CO2 ice. In our laboratory, we measure the reflectance properties of these samples as a function of wavelength (spectra) and illumination and measurement geometry (Bidirectional Reflectance Distribution Function, BRDF). We have recently complemented our instrumentation with polarization-sensitive detectors to add this property to our photometric characterizations [5]. Through collaborations, we characterize our samples using other techniques over various spectral domains [6]. We have recently started distributing the spectro-photometric data through online databases [7]. We will present different examples of our recent and current investigations that are relevant for comets, Mars polar regions, the permanently shadowed polar craters of Mercury or the surfaces of the icy satellites in the outer Solar System.

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B1.3-0035-18 GRAVITATIONAL INSTABILITY AS A PLANET-FORMING MECHANISM

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The fragmentation of self-gravitating discs into giant planets and substellar objects, until recently, has been largely a theoretical discussion. The last ten years have seen twin revolutions in both our capability to observe very young protostellar systems, and in our understanding of how multiple physical processes combine to shape disc fragments into a whole zoo of objects.

I will review our current state of progress in the gravitational instability mechanism for planet formation, from fragmentation itself, through the multiphysics process of "tidal downsizing" towards a final population of observable objects. It will be clear by the end of my review that much remains to be understood, especially the deep connections between gravitational instability and core accretion models of planet formation.

B1.3-0036-18 FOUR 5-MIN POSTER PRESENTATIONS

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Four 5-min poster presentations

B1.3-0037-18 PROBABILITY FOR CLOSE LOOK AT INTERSTELLAR OBJECTS

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Detailed study of interstellar objects is of crucial importance for understanding the connection between planetary systems formation and its interstellar surrounding. Recent discovery of the interstellar visitor Oumuamua (1I/2017 U1), by using Pan-STARRS survey, confirms previous speculations that our solar systems is populated by this transient object. These assumptions are based on the simulations of planetary systems dynamics and evolution which suggest that the early migration of giant planets ejected huge majority of original planetesimals into the interstellar space. They also give the assessment of their number density and velocity and absolute magnitude distributions in the solar neighborhood. The effective discovery of these objects gives an exclusive opportunity for the exploration of their composition and interstellar weathering in order to connect them with primordial planetesimals. In this research we analyze the probability of discovering of these objects by current and near-future surveys (such as ZTF and LSST) by applying novel techniques for their orbit determination in order to overcome their covering by tremendous number of solar system object detectable with increasing sensitivity of the surveys. We also give the qualitative analysis of the dependence of this probability on the orbital characteristics of the interstellar objects.

B1.3-0038-18 THE FEASIBILITY AND BENEFITS OF IN SITU EXPLORATION OF ‘OUMUAMUALIKE OBJECTS

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A rapid accumulation of observations and interpretation have followed in the wake of 1I ‘Oumuamua’s passage through the inner Solar System. We outline the consequences that this first detection of an interstellar asteroid implies for the planet-forming process, and we assess the near-term prospects for detecting and observing (both remotely and in situ) future Solar System visitors of this type. Drawing on detailed heat-transfer calculations that take both ‘Oumuamua’s unusual shape and its chaotic tumbling into account, we affirm that the lack of a detectable coma in deep images of the object very likely arises from the presence of a radiation-modified coating of high molecular weight material (rather than a refractory bulk composition). Assuming that ‘Oumuamua is a typical representative of a larger population with a kinematic distribution similar to Population I stars in the local galactic neighborhood, we calculate expected arrival rates, impact parameters and velocities of similar objects and assess their prospects for detection using operational and forthcoming facilities. Using ‘Oumuamua as a proof-of-concept, we assess the prospects for missions that intercept ISOs using conventional chemical propulsion. Using a “launch on detection” paradigm, we estimate wait times of order a year between favorable mission opportunities with the detection capabilities of the Large-Scale Synoptic Survey Telescope (LSST), a figure that will be refined as the population of interstellar asteroids becomes observationally better constrained.

B1.3-0039-18 PLANET-FORMING GIANT IMPACTS: MACHINE LEARNING AND OTHER NEW IDEAS

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Bombardment by large projectiles played a key role in the formation of the inner planets through accumulation of rocky planetesimals. Our group uses Smooth Particle Hydrodynamics (SPH) to model giant impacts on planetary bodies such as the Moon, Mercury and Mars. As of today, our dataset is composed of over 1,500 simulations spanning a wide range of parameters (composition, size, mass ratio, impact angle, impact velocity). Each SPH outcome is a complex N-D state (consolidated planets, clumps, unconsolidated ejecta, and their characteristics including thermodynamic states, etc.) that requires detailed analysis.

In this regard, state-of-the-art machine learning techniques allow for several advantages: 1) they can streamline the generation of data sets to most efficiently explore regions of interest in a large parameter space; and 2) they can perform accurate mappings of initial conditions and endstates, with associated probabilities, taking into account a high-dimensional parameter space. This is in contrast to human operators that are often limited to a mostly 2-D understanding of the data. Modern machine learning schemes take advantage of this big data problem to spot new and sometimes unexpected correlations.

In this pilot study, we trained, tested and validated an algorithm able to map strictly the pre-impact conditions to the accretion efficiency (defined as the fraction of the projectile mass Mp. acquired by the target Mt). The adopted scheme is supervised: the machine learns the correlation between input and output using labelled data: xi; yi, where xi is an array of four input parameters (predictors): Mt (mass of the target), Mp. (mass of the impactor), q (impact angle) and the ratio between the impact velocity and the escape velocity; and yi is the corresponding response.

Results of that supervised classification exercise will be presented. Our pilot study has shown the potentialities of machine learning in: 1) processing large planetary formation datasets without a heavy involvement/bias from the user; 2) identifying "strange" or interesting regions in the parameter space requiring further study; 3) providing a statistical description to phase boundaries as opposed to the hardline boundaries of traditional scaling laws. One long- term scientific goal is to obtain systematic guidance to solutions of complex problems such as Earth-Moon system formation and Mercury formation that may exist on phase boundaries in outcomes of giant impacts.

B1.3-0040-18 SUPER-EARTHS COMPOSITION: SIGNATURES OF PLANET FORMATION

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The composition of a planet reflects the primordial composition of the proto-planetary disk, location of formation, as well as post-processing mechanisms (such as giant impacts and atmospheric escape) that can alter the final inventory of a planet. I will focus on the results from composition constraints on low-mass exoplanets (super-Earths and mini-neptunes) and the information they provide on how they formed. In particular for the presumably rocky planets, we see a variety in the Fe/Si ratio that needs to be explained. From looking at primordial composition, to alteration through impact collisions I will present constraints on formation scenarios.

B1.3-0041-18 FOUR 5-MIN POSTER PRESENTATIONS

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Four 5-min poster presentations

B1.3-0042-18 FORMATION OF PLANETARY ENVELOPES AND ATMOSPHERES: ROLE OF VAPORIZED ICY MATERIAL

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Planetary envelopes and atmospheres are a final product of complex planet formation pro- cess and, thus, their final mass and composition depend on the properties and evolution of protoplanetary disc gas, initial solid materials, and central stars. Indeed, a diversity of volatilerich planets have been identified in the Solar System and beyond. Conventional ideas about the formation of planetary envelopes and atmospheres are gravitational capture of hydrogendominated disc gas and degassing of heavier volatiles from solid planetesimals and protoplanets. Recent planet formation theories, however, suggest that small solid particles such as pebbles and collisional fragments of planetesimals make a great contribution to planetary accretion. Such small particles are subject to gas drag and evaporation, which cause a significant change in the composition of accumulating atmospheres and protoplanetary discs. In this presentation, I will talk about current theoretical understanding of the accumulation processes of planetary envelopes and atmospheres with a focus on the effects of vaporized icy material.

B1.3-0043-18 CLOSE ENCOUNTERS OF PLANETARY EMBRYOS IN SINGLE AND BINARY STAR SYSTEMS

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In numerical simulations for terrestrial planet formation one usually traces the orbital evolution of numerous protoplanetary embryos over a timespan up to 100 Myrs. When collisional fragmentation is excluded, two embryos merge completely once their mutual distance becomes smaller than a pre-defined collision threshold. It is well known that this assumption is a weak point of such studies which needs to be improved. A more sophisticated model will consider fragmentation in different collision outcome regimes (see Leinhardt and Stewart, 2012).

In this study, we suggest a more realistic formation scenario that includes SPH (Smooth Particle Hydrodynamics) simulations of colliding embryos in the N-body computations. Since the SPH simulations provide the necessary information about volatile and material loss during impact this N-body–SPH combination yields a more realistic result for the growth of bodies and the water transport via collisions on terrestrial planets in the habitable zone.

We show the results for collisions of Moon and Mars sized objects moving in the habitable zone of a sun-like star (i.e. between 0.9 and 1.7 au) perturbed by a Jupiter-mass planet at 3 au and a secondary star at distances of 25/50/75/100 au. Besides the comparison of the different binary-star–planet configurations we also provide a study for a similar planetary system orbiting a single star. In this context, we show the mass-loss during collision depending on the impact velocity and angle. This might modify the result of perfect merging-based N-body simulations of terrestrial planet formation.

B1.3-0044-18 THE BULK COMPOSITION OF EXTRA-SOLAR PLANETESIMALS

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We know over 3000 extra-solar planets, and the past few years have seen a rapid expansion of the parameter space to wider ranges in host star and planet mass, as well as larger orbital separations. Consequently, the architectures of the known planetary systems are becoming increasingly diverse, and so does the entire field of exo-planets.

One fundamental question, "what are those other worlds made out of "?, can not be easily answered by the study of planets orbiting main-sequence stars, as radial velocity and transit surveys only provide a measurement of the bulk densities of planets, and internal compositions are model-dependent.

The key to answering the above question draws on a method well-established in planetary science: measuring the abundances of the building blocks of planets, and their fragments. We know more about the composition of the terrestrial planets in the Solar system from abundance studies of meteorites than from surface samples collected by astronauts and robots. Throughout the last decade, it has been demonstrated that the bulk composition of exo-planetary bodies can be accurately measured, in total analogy to Solar-system meteorite studies, from the spectroscopic analysis of white dwarfs accreting debris from tidally disrupted planetesimals. I will review the recent progress in this research field, highlighting the significant variety of disrupted parent bodies, which include evidence for unprocessed chondritic asteroids, differentiated cores, and even water-rich planetesimals and discussing the implications for planet formation models.

B1.3-0045-18 FOUR 5-MIN POSTER PRESENTATIONS

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Four 5-min poster presentations

B1.3-0046-18 OBSERVATIONAL CONSTRAINTS ON THE BULK COMPOSITION OF EXTRASOLAR PLANETESIMALS

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There is a vast observational gulf between the characterization of interstellar and protoplanetary disk materials, and their eventual incorporation into planetary bodies. Yet many key scientific questions require detailed information of planet compositions, which for extrasolar systems are poorly constrained by transit and radial velocity observations that yield planet radius and mass.

Fortunately, it is now clear that the bulk compositions of large planetesimals can be obtained via observations of white dwarf debris disks and atmospheric pollution by heavy elements. These systems thus provide a critical empirical link between the protoplanetary disk stage and fully formed planets, in a way that is analogous to meteoritic studies in the solar system.

I will present the current state-of-the-art in polluted white dwarf observations, including recent results from the Hubble Space Telescope. The data collected to date provide compelling evidence for distinctly terrestrial-like compositions, and chemical differentiation within large parent bodies. Intriguingly, there is now indirect evidence for water-rich (but otherwise rocky) planetesimals that may represent the building blocks of habitable exoplanets.

B1.3-0047-18 HOW IS THE DISRUPTED PLANETESIMAL AT THE PULSATING WHITE DWARF G29-38 ACCRETED?

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G29-38 was the first white dwarf found to have an infrared excess, interpreted as a dusty debris disc that formed from the tidal disruption of a planetesimal. The ongoing accretion from this debris disc explains the metals detected in the white dwarf atmosphere of G29-38. The analysis of the photospheric contamination provides a direct measurement of the bulk composition of the disrupted planetesimal, which is thought to be a blend of a chondritic object with some refractory-rich material. The discovery of G29-38 opened up a new research field in exploring the compositional make-up of exo-planetesimals. However, the geometry and the process of the accretion from the debris disc onto the white dwarf are not yet clearly understood, in particular the distribution of the metals across the white dwarf surface. The syphon model suggests the flow of the particles originates in a corona above the disc formed by evaporation of the disc. In this scenario the accretion of the metals would result in a homogeneous distribution all over the white dwarf surface, and so far, all abundance studies of debris-polluted white dwarfs assumed that this is the case. In contrast, accretion via a boundary layer or an accretion belt would result in the deposition of metals in an equatorial belt, and hence in a inhomogeneous distribution of metals, which would affect the interpretation of the abundance analyses. G29-38 displays large amplitude variability due to non-radial pulsations.The non-radial pulsations with periods between simeq110–1250,s offer a unique opportunity to diagnose any inhomogeneity of the metals across the white dwarf surface using the pulsations as a spotlight: As a consequence of the pulsations, localised areas on the white dwarf surface are heated by a few thousand degrees, outshining the flux emitted from the unheated regions. Therefore, the ultraviolet spectroscopy is largely dominated by the flux from these heated regions. I have been analysing fast highresolution ultraviolet spectroscopy obtained with the Cosmic Origins spectrograph mounted on the Hubble Space Telescope, extracting the spectra from individual pulses. Modelling the spectral absorption features of silicon and carbon in these spectra using a state-of-the art atmosphere code, I find that the distribution of metals across the white dwarf surface does not show large variations, arguing against an accretion geometry limited to an equatorial belt.

B1.3-0048-18 CONCLUDING REMARKS AND DISCUSSION BY MSOS+DOS

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Concluding remarks and discussion by MSOs+DOs

B1.3-0049-18 FORMATION OF SATELLITE SYSTEMS OF SMALL BODIES AND THE EMBRYOS OF THE MOON AND THE EARTH

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Ipatov showed [1] that the angular velocities of condensations used in [2] as initial data for computer simulations of compression of rarefied condensations leading to the formation of satellite systems of trans-Neptunian objects could be obtained at collisions of condensations. Such considered model of the formation explains well the observed dependencies of the orbital elements and masses of the components of binary trans-Neptunian objects [3]. The initial angular momenta of the condensations were not sufficient for the formation of satellite systems of small bodies. The angular momentum of the condensation used by E.M. Galimov and

A.M. Krivtsov [4] in their computer simulations of compression of the condensation leading to the formation of embryos of the Earth and the Moon could be obtained at a collision of two condensations. I showed that the angular momentum of the present Earth-Moon system could be acquired at a collision of two rarefied condensations with a total mass not smaller than 0.1ME, where ME is the mass of the Earth. The mass of the condensation that was a parent for the embryos of the Earth and the Moon could be relatively small (0.02ME or even less), if we take into account the growth of the angular momentum of the embryos at the time when they accumulated solid planetesimals. If, as it is considered in [4], initial embryos of the Earth and the Moon were almost iron free, the initial mass of the Moon embryo could be less by only a factor of 1.3 than its present mass if it accumulated planetesimals of the same composition as the Earth. In the case of small relative velocities of planetesimals, the effective radius of an embryo is proportional to the square of the radius of the considered embryo. For such a model, for the growth of the mass of the Moon embryo by a factor of 1.3, the mass of the Earth embryo grew by less than a factor of 3. Besides direct collisions with planetesimals, the Moon embryo could also grow by accumulation of almost iron-free material ejected from the Earth embryo at many impacts of planetesimals with the Earth embryo. The work was supported in part by the grant of Russian Foundation for Basic Research № 17-02-00507 (formation of satellite systems of small bodies) and by the grant of Russian Science Foundation № 17-17-01279 (formation of the Earth-Moon system). [1] Ipatov S.I. Solar System Research, 2017, 51, 294- 314, https://arxiv.org/abs/1801.05217. [2] Nesvornyi D., et al., Astron. J, 2010, 140, 785-793.

[3] Ipatov S.I. Solar System Research, 2017, 51, 409-416, https://arxiv.org/abs/1801.05254. [4]

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B1.3-0050-18 MIGRATION OF BODIES FROM BEYOND JUPITER'S ORBIT TO THE EARTH AND THE MOON

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Our studies of migration of planetesimals from the feeding zone of Jupiter and Saturn to forming terrestrial planets were based on computer simulations of the orbital evolution of planetesimals under the gravitational influence of planets. In series JN, all planets were considered in present orbits with present masses, and in series JS, Uranus and Neptune were excluded. In series JN01 and JS01 masses of planets in orbits of the terrestrial planets were by a factor of 10 smaller than the present masses of the planets. In some series of runs, orbits of the giant planets were located initially more close to each other than for the present planets. Initial eccentricities and inclinations of planetesimals were 0.3 and 0.15 rad, respectively. Their initial semi-major axes were between 4.5 and 12 AU in runs with present giant planets. For runs with closer initial orbits of the giant planets the upper boundary of the disk of planetesimals was extended to 20

or 23 AU. The obtained results show that the ratio of the fraction of the planetesimals collided with the Earth was about $2\times10-6$, and similar fraction was about $4\times10-7$ for the mass of the

Earth embryo equal to 0.1 of the Earth mass. We concluded that during the growth of the mass of the Earth embryo up to a half of the present mass of the Earth, the amount of planetesimals (or water) delivered to the embryo from the feeding zone of Jupiter and Saturn could be about 0.3 of all planetesimals (water) delivered to the Earth from this zone. The ratio of the mass of planetesimals (and water) delivered from beyond Jupiter's orbit to a planet to the mass of the planet for the Earth was smaller by a factor of 2 or 3 than that for Mars, and was about the same as that for Venus. For Mercury this ratio typically was not smaller than for the Earth. Based on our runs of migration of planetesimals from the feeding zone of Jupiter and Saturn and of migration of Jupiter-crossing objects, we calculated probabilities of collisions of such planetesimals and objects with the Moon. Such probabilities were typically smaller than probabilities of collisions with the Earth by a factor of 16 or 17. The probabilities of collisions of objects that came from beyond Jupiter's orbit with the Moon and with the Moon embryo with mass smaller by a factor of 10 than that of the Moon differed usually by about a factor of 4.7. The similar ratio for the Earth and the Earth embryo with mass smaller by a factor of 10 than that of the Earth was usually about 5.5-5.8. Based on the above results, we can conclude that the amount of the matter (water and volatiles including) delivered to the Moon from outside of the Jupiter's orbit could be about 20 times smaller than that consumed by the Earth. The work was supported by the grant of Russian Science Foundation N 17-17-01279 (migration to the Moon) and by the Program of Fundamental Studies of the Presidium of RAS

№ 17 (migration to the terrestrial planets).

B1.3-0051-18 INTERSTELLAR ICES, PROTOSTELLAR DISKS AND COMETARY COMPOSITIONS

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Comets are the end product of a variety of processes, including chemical and dynamical evolution in the interstellar medium and in the protoplanetary disk. The “mixing ratios” between observed species (CH4/C2H2/C2H6/HCN/NH3/CO/H2CO/CH3OH/H2O, etc) vary substantially among the comets sampled to date. However, the identification of distinct taxonomic classes has been challenging, and the cosmogonic significance of the observations has remained elusive.

We present preliminary results of a study into the links between comet composition and the ices formed in interstellar clouds and in protostellar disks. We compare the predicted ice compositions from chemical models with the observations of individual comets to establish whether particular patterns of relative mixing ratios are associated with a particular phase of evolution and/or physical conditions. We explore whether the range of cometary abundances can be formed in the interstellar medium, and how processing in the protostellar disk can change ice compositions from their interstellar values.

B1.3-0052-18 ACCRETION OF CENTIMETER TO METER SIZE SOLIDS ON PLANETARY CORES

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The growth of a planetary core out of a swarm of km-size (and larger) planetesimals has been studied extensively over the past five decades. Much less attention has been devoted to the accretion of smaller, 1-1000 cm size particles, during the gaseous phase of a protoplanetary disk. Over the past few years, it has been pointed out that, thanks to their greater radial mobility and accretion efficiency, these small solids may provide growth timescales far shorter than those resulting from the accretion of planetesimals. Since the dynamics of small solids can be intimately coupled to that of the gas, via aerodynamic drag, the accretion rates are bound to depend on the thermodynamical state of the gas. Series of numerical experiments are presented here, which take into account the gas-particle dynamics and quantify the accretion efficiency as a function of particle size and core mass, Mc. These experiments target both lowmass cores (embryos), Mc M⊕, and large core masses, 3M⊕ Mc 20M⊕ at various orbital distances. In the low-mass case, the calculations are based on a simplified gas thermodynamics and assume that the embryos bare no bound envelope. In the high-mass case, gas fields are instead modeled by means of high-resolution radiation-hydrodynamic calculations that include the formation of a hydrogen/helium envelope as well as the thermodynamics of the particles. Implications of the accretion efficiencies are discussed and predictions are made about the core growth timescales, neglecting vaporization of the solids in the cores' gaseous envelopes.

B1.3-0053-18 DUST EVOLUTION IN PROTOPLANETARY DISKS WITH A PAIR OF PLANETS IN ORBITAL RESONANCE

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A significant fraction of extra-solar multi-planet systems are populated by planet pairs whose orbits are in, or in proximity of, mean-motion resonances. The 2:1 and 3:2 ratios are particularly common. A pair of giant planets orbiting in a 2:1 or 3:2 resonance and still embedded in a gaseous disk may undergo various regimes of migration, driven by the disk's tidal torques. These include coupled inward and outward migration. Here we concentrate on a pair of planets orbiting in proximity of the 2:1 resonance and study how they affect the evolution of dust in the surrounding of their orbits. By means of 2D and 3D hydrodynamic simulations that include the evolution of both gas and dust, we calculate the distributions of particles in the size range from 0.01 to 10 mm. Disk properties dictate the orbital evolution of the planets, including eccentricity excitation, which can impose distinctive features in the dust distributions. Under appropriate disk conditions, peculiar dust features, such as large cavities, could be connected to the migration history of the planets. We discuss dust configurations that may deliver information on the planets' orbital evolution.

B1.3-0054-18 PROMOTION OF SPACE WEATHERING WITH SULFUR

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Space weathering is proposed as the main process that should control the change of brightness and color of the surface regolith of airless silicate bodies: optical darkening, reddening and weakening of absorption bands. Formation of nanophase iron particles is the cause of the optical property changes of the space weathering. A small S-type asteroid Itokawa, which was observed by HAYABUSA spacecraft has weakly weathered LL5/6 spectrum, which was confirmed by detailed analyses of returned samples. The returned samples contain not only nanophase iron but also nanophase FeS (and MgS) particles play some role in space weathering. In the present study, we conducted laboratory simulation experiments using nano-second pulse laser irradiation simulating high-speed micrometeorite impacts, and found that additional FeS (45-75µm, 10wt%) as well as additional Fe should promote optical change compatible with space weathering, especially darkening of infrared spectra of olivine. We observed laser-irradiated sample by TEM. The amorphous layer about 200 nm thickness is formed around an olivine particle. Abundant nano particles are observed both at the bottom and the surface of the amorphous layer. On the basis of lattice parameters, we confirmed nano Fe particles but we did not find nano FeS particles. There is possibility that additional FeS promoted production of nanophase iron particles, which would have enhanced the space weathering effect. We also tried preliminary experiments with addition of pure sulfur particles (45-75µm, 10wt%) instead of FeS particles. We observed small change of reflectance after pulse laser irradiation which is less significant compared with the case of additional FeS. We have started very preliminary experiments using FeS2, which may enhance the spectral darkening and reddening as FeS.

B1.3-0055-18 ALMA OBSERVATIONS OF OXYGEN-BEARING COMPLEX ORGANIC MOLECULES TOWARDS THE LOW-MASS PROTOSTELLAR BINARY IRAS 16293–2422

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Many questions remain concerning the formation of complex organic molecules and their presence in the inner region of solar-type protostars. The nearby low-mass Class 0 protostellar binary IRAS 16293–2422 (IRAS16293 hereafter) is an excellent object to study these species on solar system scales. The Atacama Large Millimeter/submillimeter Array (ALMA) provides the high angular and spectral resolution as well as the sensitivity needed to study the physical and chemical structure of such protostars in unprecedented detail.

We use observations from the Protostellar Interferometric Line Survey (PILS; Jørgensen et al. 2016), an unbiased line survey of IRAS16293 using ALMA, to analyse oxygen-bearing complex organic molecules in both IRAS16293A and IRAS16293B. A comparative analysis of the two sources reveals differences in abundances for some of the species and their isotopologues. For example, formaldehyde (H2CO), glycolaldehyde (CH2OHCHO) and ethylene glycol (CH2OH)2 are more than one order of magnitude more abundant towards the A source compared to the B source measured relative to methanol. In contrast, methyl formate (CH3OCHO), ethanol (C2H5OH) and dimethyl ether (CH3OCH3) show similar abundances towards the two components. This selective differentiation suggests that CH2OHCHO, (CH2OH)2 and CH3OCHO are formed on the grain surface via reactions involving H2CO and CH3OH photodissociation products, such as HCO, CH3O and CH2OH (Chuang et al. 2016). In addition, the high sensitivity of the ALMA observations enabled many deuterated species to be detected, including doubly-deuterated methyl formate (CHD2OCHO) for the first time in the ISM (Manigand et al. 2018, subm.). The D/H ratio of CHD2OCHO and CH2DOCHO were found to be extremely enhanced compared to the canonical value 2 10−5, with CHD2OCHO D/H ratio 2–3 times higher than CH2DOCHO D/H ratio. The supplementary information brought by these isotopologues confirms that methyl formate forms through grain surface reactions and suggests that the deuteration enhancement is driven by H-D abstraction substitution processes on the grain.

This study emphases the importance of high angular resolution and high sensitivity observations, for example, provided by ALMA, to separate the close components of protostellar multiple systems and detect less abundant isotopologues.

B1.3-0056-18 STATISTICS OF METEOROIDS FROM THE OUTER REGIONS OF THE SOLAR SYSTEM IN THE EARTH'S ATMOSPHERE

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In connection with the huge number of discoveries of distant cosmic objects behind the orbit of the Neptune (Sedna, Eris, etc.) and beyond the Solar system (exoplanets, 'Omuamua), including those discovered as a result of space flights, astronomers increasingly pay attention to the problems of cosmogony of planetary systems. The aforementioned discoveries have led to the emergence of new classifications of space objects (planetary and non-planetary type) and a change in the previous ones. Even the Pluto was deprived of the status of the ninth major planet of the Solar system. Previously, before the above discoveries about the structure of the most distant regions of the outer solar system, it was possible to obtain some experimental information only from the analysis of the orbital motion of long-period comets, which are not often observed, since they are only visible at sufficiently close distances from the Sun. And before, and now millions of meteoroids invade the Earth atmosphere every second. Dimensions of meteoroids are often insignificant by space standards. According to the proposed new terminology in meteor astronomy: a meteoroid is a solid natural object about 30 micrometers to 1 meter in size. At the same time, these tiny space objects are full members of the respected family of small bodies of the Solar System, and this family has been significantly enlarged due to the aforementioned discoveries. In this contribution, we presented the results of an analysis of the parameters of meteoroids that invaded the Earth atmosphere from the outer solar system. The database of 159,320 orbits of meteoroids of the Kharkiv National University of Radio Electronics (NURE MBD) is used. The research is based on the previously discovered fact that the aphelion of meteor orbits from the NURE MBD can reach 2,000 UA (KolomiyetsVoloshchuk, 2015). References Kolomiyets, S.V., Voloshchuk, Yu.I. 2015. The aphelion distribution of the Near Earth meteoroid orbits with larger eccentricities. The XXIX IAU GA, Honolulu, Hawaii. Abstract ID 2232974

B1.3-0057-18 HIGH PRIORITY DECADAL SURVEY SCIENCE FROM ORBIT AT VENUS

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Magellan, NASA's last mission to Venus, was the last mission aimed at studying the surface and interior of Venus. Launched 29 years ago, Magellan produced a better global altimetry dataset than was available for the Earth at the time, with a footprint size of 12-25 km. Global radar imaging was acquired at 125 m pixels. Magellan enabled numerous scientific breakthroughs, such as 1) Venus' relatively young surface age, comparable to Earth's, 2) the absence of plate tectonics but the presence of possible subduction, 3) an Earth-like number of 'hotspots' like Hawaii, 4) large plateaus that may be analogs of Earth's continents, and 5) thousands of volcanoes, as well as largeand small-scale mantle upwellings. These discoveries in turn have led to key questions about how Earth's twin (in terms of size, density, heat producing elements) evolved so differently. Why doesn't Venus have plate tectonics? How active is it today? ESA's Venus Express mission demonstrated the ability to see the surface of Venus from orbit in narrow windows in the CO2 atmosphere around 1 m (Helbert et al. 2018; Mueller et al., 2018), showing that orbital compositional mapping is possible. Venus Express also provided evidence for both recent volcanism (Smrekar et al., 2010) and for possible felsic crust in the highland plateaus (Gilmore et al., 2015). The case for exploring the surface of Venus from orbit has never been stronger: 1) New Earth-sized exoplanets are constantly being discovered. Understanding how Earth and Venus evolved along completely different evolutionary paths is essential to predicting habitability on such bodies. Earth developed the plate tectonic system that helps provide a clement, stable atmosphere while Venus' CO2 is largely in the atmosphere rather than locked away in rocks, as on Earth. How did this happen? 2) All other terrestrial planets (Mars, Mercury, and Earth plus Earth's Moon) have been investigated with high resolution topography, imaging and spectroscopy, yielding spectacular advances in our understanding of these planets, and in comparative planetology. The relatively poor resolution of Magellan image and altimetry data, and a lack of global, multichannel compositional data, means that Venus is effectively unexplored by comparison to its terrestrial planetary neighbors. 3) Current radar technology has

little in common with that flown on Magellan. Using onboard data processing, it is now possible to obtain geodetically controlled topography with 250 m (horz)

× 5 m (vert) resolution - 2 orders of magnitude better than Magellan. These data are critically important for a planet where high resolution visual imaging is not possible from orbit. Much of Venus (40%) is mapped as 'featureless plains' due to a lack of dielectric contrast, making radar imaging from Magellan of little value; modern imaging is possible at a scale of 15 m. Such an order of magnitude resolution improvement is likely to reveal entirely new processes. The first interferometric mapping of active deformation beyond Earth would reveal what processes are currently shaping the planet today. By optimizing a spectrometer to take advantage of the five available atmospheric windows, it is possible to provide global composition, mineralogy, surface-atmosphere interactions, and search for recent and active volcanism. Additionally, such a spectrometer would search for near surface water vapor from volcanoes, and map winds in both polar vortices effectively simultaneously. 4) As with orbital instrumentation, geochemical and other instrumentation for Venus landers has advanced well beyond what the Soviets did in the 1970s. Global reconnaissance will enable landing site characterization for safety and optimal science return. 5) This technology is ready to fly, and addresses a long list of NASA's Planetary Decadal Survey questions. NASA review panels have repeatedly rated proposed Venus missions as fully selectable, providing cost effective, ground breaking new science, with highly dependable technology. 6) Now is the time to return to Venus and resolve the unanswered question of how Earth-like planets do, and do not, become habitable. This research was partially conducted at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

B1.3-0058-18 THE FOOTPRINT OF COMETARY DUST ANALOGS IN THE LAB - LOWVELOCITY IMPACTS AND COMPARISON WITH ROSETTA DATA

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Comets are the most pristine elements of the solar system preserved to this day. The structure of cometary dust is a tracer of early growth processes in the formation of planetesimals. Measurements by the Rosetta spacecraft show that the dust in the coma of comet 67P/ChuryumovGerasimenko has a granular structure at size scales from sub-m up to several hundreds of m, indicating hierarchical growth took place across these size scales. However, the dust particles studied are a product of a collision within the instrument, which should be taken into account when interpreting the spacecraft data. We present the results of two series of laboratory experiments that simulate the collection of particles in the Rosetta instruments on the collection surfaces of COSIMA and MIDAS, instruments onboard the Rosetta spacecraft. We launched dust analogs (aggregates of pure SiO2, both polyand monodispersed) spanning a parameter range in tensile strength (1-10 kPa), size (10-500 m), and impact velocity (0.5-6 m/s). The resulting deposits on the target surface were subsequently imaged with the COSIMA and MIDAS flight spares. We found that velocity is a key driver in determining the appearance of deposits. At low velocities (< 2 m/s), particles either stick to the target plate, or bounce off, leaving a shallow footprint of monomers. At velocities > 2 m/s, particles fragment upon collision, transferring up to 50 per cent of their mass in a rubble-pile-like deposit on the target plate. The morphologies of the deposits are qualitatively similar to those found by the COSIMA and MIDAS instruments. The amount of mass transferred increases with the impact velocity, and decreases with tensile strength. Extrapolating these trends to the Rosetta data implies that more than half of the dust is lost in the spacecraft.

B1.3-0059-18 PLANET HUNTING WITH MOLECULAR EMISSION

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In the early phases of planet formation, young gas-giants still embedded in their parent disks are luminous, (1-10) x 10−4L sun, both during the accretion phase and immediately after (within a few M yr). U si mass protoplanet. Furthermore, the relevant chemical processes (freeze out and thermal desorption) are r mass planets in the T W Hya protoplanetary disk, where fine scale ringed structure was recently discovered w type, low mass stars.

B1.3-0060-18 COLLISIONAL GENERATION OF DUST IN CIRCUMSTELLAR DISKS DUE TO THE FORMATION OF GIANT PLANETS

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The amount of dust detected in circumstellar disks is expected to steadily decrease with age due to the growth from µm sized particles to planetesimals and planets. We show that this trend can be suddenly halted or reversed when the fast formation of giant planets triggers a period of dynamical excitation of nearby leftover planetesimals. Their dynamical excitation by the planetary perturbations should lead to a significant collisional dust production, rejuvenating the grain population of the disk in the µm size range. We focus on the HD 163296's circumstellar disk, observed by ALMA and thought to host three potential giant planets, as a dynamical test bench for the formation of second-generation dust. We use N-body simulations together with statistical methods to estimate the dynamical and collisional response of a putative planetesimal swarm populating the HD 163296's disk to the formation of the three giant planets. We also take advantage of impact experiments and scaling laws to assess the outcome of the collisions among the planetesimals. Our results show that the formation of HD 163296's giant planets should be followed by a global phase of dynamical excitation of the planetesimals inhabiting the circumstellar disk. This dynamical excitation will produce a violent collisional environment across the disk that might still be active today. The high impact velocities associated can cause a tenfold-to-hundredfold increase in the dust production by impacts, increasing the dust-to-gas ratio of the disk. This mechanism may be a common evolutionary process in circumstellar discs that host forming giant planets and a possible explanation of why also relatively old discs still have a significant dust population in spite of the coagulation and accretion processes. In addition to dust rejuvenation, the excited velocities of the planetesimals could result in the release of transient, non-equilibrium gas species like H_2O due to ice sublimation during impacts and, being supersonic with respect to the gas, could also produce bow shocks in the gas, possibly causing a broadening of its emission lines.

B1.3-0061-18 THE CHEMICAL CONNECTION BETWEEN 67P/C-G AND IRAS 16293-2422

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The chemical evolution of protoplanetary disk materials begins in the earliest prestellar phase of star formation. Under the dark, cold conditions of cores the initial icy mantles of grains are built up. Already at this point, grain-surface chemistry starts to set the composition of these icy layers. Once collapse is initiated, the central protostars can boost chemical processing of the ices by serving as a source of additional UV photons, thereby enhancing photochemistry in both phases, and by heating the dust grains, which allows higher mobility of radicals in the solid phase. Regionally, the heating is sufficient to thermally desorb the ice mantles entirely. In such regions, the chemistry is set via gas-phase reactions. Protoplanetary disks are built up from the collapsing core materials, which are exposed to variable intensities of UV irradiation and heating. The build up of complex organic molecules initiates in the prestellar phase and continues across the subsequent evolutionary stages. I will highlight the chemical connection across various stages of evolution by presenting the latest observational constraints. For this purpose, the results from the ALMA-PILS survey on the infant Solar System analogue IRAS16293-2422 will be presented in the context of in situ measurements made by the Rosetta mission on comet 67P/Churyumov-Gerasimenko. Such comparative studies shed light on the earliest physicochemical conditions for our infant Solar System and give hints on the uniqueness of the ingredients to life.

B1.3-0062-18 EVIDENCE FOR AN EXTRASOLAR TROJAN ASTEROID POPULATION FROM KEPLER PHASE CURVE STACKING

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We present the results of a statistical search for exo-trojans in the Kepler Data Set. By superstacking 4000 Kepler planets with a total of 90000 full orbital curves, searching for an average Trojan transit dip in the Langrange points, we find an upper limit to the average Trojan transiting area (per planet) that corresponds to one body of radius 460 km with 2 confidence. We find a significant Trojan-like signal in a sub-sample for planets with more and/or larger Trojans for periods >60 days. Our tentative results can and should be checked with improved data from future missions like PLATO 2.0, and can guide planetary formation theories.

B2.1-0001-18 REFERENCE FRAMES, GEODETIC OBSERVATIONS, AND ESSENTIAL GEODETIC VARIABLES

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Terrestrial reference frames are determined from station position measurements that are also used to characterize the deformation of the Earth's surface. Understanding the shape of the Earth and how it changes in space and time is one of the three pillars of geodesy. So, the position of geodetic observing stations can be considered to be an Essential Geodetic Variable. Essential Geodetic Variables (EGVs) are observed variables that are crucial (essential) to characterizing the geodetic properties of the Earth and that are key to sustainable geodetic observations. Examples of EGVs might be the positions of reference objects (ground stations, radio sources), Earth orientation parameters, groundand space-based gravity measurements, etc. Once a list of EGVs has been determined, requirements can be assigned to them. Examples of requirements might be accuracy, spatial and temporal resolution, latency, etc. These requirements on the EGVs can then be used to assign requirements to EGV-dependent products like the terrestrial reference frame. The EGV requirements can also be used to derive requirements on the systems that are used to observe the EGVs, helping to lead to a more sustainable geodetic observing system for reference frame determination and numerous other scientific and societal applications.

B2.1-0002-18 ITRF: THREE DECADES OF RESEARCH AND DEVELOPMENT, CURRENT STATUS AND FUTURE PLANS

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On the occasion of the thirtieth anniversary of the International Earth Rotation and Reference Systems Service (IERS), this paper reviews the progress that has been made in the development of the International Terrestrial Reference Frame (ITRF). A particular focus will be devoted to

(1) the frame definition (origin, scale, orientation and their time evolution) and how it is maintained over time, (2) technique systematic errors and their impact on the frame definition,

(3) the possible ways of dealing with station non-linear motions, and (4) the level of agreement between techniques at co-location sites. Improvements planned for the future ITRF releases will be outlined taking into account user needs in both operational geodesy and Earth science applications.

B2.1-0003-18 COMPARISON OF THE SEASONAL DISPLACEMENT PARAMETERS ESTIMATED IN THE ITRF2014 PROCESSING, WHAT CAN WE LEARN?

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In the ITRF2014 computation process, annual and semi-annual periodic coordinate variations have been simultaneously estimated with reference positions and velocities at each geodetic station. Those parameters were conventionally estimated in distinct reference frames for each space geodetic technique (GNSS, DORIS, SLR and VLBI) and so could not be compared. We have developed a combination procedure which allows a rigorous comparison of seasonal displacements estimated by different geodetic techniques. The level of agreement and the sources of discrepancies of seasonal parameters estimated by different techniques at co-location sites will be rigorously evaluated in both horizontal and vertical components. In addition, we model and supplement the elastic deformation induced by surface loading derived from the Gravity and Recovery Climate Experiment (GRACE) and the thermoelastic deformation of the ground to assess the quality of the combined seasonal parameters.

B2.1-0004-18 SYSTEMATIC EFFECTS ON THE REFERENCE FRAMES QUANTIFIED BY VLBI

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Currently three global terrestrial reference frames (TRF) are available: the ITRF2014, the DTRF2014, and the JTRF2014. Although these frames are based on identical input data, the mathematical models applied and thus some coordinates significantly differ. ICRF3 (International Celestial Reference Frame 3), the next CRF (celestial reference frame) is very close to be presented by the corresponding IAU (International Astronomical Union) WG to the IAU General Assembly for acceptance. In the sense of IUGG (International Union of Geodesy and Geophysics) Resolution No. 3 (2011) which advocates the consistent determination of CRF, TRF, and EOP (Earth Orientation Parameters), one of the main tasks will be to make sure that the two reference frames, TRF and CRF, are consistent. VLBI (very long baseline interferometry) is the key space geodetic technique for this purpose. In this presentation, we will investigate state-of-the-art models in VLBI analysis vs. the analysis configuration specified through the IERS (International Earth Rotation and Reference Systems Service) Conventions 2010 and the Convention updates. We will apply several different a priori data sets as well as geophysical and astronomical models, such as geophysical loading deformation, neutral-atmosphere propagation delays, and a priori catalogs from which the NNT/NNR constraints are realized and we will quantify their impact on the reference system realization. The systematic effects found will be in the focus of our work, for example the choice of the mean terrestrial pole for the pole tide loading model. The science-driven quality criteria defined by IAG (International Association of Geodesy) and its GGOS (Global Geodetic Observing System) will be used to judge whether the size of the identified effects is significant or can be neglected.

B2.1-0005-18 EVALUATION OF THE INTERNATIONAL TERRESTRIAL REFERENCE SYSTEM 2014 REALIZATIONS BY PRECISE ORBIT DETERMINATION OF SLR SATELLITES

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An International Terrestrial Reference System realization is a basis for precise monitoring global change phenomena, such as tectonic motion and deformations, postglacial rebound, global and regional sea level change, Earth's rotation, precise positioning applications on and near the Earth's surface, precise orbit determination (POD) and other applications. Three new ITRS realizations have been released recently. They are ITRF2014, DTRF2014 and JTRF2014. We present some results of the evaluation of these ITRS realizations for POD of 10 high and low Earth orbiting geodetic satellites using satellite laser ranging observations (SLR) over a total time span from 1993.0 to 2017.0. We show the impact of these new ITRS realizations on the root-mean-square (RMS) and mean fits of observations, weekly and pass-wise estimated mean station-specific range biases, RMS and mean of single-satellite sea surface height crossover differences using these realizations, as compared to the previous ITRS realization for SLR stations - SLRF2008.

B2.1-0006-18 ERRORS IN SLR-DERIVED TRF ORIGIN CAUSED BY DEFICIENCIES IN ORBIT AND ATMOSPHERIC DELAY MODELING

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Satellite Laser Ranging (SLR) is the space geodetic technique that is used for the definition of the Terrestrial Reference Frame (TRF) origin and along with Very Long Baseline Interferometry (VLBI) for the definition of the TRF scale. SLR is the only geodetic technique that employs optical (laser) wavelengths instead of microwave observations. In the microwave-based observations, the non-hydrostatic delay of the troposphere strongly influences the ray paths of the microwave signal. SLR observations are about 70 times less vulnerable to the non-hydrostatic delay, however, the impact of the hydrostatic delay in SLR is comparable to that affecting microwave observations.

Today, the standard SLR solutions do not employ any corrections due to the horizontal gradients of the troposphere delay. This leads to an assumption that the atmosphere is fully symmetrical above the SLR stations. All other techniques take into account the horizontal gradients into their solutions which may cause inconsistencies, because the SLR-derived TRF origin is common for all techniques. In this contribution we show that the SLR solutions are sensitive to the assymetricity of the troposphere above the stations by estimating horizontal gradients of the troposphere delay using SLR observations to LAGEOS-1/2. We also assess the impact of employing a priori horizontal gradients based on numerical weather models on SLR-derived products, such as geocenter motion, the scale and Earth rotation parameters. The neglect of the horizontal gradients in SLR causes a systematic shift in the TRF origin up to about 0.4 mm with the variations up to 1.0 mm. We also address the issue of the Blue-Sky systematic effect on the SLR solutions that is caused by the fact that SLR observations are collected only in the cloudless conditions which are typically associated with high air pressure values. The Blue-Sky effect affects not the estimated station coordinates introducing a vertical shift of about 1.4 mm, but also the scale of TRF. Finally, we address the issue of correlations between empirical LAGEOS orbit parameters used to absorb the direct solar radiation pressure and the estimated geocenter coordinates and how to avoid these correlations.

B2.1-0007-18 GEOCENTER MOTION FROM SLR OBSERVATIONS

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The Earth's center of mass (CM) is defined in the satellite orbit dynamics as the center of mass of the entire Earth system, including the solid earth, oceans, cryosphere and atmosphere. Variations of the vector from CM to the origin of the ITRF are defined as geocenter motion. Although number of 'geocenter motion' from different techniques were proposed, only Satellite Laser Ranging (SLR) can provide accurate and unambiguous range measurements to direct measure the geocenter motion (with centimeter level accuracy of precise satellite orbits), which is an important component for the realization of the Terrestrial Reference System and geoinformation applications. An accurate station laser ranging bias for SLR network is required for precise satellite orbit determination. This paper presents recent estimate of geocenter motion determined from analysis of multiple geodetic satellites of SLR data over the period from 1993 to present as a part of solution of lower degree (5x5) gravity field as well as the laser ranging bias of SLR network based on ITRF2014. Estimates of the ranging bias of SLR network and uncertainty will be presented as well.

B2.1-0008-18 THE ESTIMATION AND PREDICTION OF GEOCENTER MOTION BASED ON GNSS/SLR WEEKLY SOLUTIONS

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The development of satellite space geodesy technology makes the establishment of global terrestrial reference frame based on the Earth's center of mass become reality. Precise and stable terrestrial reference frame is the foundation of the Earth science research, while determination and analysis of the position of the Earth's center of mass and its change is an important part to build high precision terrestrial reference frame. Firstly, based on GNSS weekly solutions provided by IGS, the geocenter motion (GM) time series between 2001 and 2016 are obtained by means of net translation method. Then the trend term and periodic term of GM are derived using singular spectrum analysis method. It is shown that the GM mainly presents seasonal variation and the dominant factor is annual variation with amplitudes about 4.12mm, 4.68mm, 9.51mm in the direction of X, Y and Z respectively. In order to provide real-time GM, BP neural network method is tested and the predicted values of GM of year 2017 are gotten. It is found that the prediction accuracy can reach 0.82mm, 0.91mm and 1.01mm in the direction of X, Y and Z respectively. Finally, GM estimation and prediction results with higher precision are obtained through co-location surveying and adding strong constraint observation between GNSS and SLR reference point of the co-location.

B2.1-0009-18 EVALUATION OF IMPROVEMENTS TO PRECISE ORBIT DETERMINATION AND DORIS GEOPHYSICAL PRODUCTS USING THE RESULTS OF JASON2/T2L2

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Space geodesy applications currently demand better accuracy and better long-term stability, including the terrestrial reference frame and the Precise Orbit Determination (POD) of Earth observation satellites. This is why the Global Geodetic Observing System (GGOS) recommend both an accuracy of 1 mm and a stability of 0.1 mm/y for geodetic networks.

The Doppler Orbitography Radiopositioning Integrated on Satellite (DORIS) is a tracking technique based on an one way ground to space Doppler link. DORIS shows a robust capability in terms of data coverage and availability, due to a wide and well-distributed ground network. However, DORIS residuals remain in the range of 0.35 0.45 mm·s1, due to systematics errors (e.g. instabilities of the on-board clock to radiations encountered in space, DORIS time biases.), which limits the positioning of the beacons, especially for those located in the vicinity of the South Atlantic Anomaly (SAA).

The Time Transfer by Laser Link (T2L2) experiment carried on-board the Jason-2 satellite is a unique opportunity to read the on-board oscillator and extract frequency bias data at a level of a few parts in 1013. In addition to the frequency bias residuals deduced from the Medium Ephemeris Orbit (MOE) data, the CARMEN-2 experiment measuring particles flux, internal data (e.g. current, temperature of the DORIS receiver) and an analytical representation of environment-induced signals (e.g. radiation), we built a deterministic frequency model, reducing the DORIS residuals to a level of 0.8 × 1012 (0.24 mm·s1) over several years (20082017).

In this paper, we evaluate the impact of our new model for the on-board clock on geophysical products, such as beacon positioning, Earth Orientation Parameters (EOP) and precise orbit determination for Jason-2.

B2.1-0010-18 SCALE (IN)CONSISTENCY IN DORIS SOLUTIONS

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We analyzed the scale of the DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite) solutions w.r.t. DPOD (ITRF) 2014 with the main goal to explain the scale inconsistencies and to find the optimal DORIS solution reaching low-biased and consistent scale time series possibly participating in the future scale definition of global reference frames. Our analysis profited from 5 different strategies based only on GOP Analysis center solution, using DORIS Doppler exchange format data 2.2 from period 2011.0 - 2017.0. A difference in the sequence of the solutions directly corresponded to one of the changes in the solution settings: data elevation dependent weighting, application of data validity indicators, application of phase center - reference point correction and correction of the inaccurate a priori vector centre of mass - phase centre specifically for satellite Hy-2A. Our analysis examined scale inconsistency issues in 2011/2012 and in 2015. 2011/2012 scale increment is explained as a result of the concurrence of Hy-2A dismodeling and change in the provider data validity standards for Cryosat-2 and Jason-2. The scale increment in 2015 is explained as the effect of change in the standards for phase center - reference center corrections for Saral, Jason-2 and Cryosat-2. Moreover, we found a significant reduction of scale bias and scale variation applying data downweighting. We demonstrate that the optimal solution eventuates in a consistent scale time series with the offset w.r.t. DPOD 2014 under 10 mm and weekly scale variations under 2 mm.

B2.1-0011-18 CO-LOCATION OF SPACE GEODETIC TECHNIQUES USING A CLOSURE IN TIME AND A MULTI-TECHNIQUE REFERENCE TARGET

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The realization of a unique global terrestrial reference frame relies on the links between the different space geodetic techniques (VLBI, SLR, GNSS and DORIS). The classical approach in space geodesy is to treat individual systems separately and combine their measurements using co-located sites, where 3D-discrepancies are monitored on a regular basis using geometrical and physical dimensions of the instrumentations. However frequently repeated surveys have not provided evidence for large variable movements of reference points. Therefore, we have proposed a new calibration concept, which investigates instrumental system delays and incorporates system delays into local ties. This concept is based on a coherent time and frequency distribution system which enables to create a signal calibration loop starting in a common clock signal propagating through a multi-technique ground target, free space and the space geodetic technique itself. In this way we overcome the problem that local tie surveys monitor only distances between the geometric reference points of the instruments but not between the electronic reference points. Multi-technique ground targets use the same signal originating from a common clock and the known respective path delay for tying the instruments to a single point of reference on the observatory. The talk outlines the closure measurement concept with first results derived at Geodetic Observatory Wettzell to provide both, intraand intertechnique comparisons and delay control through the installed multi-technique ground target.

B2.1-0012-18 OBSERVATIONS OF THE APOD SATELLITE WITH THE AUSCOPE VLBI NETWORK

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The Chinese APOD (Atmospheric density detection and Precise Orbit Determination) satellite, launched in September 2015, is the first LEO (Low Earth Orbit) satellite co-locating three spacegeodetic techniques including VLBI. Being equipped with a dual-frequency GNSS receiver, an SLR retro-reflector and a VLBI beacon transmitting DOR tones in the S and X band it can be considered as a first prototype of a geodetic co-location satellite in space. With the focus on VLBI observations we present a series of experiments carried out by the AuScope geodetic VLBI array in November 2016. These experiments represent first observations of a LEO satellite by VLBI radio telescopes with the goal of deriving baseline delays as common in the geodetic VLBI. We describe all steps integrated in the established process chain: the experiment design and scheduling, the antenna control and satellite tracking scheme, the correlation, and derivation of baseline delays. To stay as close as possible to the operational analysis scheme for geodetic VLBI sessions we widely adopted the use of standard software such as DiFX for correlation and the Haystack Observatory Post-Processing System (HOPS). In the subsequent analysis of the derived delay in the Vienna VLBI and Satellite Software (VieVS) we find delay residuals in the range of a few ns. VieVS provides options to estimate a variety of geodetic parameters based on such data. These presented experiments represent the first end-to-end realizations of VLBI observations of a tie satellite on a LEO orbit, and are a valuable resource for future more sophisticated space tie satellite missions in the style of E-GRASP/Eratosthenes.

B2.1-0013-18 COMPARING AND CONTRASTING CURRENT APPROACHES TO DETERMINING TERRESTRIAL REFERENCE FRAMES

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The three IERS ITRS Combination Centers, IGN-LAREG, DGFI-TUM, and JPL-CALTECH, take three very different approaches to determining terrestrial reference frames.

IGN and DGFI both adopt a parametric representation of the frame. On the one hand, IGN individually stacks single technique space-geodetic inputs in order to determine a set of station position offsets and velocities and subsequently combine them together along with Earth Orientation Parameters and local ties.

On the other, DGFI combines frames based on the accumulation of normal equations from the four space-geodetic inputs. After stacking normal equations, they invert for linear piecewise station positions and EOPs.

JPL takes a sequential estimation approach using a Kalman filter wherein the frame is represented by a time series of station positions. These different estimation approaches and different representations of the frame have their advantages and disadvantages. For example, parameterizing the station motion leads to convenient models that can be easily evaluated at any epoch, both in the past and in the future. But the parameterized approach suffers from the inability to capture station motion that is not included in the model. On the other hand, while the time series approach allows arbitrary station motion to be captured, evaluating the position of the station at an arbitrary epoch, either in the past or in the future, is more complicated because the time series must be interpolated to the epoch of interest.

In this talk, the different approaches that are currently used to determine terrestrial reference frames will be reviewed and their advantages and disadvantages discussed.

B2.1-0014-18 DETERMINATION OF KALMAN FILTER TRF SOLUTIONS BASED ON WHITE NOISE STATION COORDINATE BEHAVIOR

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Kalman filtering has become an established technique for the creation of terrestrial reference frame (TRF) solutions, and has been successfully used in the determination of JTRF2014, the most recent ITRS realization by Jet Propulsion Laboratory. So far, the station coordinates have typically been modeled as random walk processes. Advantages of random walks are, for example, that they are computationally efficient and easy to implement in a Kalman filter environment. Furthermore, they guarantee a certain short-term stability of the station coordinate time series, since the coordinates of one epoch directly depend on those from the previous epoch.

However, time series of station coordinates from different space-geodetic techniques as well as non-tidal loading displacements, which are often associated with the non-linear part of coordinate variations, indicate a different stochastic behavior. Most often, the appropriate stochastic model would be white noise.

For this reason, we have implemented the option to use white noise as the process noise type for station coordinates, realized by including an additional parameter per coordinate component in the state vector of the Kalman filter (in addition to offset, velocity, and seasonal signals). Based on data from very long baseline interferometry (VLBI), we will compare the performance of white noise Kalman filter solutions with conventional solutions based on random walk processes. In particular, we will investigate their agreement with existing VLBI coordinate time series, as well as their capability of accurately predicting future station coordinates.

B2.1-0015-18 A SIMULATION STUDY TO INVESTIGATE REFERENCE FRAME STABILITY

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Terrestrial reference frame origin stability is critically important to monitoring sea level change through altimetry satellite orbit and crustal motion determinations. Accurate measurements of translational motion between the center-of-mass of the Earth system and the geodetic network can also provide a stronger signal to infer degree-1 spherical harmonic components of Earth's surface mass variations with GRACE and other data. However, complications of GIA, plate motions, uncertainty of terrestrial reference frame origin, certain modeling concepts, and nonlinear motions have so far prevented translational signatures to be used in the determination of geocenter velocities. Also, the current ITRF frame has a net rotation of more than 1 mm/yr from a geodesy-based no-net-rotation plate motion model. We investigate the origin and orientation stability issues by a progressively realistic simulation study. First, synthetic geodetic data are generated from real world geodetic networks with realistic plate motion, GIA, surface loading, geocenter motion signals. These with or without noises generated using full covariance matrices of real geodetic input SINEX files are then passed to several TRF realization procedures to investigate their effects on TRF stability and possible systematic errors.

We found that geology-based plate motion model and apparent rotation due to geocenter motion likely included in the no-net-rotation constraint can both contribute to the net TRF frame rotation with the right order of magnitude. Fortunately, as long as plate motions are freely estimated along with other signals in post-TRF procedures, the origin and translational signals are not negatively impacted. Still, the use of a geodesy based no-net-rotation plate motion model and a no-pure-net-rotation constraint are recommended for future TRF realizations. Results

and challenges of studying other effects on reference frame origin and orientation stability such as those due to non-linear and accelerating surface load variations will be discussed.

B2.1-0016-18 POSTER HIGHLIGHTS SESSION

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This oral presentation slot is set aside for 2-minute oral summaries from each poster presenter. In the interest of time, presenters can display no more than a two slides, which must be submitted in advance before the conference by email to gblewitt@unr.edu.

B2.1-0017-18 THE IMPACT OF ATMOSPHERIC AND HYDROSPHERIC SURFACE LOADING DEFORMATION ON GLOBAL STATION NETWORKS

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Time-dependent mass variations of near-surface geophysical fluids in the atmosphere, the oceans and the continental hydrosphere lead to significant and systematic load-induced deformations of the Earth's crust. Based on station coordinate time series it is possible to assess the impact of time-dependent mass variations on the Earth's surface geometry and, thus, to assess the impact of uncorrected deformations on station positions and terrestrial reference frame parameters. Model-based deformation products publicly available at http://isdc.gfzpotsdam.de/esmdata/loading contain vertical and horizontal crust deformations imposed by surface loading of geophysical fluids in atmosphere, oceans and the continental hydrosphere with a spatial resolution of 0.5° and a temporal sampling of down to 3 hours (Dill and Dobslaw, 2013).

More than 10 years of GNSS and VLBI observations from more than 300 GNSS stations and nearly 40 VLBI stations were reprocessed in order to quantify the impact of surface deformations on station positions. In the first part of this contribution, we discuss the impact of surface loadings on the local and regional scale based on the GNSS stations processed in PPP mode. Here the focus is especially on areas known for large annual surface deformations. The second part concentrates on the impact of surface loading deformations on the terrestrial reference frame. Based on transformation parameters between GNSS as well as VLBI network solutions corrected for different sets of loading deformations we discuss the effect of geophysical fluids on the terrestrial reference frame.

Dill, R. and H. Dobslaw (2013), Numerical simulations of global-scale high-resolution hydrological crustal deformations, J. Geophys. Res., 118 (9), 5008-5017, doi:10.1002/jgrb.50353.

B2.1-0018-18 COMPARING NON-LINEAR GEOCENTER MOTION DERIVED FROM GNSS AND SLR OBSERVATIONS CORRECTED FOR LOADING AND THERMOELASTIC DEFORMATION

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Seasonal mass redistribution of continental water, atmospheric pressure, and non-tidal oceanic loading deforms the Earth, inducing horizontal and vertical surface displacements of a few mm and a few cm respectively. In addition, long wavelength annual temperature variations induce a thermoelastic deformation field, with vertical surface displacements of a few mm. The longest wavelength component of both effects, their spherical harmonic degree-1 component, not only deforms the solid Earth, but also induces geocenter motion between the Center-of-Mass of the total Earth system (CM) and the Center-of-Figure (CF) of the solid Earth surface.

SLR and GNSS station position time series used to retrieve geocenter motion are strongly affected by the deformation induced by surface loading and thermoelastic effect. We propose to evaluate the impact of both effects on geocenter motion estimates by correcting the station position time series using physical loading and thermoelastic deformation models. On the one hand, we model surface displacements induced by variations in continental water, atmospheric pressure, and non-tidal oceanic loading, derived from the Gravity and Recovery Climate Experiment (GRACE) for spherical harmonic degrees

two and higher. On the other hand, we model the thermoelastic deformation as the response of a realistic Earth rheological model to land surface temperature variations (NOAA).

We compare non-linear geocenter motion derived separately from SLR (using the network shift approach) and GNSS (using a the degree-1 deformation approach) and discuss the relative impact of loading and thermoelastic effects on each both estimates.

B2.1-0019-18 STOCHASTIC MODELING OF NON-TIDAL GROUND DEFORMATION USING GRACE DATA FOR TERRESTRIAL REFERENCE FRAME ESTIMATION

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In recent realizations of terrestrial reference frame (TRF), such as ITRF2014 and JTRF2014, non-tidal ground deformation parameters are co-estimated to improve the accuracy of the frame estimate. The traditional linear motion model for TRF is enhanced by additional ground motion models including post-seismic displacements as well as annual, semi-annual, and random ground deformations due to atmospheric, oceanic, and ground water storage loading. Although such motions are often regionally correlated, the ground deformation models used so far for TRF realizations are formulated to be strictly local in space. We are investigating application of the GRACE data to improve the TRF stochastic models (used in JTRF2014) by determining spatial

statistics of the deformation of the Earth's surface caused by mass loading. A potential target of improvement is the non-uniform distribution of the geodetic observation sites, which can introduce biases in estimated TRFs. We compare the GRACE observation-derived spatial statistics to ones derived from numerical models of atmospheric, oceanic, and ground-water loading as well as ones from GNSS observation network.

B2.1-0020-18 GOING BEYOND REFERENCE FRAMES TO IMPROVE THEM: THE EXAMPLE OF HORIZONTAL DEFORMATION INDUCED BY GLACIAL ISOSTATIC ADJUSTMENT

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A common theme in scientific technique development is the need to go beyond that technique to obtain independent validation and evidence that can lead to further improvements. For example, the early days of GPS technique development was validated and facilitated by having ground truth from VLBI and SLR. A similar lesson can be applied to reference frames. The analogy would be to use measures of Earth surface deformation that are sufficiently insensitive to reference frame such that they can be used to improve geodynamic models that feedback into the definition of the reference system, thus ultimately improving the next generation of reference frames. Here, we illustrate this with the example of glacial isostatic adjustment (GIA) models that can disagree significantly in predictions of contemporary surface velocities, even at plate-scale distances. Thus, by the definition of geodesy, this can be considered a first-order problem. One problem with using station velocities to assess GIA models is that they are reference frame dependent, and so are affected both by rotation and translation rates. Ensuring that the modeled and observed station velocities are in the same reference frame is not trivial, particularly with regard to the rotation of the horizontal velocity field in the presence of plate tectonics and more localized processes that also affect the velocity field. To mitigate this problem, we use GPS velocities to create a robust image of the horizontal strain rate tensor. This can then be decomposed into reference-frame-insensitive scalar fields such as dilitation rate and shear magnitude rate. Here we use a new robust strain rate estimation method (MELD– Median Estimation of Local Deformation) applied to 3,271 GPS velocities in North America that were estimated using a robust algorithm MIDAS (Median Interannual Difference Adjusted for Skewness). The resulting images of strain rate are robust to anomalies localized in time or space, while respecting the inherent spatial resolution of the network. Despite the inherent high resolution of this method when applied to dense networks, our results show ultra-low strain rates with plate-scale coherence in intraplate North America, thus providing a coherent image of GIA, superimposed by more localized processes such as delta subsidence and ground fluid extraction. Our key finding is that the area underneath the Laurentide ice sheet is undergoing extension, surrounded by a semi-annular belt of contraction of up to 4 nanostrains (parts per billion) per year. Such observed long wavelength characteristics

of the ultra-low strain rate field in intraplate regions can therefore be used to provide robust constraints on viable GIA models, with the prospect of eventually contributing to an improved reference system and future realizations of the reference frame, including plate-fixed reference frames.

B2.1-0021-18 MONITORING OF PERMANENT GNSS NETWORKS USED FOR ACCESSING THE TERRESTRIAL REFERENCE FRAME

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Scientific GNSS networks likes the ones operated by the International GNSS Service (IGS) and the EUREF Permanent Network (EPN) are continuously evolving, e.g. the number of stations increases, new satellite constellations are tracked, observation data and metadata formats change, and the importance of real-time data provision increases. Both the IGS and EPN are based on voluntary contributions. More than 130 agencies all over Europe contribute to the EPN. Although guidelines (based on IGS guidelines) exist within the EPN for data quality and data flow, equipment changes, or maintenance of metadata, different institutes use different practices and there is no formal guarantee that EPN stations are operated following the EPN guidelines. This explains the need for the extensive central monitoring of the EPN performed by its Central Bureau (http://epncb.eu).

To deal with the evolving GNSS landscape, the EPN Central Bureau (CB) revisited its monitoring procedures and interface with users and data providers. The frontend of the web site (http://www.epncb.eu) was completely redesigned and the majority of the backend software was rewritten. We will outline the philosophy behind the upgraded

GNSS data quality, availability and latency checks,

Monitoring of real-time data streams,

Position time series,

Management of individual receiver antenna calibrations,

System for the 'Management and distribution of GNSS Metadata for Multiple networks' (M3G).

We will illustrate the effectiveness of these monitoring procedures by focusing on the Galileo and real-time capability of the EPN.

The EPN CB monitoring and metadata maintenance procedures use standardized inputs and can therefore be applied to any

large-scale permanent GNSS network maintained by several contributors. Although often taken for granted, these procedures enhance the reliability of GNSS data for providing access to the terrestrial reference frame.

B2.1-0022-18 QUALITY ASSESSMENT OF THE EPN MULTI-YEAR POSITION AND VELOCITY SOLUTION

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The primary purpose of the EUREF Permanent Network (EPN) is to provide access to the European Terrestrial Reference System 89 (ETRS89) which is the standard precise GNSS coordinate system throughout Europe. To maintain the ETRS89, EUREF provides multi-year coordinates/velocities of the EPN stations in the latest ITRS/ETRS89 realization, also called the 'EPN multi-year solution'. The coordinates/velocities of the EPN multi-year solution are regularly updated (each 15 weeks) and are used as the reference coordinates/velocities for densifying the IGS14 realization of the ITRS in Europe. It is the core product of EUREF, the IAG (International Association of Geodesy) Reference Frame sub-commission for Europe. Starting with the release of IGS14 (January 2017), the EPN multi-year position and velocity solution is replaced by a new version based on the daily solutions instead of weekly solutions and on EPNrepro2 and routine solutions. The EPN multi-year position and velocity solution is computed with the CATREF software (Altamimi et al., 2007). The positions and velocities are expressed in IGS14 reference solution using minimal constraints on a selection of IGS14 reference stations. During the stacking, discontinuities are introduced to account for jumps in the position time series. In addition, this solution incorporates the ITRF2014 post-seismic deformation models. The EPN stations are categorized into Class A and Class B stations. Class A stations represent stations whose multi-year positions and velocities are reliable enough to be used as reference station for densification projects. The criteria for distinguishing between Class A and Class B stations have been recently revisited. They take into account the length of the available observation span and the "station quality". In order to assess the quality of the stations, the sensitivity of the velocity and its error estimation with respect to time correlated noise, used software, and tracking performance of the station has been investigated.

B2.1-0023-18 TOWARDS NEXT GENERATION REFERENCE FRAMES IN EUROPE

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The IAG Sub-commission 1.3a EUREF merges efforts of National Mapping and Cadastral Agencies (NMCA), Universities and research institutes to define, realize and maintain the European Terrestrial Reference System 1989 (ETRS89) and the European Vertical Reference System (EVRS) for scientific and practical purposes in Europe. Technical development, new applications and increased accuracy of observations are setting new demands for the practical realizations of the reference systems. The release of the global International Terrestrial Reference Frame ITRF2014 raised also the question on future and needs on renewal of the realization of the European Terrestrial Reference System.

It is foreseeable an emerging mass market for precise positioning based on centimetre level positioning services worldwide without any regional or national reference frames. There will be also precise point positioning (PPP) service from Galileo and other provides. These worldwide services will most likely use ITRF in current epoch.

Crustal deformations and movements deteriorate the accuracy of static reference frames with time (like the currently used European realizations ETRF2000 or ETRF2014) as distortions are increasing. Monitoring the deformation with EUREF permanent GNSS Network (EPN) and research within EUREF working groups are necessity for the future, but these alone do not answer the question of future reference frames. We have to solve the European-wide question of national static reference frames.

There are many countries that have invested a lot in their national realizations of ETRS89 which are even fixed in their legislation and they will use the current frame effectively for many years to come. Additionally, the Directive 2007/2/EC of the European Parliament and of the Council of Infrastructure for Spatial Information in the European Community (INSPIRE) requires that the European Terrestrial Reference System 1989 shall be used, and for elevations, i.e. gravity-related heights, the European Vertical Reference System shall be the system.

Instead of a static reference frame, one can use semi-kinematic or kinematic approaches where either the transformation from global to the national reference frame or the coordinates of the benchmarks realizing the reference frame are time-dependent. For some years to come we may have a two frame approach where ETRS89 and ITRF will be used together, depending on the application. Using European-wide 3D deformation models, and dense network of permanent GNSS stations, we may link these together (semi-kinematic approach). However, shifting fully to an ITRF kinematic frame will pose problems both on the practical level and in national and European legislation. On the gravity related global heights we do not yet have a similar approach, which will take even longer time to get adopted. However, a need to be prepared on EUREF level is more urgent than ever and it should be discussed within the European geodetic community to find the best solution for the future both for scientific and practical use.

B2.1-0024-18 IMPROVING INFRASTRUCTURE AND STANDARDS TO MAXIMISE THE BENEFITS OF POSITIONING TECHNOLOGY IN AUSTRALIA

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Sub decimetre accurate positioning in mobile devices from Global Navigation Satellite Systems (GNSS) with corrections from satellite or internet communications is expected within the coming decade. This will provide an expanding user base with positioning, navigation and timing information in a global reference frame such as ITRF. In recognition of this, Australia has recently updated its national datum to the Geocentric Datum of Australia 2020 (GDA2020); a static datum based on a continental scale adjustment of approximately two million measurements to rigorously propagate coordinates and uncertainties to 250,000 survey marks across Australia. This is the first update since the Geocentric Datum of Australia 1994 (GDA94) and reduces the offset between the national datum and ITRF2014 from 1.6 m to 0.2 m at present.

A static datum however, cannot meet the requirements of some current and future positioning applications which require real-time, high precision positioning aligned to a global reference frame such as the intelligent transport sector (e.g. autonomous vehicles and mining) and location based services (e.g. asset management, emergency services). To meet user demands, Australia plans to introduce a time-dependent reference frame in 2020 known as the Australian Terrestrial Reference Frame (ATRF). This reference frame will be an accurate and densely realised geodetic framework based on continuous observation and analysis of GNSS data and provide the Australian community with traceable, high-precision coordinates, closely aligned to ITRF and capable of meeting the most demanding positioning requirements. There will be very close alignment between ATRF and ITRF; in fact Australian sites contributed to ITRF will be a subset of reference sites constrained in ATRF.

The development of GDA2020 and the future ATRF are enabled in large part due to the design and construction of world class geodetic infrastructure. Over the past two decades Australia increased the number of high-quality GNSS Continuously Operational Reference Station (CORS) sites (geodetic antennas mounted on pillars attached to bedrock) from eight to 120. When plate tectonic motion is removed from the time series of these sites, the residuals are typically less than one millimetre. This reflects both the stability of the Australian continent and the quality of the infrastructure.

The geodetic community are increasing called upon to provide greater volumes of, and higher accuracy data and products to support a broad and expanding spectrum of government, industry, science and societal applications. To achieve this there is a need to combine the high quality infrastructure, data and analysis with high quality, autonomous, machine-to-machine communication based on international standards to abstract the lay user from the complexities of geodesy. In response, Australia and New Zealand are leading the development of geodetic standards (GeodesyML) in collaboration with the IGS Data Center Working Group. The vision in Australia is to use standards such as GeodesyML to better connect users with data and information to enable industry, scientists and the public to capitalise on this positioning technology and maximise its benefit.

B2.1-0025-18 REGIONAL REFERENCE FRAMES FOR NORTH AMERICA: CURRENT STATUS AND FUTURE PLANS OF REGIONAL SUB-COMMISSION SC1.3C

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In collaboration with the IAG community, its service organizations and the national geodetic organizations of North America, the IAG Regional Sub-commission SC1.3c (Regional Reference Frames for North America) provides international focus, cooperation and coordination for issues involving the geodetic reference frames and control networks of North America. These issues include the establishment, maintenance, future evolution and inter-relation of reference frames throughout the continent, and the specification of consistent standards and guidelines. In order to realize these objectives the Sub-commission has been organized into three working groups dealing with (1) the densification of the ITRF and IGS reference frames in North America (NAREF), (2) the definition of new geocentric, ITRF-based plate-fixed reference frames to replace the existing non-geocentric NAD83 in North America, the Caribbean, and U.S. territories on the Pacific and Mariana plates, and (3) the maintenance of the relationship between NAD83 and global reference frames. Over the past few years there has been much preparation for major activities that are just now beginning. We report on these activities and the future plans of the working groups. In particular, we highlight work towards the implementation of the new plate-fixed references frames to replace NAD83 in 2022, including the reprocessing of all continuously operation reference stations and cumulative solutions with velocities. Other important efforts include the updating of NAD83 and transformations with respect to ITRF2014.

B2.1-0026-18 NAD83(CSRS) VERSION 7: AN UPDATED REALIZATION OF NAD83 FOR CANADA

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The North American Datum of 1983 (NAD83) is the geometric reference frame of the Canadian Spatial Reference System (CSRS) and has been adopted by the federal and provincial agencies for georeferencing in Canada. In collaboration with the U.S., NAD83 was redefined in 1998 as a seven-parameter similarity (Helmert) transformation from ITRF96. Referred to as NAD83(CSRS), the frame was kept aligned with the North American tectonic plate using the NNR-NUVEL-1A plate motion model. NAD83(CSRS) has since been updated to later realizations of ITRF using the transformations between ITRFs published by the IERS and identified by version numbers. In order to account for crustal motions within the NAD83(CSRS) frame, a crustal velocity model based solely on GPS velocities was introduced with version 5 (based on ITRF2005) and updated in version 6 (based on ITRF2008). The velocity model, represented by an interpolation grid, enables coordinates to be propagated to different reference epochs, including those of the realizations of NAD83(CSRS). These velocity models were unreliable in the northern territories where GPS coverage was sparse. A new NAD83(CSRS) version 7 has recently been published based on a transformation from ITRF2014 and a reprocessing of all continuous and high accuracy repeated GPS campaign surveys in Canada, bordering areas of the U.S. and all of Greenland. A set of approximately 80 global IGS stations used for alignment to IGS14. To overcome the weakness of the previous GPS-only velocity models, a new model was created based on a novel integration of GIA models with the new GPS velocity field. In addition to providing a more precise regional reference frame for geospatial positioning throughout all of Canada, the new NAD83(CSRS) version 7 is capable of providing more accurate predictions of crustal velocities for propagating coordinates to different reference epochs and for supporting geoscience studies such as natural hazards related to earthquakes and relative sea level rise.

B2.1-0027-18 THE IMPACT OF INDEPENDENT GNSS GEOCENTER AND SCALE INFORMATION ON FOUR-TECHNIQUE REFERENCE FRAMES

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GNSS geocenter and scale information has typically been excluded from terrestrial reference frame combinations because current IGS combinations have been aligned with ITRF by application of rotational and translational constraints and adjustment of antenna offsets. Haines et al. (JGR, 2015) have computed alternate GNSS solutions with independent geocenter and scale information. We can now investigate the use of GNSS geocenter and scale information in the context of a four-technique reference frame. JPL's new GipsyX software will be used to compute linear reference frames based on traditional IDS, IGS, ILRS, and IVS inputs and then the IGS combinations will be replaced by Haines GNSS solutions. These frames will be compared to assess the viability of GNSS geocenter and scale information.

B2.1-0028-18 INTER-SATELLITE LINKS WITHIN FUTURE GNSS CONSTELLATIONS AND THEIR IMPACT ON THE TRF-DEFINING PARAMETERS

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The four main space geodetic techniques, namely Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), Global Navigation Satellite Systems (GNSS), Satellite Laser Ranging (SLR), and Very Long Baseline Interferometry (VLBI), are currently combined to determine global terrestrial reference frames (TRF). The origin of the TRF is realized by SLR only and the scale by SLR and VLBI. DORIS and GNSS do not contribute to the realization of the origin and scale mostly due to persisting systematic effects. Since the Global Geodetic Observing System (GGOS) requirements of 1mm accuracy and 1mm/decade long-term stability are not met by current TRFs, it seems worth to investigate the potential of future GNSS constellations using innovative optical ranging and time transfer technology. Within the joint project ADVANTAGE (Advanced Technology for Navigation and Geodesy) by the German Aerospace Center (DLR) and the GFZ German Research Centre for Geosciences, simulations of a future satellite constellation connected by two-way optical links are carried out to investigate potential improvements in the TRF-defining parameters. The chosen ADVANTAGE constellation consists of 24 Middle Earth Orbit (MEO) navigation satellites and 4 Low Earth Orbit (LEO) satellites. We evaluate the impact of highly precise clocks and inter-satellite ranging on the TRF in terms of origin, scale and orientation. We also assess the effect of systematic modeling errors like solar radiation pressure, antenna phase center offsets, and others.

B2.1-0029-18 THE ILRS ROAD TO ITRF20XX

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The International Laser Ranging Service (ILRS) has completed a full re-analysis of the modernera data (1993 to present), based on an improved modeling of the data and a novel approach that ensures the results are free of systematic errors in the underlying data. Over the past three years, since the completion of the last ITRF (2014), the ILRS Analysis Standing Committee (ASC), devoted almost entirely its efforts to develop, evaluate and implement the new approach. Initially with the execution of a Pilot Project (PP) that demonstrated the robust estimation of persistent systematic errors at the millimeter level, and now, with the production of essentially an improved version of the ILRS contribution to ITRF, using the new approach. The improved results for the TRF attributes were reflected in the resulting new time series of the TRF origin and scale. The ILRS ASC is now using the new approach in the development of its operational products and we are using this as a tool to monitor station performance and to extend the history of systematics at each station, to be used with each re-analysis for all future ITRF model developments. The new operational products form a seamless extension of the re-analysis series, providing a continuous product based on our best knowledge of the ground system behavior and performance, without any dependence whatsoever on a priori knowledge of systematic errors. The presentation will demonstrate the level of improvement with respect to the previous ILRS product series.

B2.1-0030-18 SLR TARGET CONSTELLATION FOR AN IMPROVED FUTURE ITRF

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The International Terrestrial Reference Frame (ITRF) is the prime contribution of the Global Geodetic Observing System-GGOS, to the Global Earth Observation System of Systems (GEOSS) by the organization itself, as well as a product of the International Association of Geodesy-IAG Services that contribute to its development. To meet the stringent requirements imposed by the user community, GGOS set strict goals for the accuracy and stability for the ITRF: definition of its origin at 1 mm or better, temporal stability of 0.1 mm/y, and similar numbers for its scale and orientation components. None of the IAG positioning techniques can achieve this goal alone. The main reason is the non-observability of certain TRF attributes from each technique. Another reason is the poor state of the ground segment and/or limitations of the space segment. The ground segment of all four space geodetic techniques is now under renovation and upgrade. The SLR network in particular, has already more than a dozen new systems operating in kHz repetion rates, as expected for next-generation systems. In the case of the space segment, the unavailability of suitable SLR targets in a more frequent daily schedule results in lower accuracy and resolution for some of the SLR products. The small number of satellite targets used in ITRF development at present has been a driving force behind several attempts to launch better-designed targets in various configurations. The first successful mission was ASI's LARES (LAser RElativity Satellite), launched by ESA in February 2012. This new cannonball target added to the existing two LAGEOS' and two ETALON satellites will certainly contribute to the next ITRF model. Furthermore, ASI has recently approved the launch (provided again by ESA) of a second LARES-type satellite-LARES-2, in the very near future (late 2019). However, it is already possible to increase the number of the available targets, even if not as optimal in design as the cannonball satellites may be, by including all or some of the GNSS spacecraft that carry Laser Retroreflector Arrays-LRAs. With the planned outfitting of current and future GNSS constellations with LRAs, there is an opportunity to dramatically improve the sky-coverage, the chances that a SLR station has a target to track at any time, and the geometry of available data over each station per day. In the case of future launches, with careful designs and a calibration of the LRA location with respect to the radiometric phase center and the center of gravity of the s/c, these targets can become a very significant contribution in the development of the future ITRF realizations, imposing a strong tie between the two techniques in space. With the number of such targets reaching well over one hundred over the next decade, we will soon need to define minimum requirements and a concept of operations in order to avoid undue burdening of the SLR network and a waste of resources. Our current effort is to evaluate at first the contribution of LARES and subsequently that of LARES-2, with the next additions coming from existent in-orbit missions like Starlette, and in a final stage the addition of selected GNSS targets. We plan to eventually examine the utility of bringing the two techniques together in orbit and the tangible benefits that we expect to reap on the ground in realizing the ITRF. We will present here initial results of specific targets' combination studies aimed at achieving the GGOS accuracy goals.

B2.1-0031-18 ICRF-3: AN OVERVIEW OF THE PROPOSED NEXT GENERATION MULTIWAVELENGTH ICRF

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The ICRF-3 proposal to the 2018 IAU General assembly improves the precision, spatial coverage, and frequency coverage relative to the current standard, the ICRF-2 (Ma et al, 2009).

This paper will discuss all three frequencies (8, 24, 32 GHz) of the proposed ICRF-3 highlighting their strengths and weaknesses. Inter-comparisons will be used to estimate true accuracy of the frame. Comparisons of radio-based VLBI frames to the optical Gaia DR2 frame will provide a complementary assessment from an independent wavelength and technique. We will close with prospects for future development of the ICRF.

B2.1-0032-18 WHERE - A NEW SOFTWARE FOR GEODETIC ANALYSIS

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The Norwegian Mapping Authority (Kartverket) is an associated analysis center within the IVS. We are currently developing Where, a new software for geodetic analysis. Where is built on our experiences with the Geosat software, and will be able to analyse geodetic data from the VLBI, SLR, and GNSS techniques. At the moment we are preparing to contribute VLBI analyses to IVS. We plan to make the Where-software available to the community.

This presentation will show some of the current capabilities of Where, including benchmarks against other software packages. Where supports parameter estimation using Kalman filters, and a comparison to the classical methods will be shown.

B2.1-0033-18 THE ISO GEODETIC REGISTRY AND RELATED STANDARDS

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The International Standards Organization Technical Committee 211 (ISO/TC 211) on Geographic Information/Geomatics has taken responsibility for establishing the ISO Geodetic Registry, a registry of international geodetic reference systems and transformations. A principal use of the Registry is in defining the various reference frames and transformations used for applications in the geosciences, such as for satellite orbital coordinates and geographical information systems software. The data contained in the registry are the parameters defining geodetic reference systems and adopted transformations between them and need to be validated by official sources. The ISO Geodetic Registry has been defined in accordance with the new ISO International Standard (IS) 19127 (Geodetic register). This standard defines the data elements required, as well as the rules for its maintenance, in compliance with IS 19135 (Procedures for item registration) and the recently updated IS 19111 (Referencing by coordinates) that describes the elements necessary to fully define reference systems. As specified in IS 19135, the ISO Geodetic Registry consists of an online information system or database with a user interface and web services for access, a Registry Manager hosting the Registry and taking care of its daily operations, and a Control Body that approves the content of the Registry. The Norwegian Mapping Authority is serving as the initial Registry Manager and has funded and hosted the registry management software. The Control Body consists of geodetic experts nominated by the TC 211 member and liaison organizations with its chair and vice-chair appointed by the IAG. After significant delay, the ISO Geodetic Registry was made publically available earlier this year, populated with an initial set of most global and regional reference frames and their associated transformations. Further population of the Registry continues and geodetic agencies are encouraged to submit their own reference frames and transformations. We describe the parameters required to be entered for such reference frames and transformations as well as the status of recent revisions to the defining standards IS 19111 and IS 19127.

B2.1-0034-18 TIME EVOLUTION OF THE SIRGAS REFERENCE FRAME

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Studying, understanding, and modelling geophysical phenomena, such as global change and geodynamics, require geodetic reference frames with (1) an order of accuracy higher than the magnitude of the effects we want to study, (2) consistency and reliability worldwide, and (3) a long-term stability. The definition, realisation and maintenance of the ITRS are oriented to guarantee a globally unified geometric reference frame (i.e., the ITRF) with reliability at the mm-level. The densification of the global ITRF in Latin America and The Caribbean is given by SIRGAS (Sistema de Referencia Geocentrico para Las Americas), primary objective of which is to provide the most precise coordinates in the region. At present, SIRGAS is the backbone for all regional projects based on the generation, use, and analysis of geo-referenced data at national as well as at international level. Besides providing the reference for a wide range of scientific applications such as the monitoring of Earth's crust deformations, vertical movements, sea level variations, atmospheric studies, etc., SIRGAS is also the platform for practical applications such as engineering projects, digital administration of geographical data, geospatial data infrastructures, etc. However, the reliability of SIRGAS as reference frame is being affected by the frequent occurrence of seismic events deforming the geometry of the network and by the omission of non-lineal station movements including systematic errors in epoch coordinates. In this context, this presentation summarises the main challenges faced currently

by SIRGAS: (1) A high-resolution monitoring of the reference frame deformation by means of more reference stations and improved analysis standards; (2) Co-seismic deformation models for the transformation of station positions between preand post-seismic frame realisations;

(3) Reliable modelling of non-lineal station movements in the reference frame computation to improve the estimation of epoch coordinates.

B2.1-0035-18 MASS AND MOTION TERMS OF ATMOSPHERIC AND OCEANIC ANGULAR MOMENTUM AND THEIR IMPACT ON GEODETIC HYDROLOGICAL EXCITATIONS

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The Earth's rotation is not constant over the time and these changes are observed both in terms of rotation speed and the orientation of the rotation axis. The determination of the Earth's rotation parameters is a very important challenge in present-day geodesy since they are the elements of the transformation matrix between celestial and terrestrial reference frames.

Here, we would like to focus on the changes in the orientation of the Earth's rotational axis in relation to the terrestrial reference frame known as the polar motion. The main conductor of non-tidal changes in the pole's coordinates is the time-depend variability of mass distribution in the geophysical surficial fluids: atmosphere, oceans and land hydrosphere.

The main method to determine the influence of the atmosphere and ocean on polar motion excitation is a computation of so-called Atmospheric Angular Momentum (AAM) and Oceanic Angular Momentum (OAM) functions. Nevertheless, the mass terms related to the air and ocean bottom pressure as well as motion terms reconnected with wind speed and ocean currents, vary from one model to another.

The choice of combination of atmospheric and oceanic models is essential for designation the hydrological signal in observed polar motion excitation provided by geodetic techniques (socalled geodetic residuals - GAO). This contribution is calculated as a difference between geodetic excitation (Geodetic Angular Momentum - GAM) and the sum of AAM and OAM. The discrepancies between observed polar motion variations and geophysical contributions appear more likely to be caused by the errors of the atmospheric, in particular of the motion term, and oceanic models.

Here, we would like to present the consistency of full polar motion excitation provided by geodetic measurements (GAM) with geophysical excitations that are the sum of AAM (pressure + wind) and OAM (bottom pressure + currents) contributions. To do this, we use several models of atmosphere and oceans. For determination of AAM we use the following models: NCEP/NCAR reanalysis model provided by the Sub-bureau for the Atmosphere of the Global

Geophysical Fluid Centre (GGFC), Effective Atmospheric Angular Momentum (EAAM) obtained from GeoForschungsZentrum (GFZ) and Atmospheric Angular Momentum (EAAM) obtained from the analysis of the European Centre for Medium-Range Weather Forecasts (ECMWF). Oceanic Angular Momentum is calculated here with the use of: ECCO kf079 and ECCO kf080 ocean models provided by Jet Propulsion Laboratory (JPL) as well as effective angular momentum functions (EAMF) of the ocean calculated from Max Planck Institute Ocean Model (MPIOM). An additional data set for our analyses are the time series of sea-level angular momentum function (SLAM) that reflect the impact of sea level mass balance and are provided by the GFZ.

In this study, we present the comparable analysis of mass and motion terms of Atmospheric and Oceanic Angular Momentum in terms of decadal, seasonal, and short term oscillations. The comparison of prograde and retrograde annual and semiannual oscillations is also included. These analyses could let us indicate, which components of different AAM and OAM models cause the biggest errors in the geodetic budget.

B2.1-0036-18 IMPROVING THE ACCURACY OF INTER-TECHNIQUE TIES AT CORE GEODETIC SITES THROUGH ESTIMATION STRATEGIES THAT EXPLOIT ATMOSPHERIC STRUCTURE

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Local ties between reference points of geodetic instruments at colocation sites are one of the limiting error sources in establishing a robust multi-technique terrestrial reference frame (TRF) suitable for geophysical applications having stringent accuracy requirements, such as global sealevel change. Generally, disagreement between local ties and space geodetic solutions is significantly larger than the formal uncertainties of the local surveys. We are investigating approaches that could improve the accuracy of relative positions obtained from geodetic techniques and their ties, and hence of TRF combinations. These approaches use external constraints based on local atmospheric structure at core geodetic sites where multi-techniques are co-located. This method considers known stochastic (i.e., turbulent) structure as well as systematic (e.g., fronts, gradients) atmospheric structure. The challenge is to add information to the geodetic solution based on our knowledge of atmospheric structure without biasing the estimates of the intersite vectors. We will present results from preliminary tests wherein atmospheric structure is used to enhance the strength of geodetic solutions and combinations.

B2.1-0037-18 MONITORING OF EARTH SURFACE DISPLACEMENTS USING INTEGRATED MULTI-GNSS, GRAVITY, SEISMIC, AND INSAR DATA IN THE FRAMEWORK OF GGOS-PL++

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The infrastructure of the Global Geodetic Observing System in Poland (GGOS-PL) is currently being extended in order to fulfill the goals of the EPOS-PL by providing the reliable geodetic reference frames. The project EPOS-PL, European Plate Observing System for Poland, was launched in January 2017 with the main objective of observing surface land deformations and seismicity affecting inhabitants, environment, infrastructure and buildings in two mining regions of Upper Silesia, south Poland. These regions are subjected to present or former intensive coal exploitation activities. EPOS-PL engages scientists and industry experts from various fields: geophysics, seismology, geodesy, mining, geology, geomagnetism, and gravimetry with a common goal of providing comprehensive and complementary information on the effects and possible causes of surface land deformations. EPOS-PL is founded by the National Centre for Research and Development in the Smart Growth Operational Programme 2014-2020.

The new GGOS-PL infrastructure includes multi-GNSS permanent stations, radiometers, tidal gravimeters, seismometers, and ground reflectors for synthetic aperture radar (SAR) observations. In total, eight new GNSS receivers will be installed; four of which will serve as reference receivers installed in stable areas and another four receivers in the area, where surface displacements are expected. The receivers will have the capability of tracking multi-GNSS signals which included six GNSS and RNSS systems: GPS, Galileo, GLONASS, BeiDou, SBAS, and QZSS with the possibility of 20Hz to 50Hz data recording.

The high-rate GNSS data shall be compared with seismic records for the integrated near realtime seismic wave detection. The seismic records will be confronted with signals recorded by tidal gravimeters. Two GNSS receivers will be supported by radiometers for integrated GNSS troposphere modelling. One reference GNSS receiver will additionally be supported with an external frequency standard realized by an atomic clock for future experiments with the clock parameter stability in multi-GNSS real-time Precise Point Positioning solutions. Finally, the surface mass displacements in long and medium timescales will be determined using SAR technique data and validated using results from multi-GNSS permanent stations. This paper will outline the concept of the integrated geophysical and geodetic monitoring of surface deformations and geodynamic processes as well as first results from the project.

B2.1-0038-18 SIMULATIONS OF VLBI OBSERVATIONS OF GEODETIC SATELLITES PROVIDING CO-LOCATION IN SPACE

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Precise knowledge of the terrestrial reference frame is essential in order to meet numerous existing and future science requirements for the study of the effects of, for example, tectonic motions, climate change, and sea-level rise. With the aim of improving space and time references on Earth, and the realization of a terrestrial reference frame accurate to 1 mm and a long-term stability of 1 mm in 10 years set by the Global Geodetic Observing System (GGOS), satellite missions have been proposed providing co-location in space, e.g., GRASP (Geodetic Reference Antenna in Space) to NASA and E-GRASP/Eratosthenes to ESA. Our VLBI group at the GFZ Potsdam has performed numerical simulations of observations of different satellites proposed to be equipped with a very long baseline interferometry (VLBI) transmitter, including GRASP, E-GRASP, and Galileo sub-constellation, in order to investigate how well the VLBI frame can be linked to the satellite frames under various observation scenarios. In addition to a simulation of standard VLBI observables, we also investigate the contribution to the solution of time of flight (TOF) information transmitted by the satellite VLBI frequency transmitters and received by the VLBI stations. Our simulations show that VLBI observations can meet the 1 mm and 1 mm/decade frame requirements as long as the observing VLBI network contains a large number of stations, many weeks per year are allocated to observing the spacecraft, and the VLBI and spacecraft techniques are independently able to reach the GGOS accuracy goals for their own frames.

B2.1-0039-18 EARTH ORIENTATION PARAMETERS ESTIMATED FROM K-BAND VLBA MEASUREMENTS

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The Earth Orientation Parameters (EOP) which connect the Terrestrial and Celestial Reference Frame are regularly estimated by Very Long Baseline Interferometry (VLBI). The UT1-UTC and nutation components of EOP can only be measured using the VLBI technique. Until now, published VLBI estimates of EOP were based solely on observations from the S/X frequency band. For the first time, we present VLBI estimates of EOP from an observing frequency independent of the traditional SX-band using Very Long Baseline Array (VLBA) measurements at K-band (24 GHz, 1.2 cm). By June 2018, we will have about 1.5 years of regular VLBA experiments conducted with telescopes located in U.S. territory. We investigate the potential of K-band VLBI to produce more accurate EOP because of its reduced source structure effects relative to SX-band. We will compare our K-band EOP S/X VLBA results and the IERS C04 data.

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B2.1-0040-18 CONSISTENT REALIZATION OF CRF, TRF, AND EOP

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The International Celestial Reference Frame (ICRF) and the International Terrestrial Reference Frame (ITRF) are the realizations of the International Celestial Reference System (ICRS) and the International Terrestrial Reference System (ITRS), respectively. The Earth orientation parameters (EOP) are the parameters linking these two frames, and they are common parameters between the space geodetic techniques whose observations are used to estimate the ICRF and ITRF. Both realizations have been computed separately based on different data sets and by fixing parameters corresponding to the other frame, respectively. This causes inconsistencies between the frames themselves but also between the EOP series resulting from the two computations even though they should be the same. To gain consistency between the two reference frames, a common adjustment is performed. This implies the usage of identical input data, a consistent parameterization and that no parameters are fixed. The realizations benefit in many ways: consistency of the frames and EOP is reached, poorly estimated parameters of one technique could be strengthened by information from the other techniques and consequently the quasar coordinates are improved. In this study, we simultaneously estimate the celestial and terrestrial reference frames together with the full set of EOP based on homogeneously processed GNSS, VLBI, and SLR data over a time period of 11 years (2005.0-2016.0). We present the impact of various combination setups for the EOP and for the local tie handling and discuss the benefits of a simultaneous estimation.

B2.1-0041-18 GEO-REFERENCING SYSTEM INDEPENDENT FROM GNSS SYSTEMS.

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A new system's geo-referencing from space is entirely free from any GNSS (GPS or equivalent) systems. The system addresses to various strategic and economic applications such as in remote clock synchronism, aircraft and balloon navigation, missile and smart bombs tracking, satellite orbital determination and remote target geo-positioning. The new geometry concept corresponds to an "inverted GPS" configuration, utilizing four ground-based reference stations, synchronized in time, installed at well known geodesic coordinates and a repeater in space, carried by an aircraft, balloon, satellite, etc. Signal transmitted by one of the reference bases is retransmitted by the transponder, received back by the four bases, producing four ranging measurements which are corrected for the time delays undergone in every retransmission. A minimization function was derived to compare the repeater's positions referred to at least two groups of three reference bases, to correct for the signal transit time at the repeater and propagation delays, and consequently to provide the accurate repeater position for each time interaction. Once the repeater's coordinates are known, the other determinations and applications become straightforward. The system solving algorithm and process performance has been demonstrated by simulations adopting a practical example with the transponder carried by an aircraft moving over bases and a target on the ground. Effects produced by reference clock synchronism uncertainties at the four bases on the measurements are reviewed.

B2.1-0042-18 VERY LONG ARC TIMING COEFFICIENT AND SOLAR LUNAR PLANETARY EPHEMERIS FILES AND APPLICATIONS

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Previously the Timing Coefficient (TCoeff) and the Solar Lunar Planetary (SLP) ephemeris file function-alities of the TRAMP program were ported to the Linux platform. We used the Linux TRAMP program to generate binary TCoeff and SLP files that allow the GTDS orbit propagation and orbit determination pro-grams to generate results that closely match GTDS results generated with TCoeff and SLP files received from the NASA Flight Dynamics Facility (FDF). The design of the Timing Coefficient file was updated to support arcs that are hundreds of years in length and associated software modifications to the TRAMP and GTDS programs were made. We demonstrated the extended format TCoeff and SLP files for an 110-year GPS orbit using both GTDS numerical integration and semi-analytical orbit propagator programs. These 110-year files employ the JPL DE 200 ephemeris file. The DE 200 file is referred to the dynamical equator and equinox of 2000. In the current work, we further extend the GTDS TCoeff and SLP files to cover the interval from 1973 to 2169: a total of 196 years. The 1973 start date is dictated by the availability of the time difference, polar motion, and EOP data in the modern format from the US. Naval Observatory. The 2169 end date is the end of the DE200 file. Subsequent JPL files such as DE 405 or later provide data referred to the International Celestial Reference Frame (ICRF). The ICRF files, while allowing even longer orbit propagation intervals, will require implementation of compatible integration coordinate systems in GTDS. We use exploratory data analysis techniques to develop statistical models for the errors in the TCoeff and SLP file representations for the A.1-UT1 time difference, the polar motion parameters, and the rotation matrix data. The Cumulative Distribution Function (CDF) plots are important to this analysis. A goal is to connect the statistical errors in the EOP representations with the deterministic errors observed in the orbit propagation results. Long arc orbital evolution using the 196-year files is investigated for several test cases: 1. GPS

2. EGP/Ajisai (modified to be near critical inclination) 3. High eccentricity test cases 4.

WT1190F Near Earth Asteroid case

B2.1-0043-18 METHOD RESEARCH AND ACCURACY ANALYSIS ON THE INTRA-TECHNIQUE COMBINATION FROM SPACE GEODETIC TECHNIQUES

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Precisely determined Terrestrial Reference Frame and the Earth Orientation Parameters independently in China has become the urgent needs in the precise orbit determination ,navigation, the exploration of deep space, the realization and application of the high-precision geodetic datum. Before the inter-technique combination of the space geodesy techniques, it needs to finish the intra-technique combination of different solutions from different analysis centers. Method researches on the intra-technique combination of weekly or 24-h session-wise solutions from various analysis centers for SLRhas been done. We described the intra-technique combination methods of ILRS. It mainly includes: the models of the intra-combinations, the realization of the datum definition or datum-free of the intra-combined TRF, the re-weighting of the solutions from the different analysis centers. Thenthe precision of the stations' coordinates and the EOP of the time series of the intra-technique solutions from ILRSwas estimated and the long-term characteristic of the datum definition of the underlying TRF was analyzed. From the perspective of datum definition, the translation of SLR intra-combined SINEX series w.r.t the ITRF2014 are of the longest time-span and has no significant bias of drift. While, the series of the GPS intra-combined weekly solutions have the smallest scatters in the translation w.r.t. the ITRF2014 but has drifts in Xand Y-translation and jumps in Z-translation, similar as the DORIS intra-combined solutions. From the perspective of the stations' precision, the distinguishment of the core and non-core stations is of great importance. Moreover, due to the good global distribution of GPS stations the EOP from GPS is more accurate than that from other techniques.

B2.1-0044-18 DENSE ITRF2014/IGS14 VELOCITIES FIELD OF POLAND BASED ON GNSS COMMERCIAL NETWORKS

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Coordinates velocities are becoming an important improvement of the accuracy of reference frame realization in Europe. Increase number of global navigation satellite system (GNSS) stations, and availability of long-term observations, caused that coordinates time series can be used to determine dense fields of velocities which should be an enhancement to the classical coordinates for all mapping agencies. In Poland there has been a sharp increase of the number of stations belonging to private companies since 2013. Currently, their number is almost 400. Most of stations are quipped with multi-GNSS receivers which allow the acquisition of observations from GPS, Galileo, GLONASS, and BDS satellites. Such high number of stations may be an alternative source of coordinates velocities which can be used for multiple task, such as dense velocities field determination, better realization of European reference frame in regional area, or local strain determination. The importance of having a dense velocities field is very clearly visible in such countries as Italy, Greece, or in Scandinavia region, where high movement of tectonic plate can be seen. However, even in relative stable part of Euroasian plate, the local stresses may occur. In this presentation we determine dense velocities field in Poland in global reference frame (ITRF2014/IGS14). We used daily GPS/GLONASS observations, from 1735 to 1982 GPS week, from almost 400 stations belonging to private companies. Our calculations were made using Bernese GNSS Software ver. 5.2 in relative (double differencing) and precise point positioning (PPP) mode. We present comprehensive analysis which relate to verification of availability and quality of observations, and identification of network errors and its impact on coordinates and velocities. All of these activities were aimed to determine velocities on the accuracy below ±0.3 mm/year. We also show analysis of accuracy and quality of obtained velocities field.

SPACE STUDIES OF THE EARTH-MOON SYSTEM, PLANETS, AND SMALL BODIES OF THE SOLAR SYSTEM (B)

LUNAR SCIENCE AND EXPLORATION (B3.1)

B3.1-0001-18 INTRODUCTION TO LUNAR SCIENCE AND EXPLORATION

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This session will address:

Recent lunar results: geochemistry, geophysics in the context of open planetary science and exploration

Synthesis of results from SMART-1, Kaguya, Chang'e 1, 2 and 3, Chandrayaan-1, LCROSS, LADEE, Lunar Reconnaissance Orbiter and, Artemis and GRAIL

Goals and Status of missions under preparation: orbiters, Luna-Glob, Google Lunar X Prize, Luna Resurs polar lander, SLIM, Chandrayaan2, Chang'E 4 and 5, Lunar Resource Prospector, Future landers, Lunar sample return missions

Precursor missions, instruments and investigations for landers, rovers, sample return, and human cis-lunar activities and human lunar surface sorties

Preparation for International Lunar Decade: databases, instruments, missions, terrestrial field campaigns, support studies

ILEWG and Global Exploration roadmaps towards a global robotic/human Moon village

Strategic Knowledge Gaps, and key science Goals relevant to Lunar Global Exploration

Lunar science and exploration are developing further with new and exciting missions being developed by China, the US, Japan, India, Russia, Korea and Europe, and with new stakeholders.

Space exploration builds on international collaboration. COSPAR and its ILEWG International Lunar Exploration Working Group (created in 1994) have fostered collaboration between lunar missions.

A flotilla of lunar orbiters has flown in the last international lunar decade (SMART-1, Kaguya, Chang'E 1 and 2, Chandrayaan-1, LCROSS, LRO, GRAIL, LADEE). Chinese Chang'E 3 lander and Yutu rover. Upcoming other landers from 2018 (GLXP, Chang'E 4 and 5, SLIM, Luna, LRP) will constitute a Robotic Village on the Moon.

B3.1-0002-18 SYNTHESIS OF RESULTS & PROSPECTS FROM LRO MISSION

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Since entering lunar orbit on June 23, 2009, the Lunar Reconnaissance Orbiter (LRO) has made comprehensive measurements of the Moon and its environment. The seven LRO instruments use a variety remote sensing techniques to obtain a unique set of observations. These measurements provide new information regarding the physical properties of the lunar surface, the lunar environment, and the location of volatiles and other resources. Scientific interpretation of these observations improves our understanding of the geologic history of the Moon, its current state, and what its history can tell us about the evolution of the solar system. Scientific results from LRO observations overturned existing paradigms and deepened our appreciation of the complex nature of our nearest neighbor. LRO has been in orbit for nine years, in that time it has been a witness and leader of a remarkable era of lunar science where a paradigm shift is taking place from the view of the Moon as a static planet to one with active processes on multiple scales. With ample fuel to remain in orbit (for up to eight more years) and a healthy suite of instruments and spacecraft systems, LRO is ready to continue uncovering and addressing key planetary science questions. In addition, LRO will support key exploration goals of NASA as well as assist in the planning and targeting of future missions to the Moon by governmental space agencies and commercial endeavors. In this presentation we will discuss recent results and describe the LRO created resources available to the community for planning lunar missions.

B3.1-0003-18 SYNTHESIS OF RESULTS FROM GRAIL MISSION

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The GRAIL Discovery mission was launched to the Moon on 10 September 2011 with the primary objective to map the lunar gravity field with unprecedented accuracy and resolution. The mission consisted of twin spacecraft inserted into lunar polar orbit on 31 December 2011 and 1 January 2012. GRAIL had two primary science objectives: (1) determine the structure of the lunar interior, from crust to core; and (2) advance understanding of the thermal evolution of the Moon. The fundamental measurement was spacecraft-to-spacecraft tracking of the velocity changes between the two spacecraft, from which models of the lunar gravity field were developed in spherical harmonic degree and order. By the end of the mission, the resolution of the field was degree and order 1800, with an effective global surface resolution of 3 - 5 km. The GRAIL lunar gravity field revealed features not previously resolved, including tectonic structures, volcanic landforms and intrusions, basin rings, crater central peaks, and abundant simple craters. From degrees 80 through 600, over 98% of the gravitational signature is associated with topography, a result that reflects the preservation of crater relief in highly fractured and homogenized crust. The remaining 1-2% represents fine details of subsurface structure not previously resolved. In addition to making scientific discoveries the GRAIL gravity models enabled significant improvement in the determination of spacecraft in lunar orbit, including the orbit of the Lunar Reconnaissance Orbiter, which was obtaining accurate topography of the Moon and was used in the interpretation of the gravity data.

B3.1-0004-18 CUBESATS TO THE MOON

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Overview: Cubesats, first successfully launched into Earth orbit just over a decade ago, are about to be launched into deep space. A disruptive technology initially made possible by advances in consumer electronics, cubesats (named by Bob Twiggs for the 10-centimeter cube size (1U) of the very first one) are spacecraft that combine several desirable attributes: compactness, rapid development, low cost, standardization of deployers, buses and interfaces, and a 'test by flying' risk posture not unlike that of the early space program. In fact, the very first cubesats designed with the goal of obtaining scientific data from another body will head for the Moon, after being deployed from the second stage of the NASA heavy lift launch vehicle (SLS) in 2019. Three of them will enter lunar orbit with the goal of increasing our knowledge of lunar volatiles, acting as the first de facto deep space cubesat cluster. Three in-ternational participants will also be deployed at that time: the ESA Equuleus radiation monitor, and JAXA Omotenashi impactor and ArgoMoon camera. Overcoming Challenges: Cubesats operating in deep space face challenges Earth-orbiting cubesats do not. Earth-orbiting cubesats required minimal resources and few active control systems: once deployed in an acceptable orbit (without the need for propulsion), they can utilize the Earth's magnetic or gravitational fields for attitude con-trol, GPS for navigation, and a simple UHF system (and prevalent ground stations) for communication. Deep space cubesats will be required to have the full functionality, and active control systems, of any spacecraft operating in deep space. MARCo, the 2018 demonstration of dual communication system at Mars, and the 13 diverse cubesats being deployed from SLS the following year, are effectively 'prototypes' for deep space cubesats. These are 6U cu-besats, larger than their typical Earth-orbiting counterparts (3U) to accommodate additional needs. Many of them will utilize the JPl Iris X-band radio and the DSN for communiciation, navigation, and tracking. Bandwidth is a limited resource and a variety of strategies are used to manage it. All of the cubesats have small propulsion units, adequate to get them into lunar orbit in the cases where that is needed (up to 1.5 km/sec DeltaV). Thermal engineer-ing has turned out to be a major challenge for those in orbit around the Moon, and much of the new work in cubesat design is going on in this area, as well as in the development of micro-cryocoolers, more compact versions of re-quired instruments and more capable micro-propulsion systems. Architectures and Roles: The cubesat technology attributes are particularly suitable for demonstrating and qualifying new technologies and new systems, and for multi-platform concepts. The first spatially and temporally distributed networks, created based on the cubesat paradigm, could study the dynamics of lunar and planetary envi-ronments in situ for less than the cost of a flagship mission. Such concepts have already been proposed. On the other hand, getting individual cubesats to remote targets with their own low impulse propulsion systems is time consuming and a major driver for the design and resource utilization. Using a 'carrier' to deliver a small swarm to a target and provide communication and tracking support would be ideal. Current science missions and measurements: Four of the cubesat missions to be deployed at the Moon have instruments for lunar surface/regolith measurements. Lunar Ice Cube, with its 1-4 micron broadband IR spectrometer, and LunIR, with its thermal IR spectrometer, were selected by the NASA HEOMD NextSTEP program to demonstrate a cubesat-scale instrument capable of addressing NASA HEOMD Strategic Knowledge Gaps related to lunar volatile distribution (abundance, location, and transportation physics of water ice), as well as, for Lunar Ice Cube, to demonstrate cubesat propulsion, via the Busek BIT 3 RF Ion engine. Lunar Flashlight was selected by HEOMD Advanced Exploration Systems to confirm the presence of surface ice at the lunar poles, utilizing an active source (laser), and looking for absorption features in the returning signal indicating the presence of surface ice. Lu-naHMap was selected for NASA SMD SIMPLEx program to characterize ice at or below the surface at the poles with a compact neutron spectrometer. In addition, the BIRCHES instrument on Lunar Ice Cube will provide the first demonstration of a microcryocooler (AIM/IRIS) in deep space. Although not originally required, all will be delivering science data to the Planetary Data System, the first formal archiving effort for cubesats. The future: As I write this abstract, interest in deep space cubesats escalates. The final reports of approximately 20 NASA-sponsored (PSDS3) studies for deep space cubesat/smallsat mission concepts, most involving 12U cu-besats, are about to be completed. These include 5 lunar mission concepts: BOLAS, MiLUV, Innovative Strategies for Lunar Surface Exploration CUBEx and WATER. NASA is about to release the SIMPLEX 2/SALMON 3 AO, creating ongoing opportunities for proposing cubesat/smallsat missions as 'rides' on government space program or private sector vehicles become available. Finally, several private sector contenders already have partnerships with NASA to provide transportation to the lunar surface or lunar orbit for small payloads before the end of the decade.

B3.1-0005-18 LUNAR METEOROID IMPACT OBSERVER: A CUBESAT AT EARTH-MOON L2

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The Lunar Meteoroid Impact Observer (LUMIO) is a CubeSat mission to observe, quantify, and characterise the meteoroid impacts by detecting their flashes on the lunar farside. This complements the knowledge gathered by Earth-based observations of the lunar nearside, thus synthesising a global information on the lunar meteoroid environment.

The mission utilises a CubeSat that carries the LUMIO-Cam, an optical instrument capable of detecting light flashes in the visible spectrum. On-board data processing is implemented to minimise data downlink, while still retaining relevant scientific data: only those images containing flashes are stored.

The mission implements a sophisticated orbit design: LUMIO is placed on a halo orbit about Earth-Moon L2 where permanent full-disk observation of the lunar farside is made. This prevents having background noise due to Earthshine, and thus permits obtaining high-quality scientific products. Repetitive operations are foreseen, the orbit being in near 2:1 resonance with the Moon orbit. Innovative full-disk optical autonomous navigation is proposed, and its performances are assessed and quantified.

The spacecraft is a 12U form-factor CubeSat, with <22 kg mass. Novel on-board micropropulsion system for orbital control, de-tumbling, and RW desaturation is used. Steady solar power generation is achieved with solar array drive assembly and eclipse-free orbit. Accurate pointing is performed by using reaction wheels, IMU, start trackers, and fine sun sensors. Communication with the Lunar Orbiter is done in UHF band. Advanced thermal coating and resistance heater for thermal control, as well as lightweight structure with radiation shielding are considered.

LUMIO is one of the two winner of ESA's LUCE (Lunar CubeSat for Exploration) SysNova competition, and as such it is being considered by ESA for implementation in the near future.

B3.1-0006-18 VMMO LUNAR VOLATILE AND MINERALOGY MAPPING 12U CUBESAT

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VMMO is a low-cost 12U Cubesat that is being designed for operation in a low-eccentricity lunar frozen orbit to enable both new science and supporting technology demonstration. It comprises two payloads; the LVMM Lunar Volatile and Mineralogy Mapper and the CLAIRE Compact LunAr Ionising Radiation Environment. The supporting 12U Cubesat bus accomodates dual ion and cold-gas propulsion, UHF communications to the potential SSTL Lunar Communications Pathfinder Orbiter, as well as direct to Earth X-band and optical communications, on board data processing and a suite of altitude and pointing sensors for semiautonomous navigation and mission operations. VMMO addresses the need for understanding the lunar near-surface distribution of relevant in-situ useable resources, such as ilmenite (FeTiO3), and volatiles, such as water/ice. This data is critical for the planning of future potential manned missions and sustained bases on the lunar surface. The compact LVMM is a multi-wavelength Chemical Lidar (<6.1 kg) using 3W fiber lasers emitting at 532 nm and 1560 nm for stand- off mapping of the lunar ice distribution using the active laser illumination, with a focus on the permanently-shadowed craters in the lunar south pole and detection of frosting during the lunar night. This combination of spectral measurement channels can provide very sensitive discrimination of water/ice in various Mare and Highland regolith. The associated fiber-laser technology has heritage in the ongoing MPBC Fiber Sensor Demonstrator flying on ESA's Proba-2 spacecraft. LVMM can also be used in a low-power passive mode to map the lunar mineralogy and ilmenite in-situ resource distribution during the lunar day using the surfacereflected solar illumination. This configuration includes a 280 nm UV channel to enhance the ilmenite discrimination. The CLAIRE payload (0.5 kg) is designed to provide a minimum impact, highly miniaturized radiation environment and effect monitor, suitable for CubeSat operation in cis-lunar space. The payload draws on heritage from the MuREM and RM payloads, flown on the UK's TDS-1 spacecraft launched in 2014. The payload includes PIN-diode sensors to measure ionizing particle fluxes (protons and heavy-ions) and to record the resulting linear energy transfer (LET) energy-deposition spectra. It also includes solid-state RADFET dosimeters, to measure accumulated ionizing dose, and dose-rate diode detectors, designed to respond to a Coronal Mass Ejection (CME) or Solar Particle Event (SPE). The CLAIRE payload also includes an electronic component test board, capable of measuring SEEs and TID effects in a selected set of candidate electronics. Thus, direct correlations can be drawn between effects and the real measured environment. This will assist the TRL advancemnet of critical

COTS components (FPGAs, RAM, A/Ds) for beyond-LEO space applications. This paper provides an overview of the ongoing VMMO mission development and some of the supporting relevant lab predevelopment.

Acknowledgements

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B3.1-0007-18 POLAR REGIONS ON THE MOON AS LOCATIONS FOR FUTURE OUTPOSTS

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Results of lunar polar surface analysis, focused on searching for the best potential outpost locations for the future robotic and manned scientific and exploration missions, are presented. Data from LEND [1], LOLA [2], Diviner [3] and LROC [4] instruments are taken into account. The method of spatial analysis initially developed for Luna-25 landing site selection [5] was used to identify possible location candidates, and multi-parameter prioritization was performed to determine the best of them. Several location candidates are described in details, with the main characteristics of their environment presented.

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B3.1-0008-18 LUNAR SURFACE HYDRATION CONSTRAINED BY LADEE'S OBSERVATIONS OF EXOSPHERIC WATER

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It has long been thought that the Moon was dry upon its formation and therefore devoid of native water. Recent observations suggest that water from external sources may be extensive on the lunar surface. Here, we report the first detection of signatures of near-surface water released into the lunar exosphere using observations collected by the Neutral Mass Spectrometer onboard the Lunar Atmosphere and Dust Environment Explorer spacecraft during its 8 monthlong mission. The water signatures were measured as 736 distinct episodic, short-lived signal increases above the instrument background level of 5 cm^{-3}. The most intense event was recorded with a magnitude of 600 cm^{-3}. An analytical description of the behavior of the instrument when subjected to exospheric water reveals that these fluctuations in instrument background capture variations of the underlying source of water released into the exosphere. Our study shows that the intensity and frequency of these water events are correlated with the Moon's encounter with known intense meteoroid streams. These fluctuations carry information on both the nature of the meteoroids that triggered the water release into the exosphere and the nature of the reservoir that was sequestering the water beforehand. In order to shed light on the nature of the water reservoir, we use a Monte Carlo model to simulate the evolution of released water produced by the impact of meteoroids on the surface of the Moon. The model shows that the signatures detected by the NMS instrument are commensurate in size and distribution with vapors released from shallow depths in the lunar soil by impacts that occurred at various distances from the spacecraft. Using this model, information about water concentrations in the lunar soil and its variation with depth were inferred by comparing the distribution of the intensity of the observed water events against the distribution that would result from a given impactor flux distribution.

B3.1-0011-18 NASA'S MOON TREK: EXTENDING CAPABILITIES FOR LUNAR MAPPING AND MODELING

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NASA's Moon Trek (https://moontrek.jpl.nasa.gov) is the successor to and replacement for NASA's Lunar Mapping and Modeling Portal (LMMP). Released in 2017, Moon Trek features a new interface with improved ways to access, visualize, and analyze data. Moon Trek provides a web-based Portal and a suite of interactive visualization and analysis tools to enable mission planners, lunar scientists, and engineers to access mapped lunar data products from past and current lunar missions. This presentation will provide an overview of the uses and capabilities of NASA's Moon Trek online mapping and modeling portal, and describe recent enhancements to the portal. Moon Trek provides a suite of interactive tools that incorporate observations from past and current lunar missions, creating a comprehensive lunar research Web portal. The online Web portal allows anyone with access to a computer to search through and view a vast number of lunar images and other digital products. The portal provides easy-to-use tools for browsing, data layering and feature search, including de-tailed information on the source of each assembled data product and links to NASA's Planetary Data System. Interactive maps, include the ability to overlay a growing range of data sets including topography, mineralogy, abundance of elements and geology. Originally designed for mission planning, Moon Trek also addresses the lunar science community, the lunar commercial community, education and out-reach, and anyone else interested in accessing or utilizing lunar data. Its visualization and analysis tools allow users to measure the diameters, heights and depths of surface features, perform analyses such as lighting and local hazard assessments including slope, surface roughness and crater/boulder distribution. Moon Trek features a generalized suite of tools facilitating a wide range of activities including the planning, design, development, test and operations associated with lunar sortie missions; robotic (and potentially crewed) operations on the surface; planning tasks in the areas of landing site evaluation and selection; design and placement of landers and other stationary assets; design of rovers and other mobile assets; developing terrain-relative navigation (TRN) capabilities; deorbit/impact site visualization; and assessment and planning of science traverses. Significant advantages are afforded by Moon Trek's features facilitating collaboration among members of distributed teams. Team members can share visualizations and add new data to be shared either with the entire Moon Trek community or only with members of their own team. Sharing of multi-layered visualizations is made easy with the ability to create and send URL-encoded visualization links. Moon Trek is also a powerful tool for education and outreach, as is exemplified by its being designated as key supporting infrastructure for NASA Science Mission Directorate's STEM Activation Initiative, and its serving of data to a growing community of digital planetariums. Developed at NASA's Jet Propulsion Laboratory (JPL) and managed as a project of NASA's Solar System Exploration Research Virtual Institute (SSERVI) at NASA Ames Research Center, Moon Trek is a browser-based web portal. There is nothing additional to buy or install. New tools have been added to facilitate traverse path planning, surface potential analysis, and laser retroreflector studies. A new pipeline to the PDS is facilitating the creation of NAC mosaics and NAC stereo pair DEMs. The Moon Trek interface provides enhanced 3D visualization and navigation. Standard keyboard controls allow the user to maneuver a first-person visualization of "flying" across the surface of the Moon. User-specified bounding boxes can be used to generate STL and/or OBJ files to create physical models of surface features with 3D printers. This interface has become the standard across all of the existing and upcoming Trek products including the portals for Mars, Phobos, Vesta, Titan and more.

B3.1-0012-18 TRANSFORMATIVE LUNAR SCIENCE

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The foundation of Apollo and Luna programs implemented 50 years ago combined with more recent results from the renaissance of international lunar exploration over the last 15 years has provided humanity a deeper and more intimate view of the Moon. It has also opened enormous opportunity for accomplishing Transformative Lunar Science (TLS) which are the next major breakthroughs in understanding the origin and early habitability of our Earth-Moon system as well as fundamental constraints on events that control the evolution of our Solar System. A few examples of TLS topics include: a) Establish the period of early giant planet migration and its effects in our Solar System, b) Provide an absolute chronology for Solar System events over 4 billion years, c) Understand and utilize the recently recognized water cycle of the Moon and other airless bodies, d) Characterize the Moon's interior to reveal how this differentiated cousin of Earth formed and evolved, e) Use the accessible vantage from the lunar farside to view the universe, f) Evaluate the extended record of space weather and fundamental processes of plasma interactions with surfaces. As human/robotic partnerships are developed further for space exploration, the next era of significant lunar exploration is a broad international undertaking, including commercial involvement. An enabling element for such Transformative Lunar Science is joint development of a stable infrastructure for efficient integrated activities.

B3.1-0013-18 THE FUTURE OF LUNAR SCIENCE AT NASA

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The future is bright for lunar science. In the last decade, enormous advances have been made in our understanding of the Moon, enabled by several successful orbital missions (LRO, LADEE, GRAIL, Chandrayaan-1, Kaguya, ARTIMIS), as well as continued efforts with samples and through laboratory studies and modeling. This work has answered some of our questions, and given us some new questions, but most of all, has allowed us to better refine our lunar science goals and placed us in a strong position to take maximum advantage of the next era of lunar exploration. While there is still room for additional progress to be made from orbital missions, the advancement of many of our science goals now requires landed missions. In parallel to our science efforts, a number of commercial companies, spurred on in part by the Google Lunar X-Prize, have been working towards developing lunar lander capabilities. These capabilities, along with international partnerships, opens up a new trade space of opportunities for lunar science and we are well poised to take advantage. NASA is creating a new Lunar Discovery and Exploration program that will develop instruments and other payloads for missions to the lunar surface. In partnership with industry, the international community, and other NASA organizations, science will lead the way as the agency prepares for a sustained program of lunar exploration.

B3.1-0014-18 RESOURCE PROSPECTOR: EVALUATING THE ISRU POTENTIAL OF THE LUNAR POLES

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Resource Prospector (RP) is a lunar volatiles prospecting mission currently in development for potential flight as early as CY2022. The mission includes a rover-borne payload that (1) can locate surface and near-subsurface volatiles, (2) excavate and analyze samples of the volatilebearing regolith, and (3) demonstrate the form, extractability and usefulness of the materials. The primary mission goal for RP is to evaluate the In-Situ Resource Utilization (ISRU) potential of the lunar poles.

Mission Goals: While it is now understood that lunar water and other volatiles have a much greater extent of distribution, possible forms, and concentrations than previously believed, to fully understand how viable these volatiles are as a resource to support human exploration of the solar system, the distribution and form needs to be understood at a "human" scale. That is, the "ore body" must be better understood at the scales it would be worked before it can be evaluated as a potential architectural element within any evolvable lunar or Mars campaign. To this end the primary mission goals for RP are to: (1) Provide enough information to allow for the next step: e.g., targeted survey, excavation and pilot processing plant demonstration; (2) Provide ground truth for models and orbital data sets, including: temperatures at small scales, subsurface temperatures and regolith densities; surface hydration; hazards (rocks and slopes).

(3) Correlate surface environments and volatiles with orbital data sets to allow for better prediction of resource potential using orbital data sets. (4) Address key hypotheses regarding polar volatile sources and sinks, retention and distribution, key to developing economic models and identifying excavation sites.

To address the viability/economics of lunar ISRU the volatile distribution (concentration, including lateral and vertical extent and variability), volatile form (H2, OH, H2O, CO2, ice vs bound, etc.), and accessibility, including overburden, soil mechanics, and trafficability, must be understood. To this end RP will assess the hydrogen and water distribution across several relevant environments that can be extended to a more regional and global assessment. Currently these environments are defined by their thermal character: (a) Dry: Temperatures in the top meter expected to be too warm for ice to be stable; (b) Deep: Ice expected to be stable between 50-100 cm of the surface; (c) Shallow: Ice expected to be stable within 50 cm of surface; (d) Surface: Ice expected to be stable at the surface (i.e., within a Permanently Shadowed Region, PSR).

Real-time Prospecting and Combined Instrument Measurements: Given the relatively short planned duration of this lunar mission, prospecting for sites of interest needs to occur in near real-time. The two prospecting instruments are the Neutron Spectrometer System (NSS) and the NIR Volatile Spectrometer System (NIRVSS). NSS will be used to sense waterequivalent hydrogen at concentrations as low as 0.5 wt% to a depth of approximately 80-100 cm. This instrument is the principle instrument for identifying buried hydrogen-bearing materials. NIRVSS, which includes its own calibrated light source, radiometer (for thermal correction and surface temperature measurements) and multicolor context camera, will look at surface reflectance for signatures of bound H2O/OH and general mineralogy. Once an area of interest is identified by the prospecting instruments the option to map the area in more detail (an Area of Interest activity) and/or sub-surface extraction via drilling is considered. The RP drill, The Regolith and Ice Drill for Exploration of New Terrain (TRIDENT), is an auger which can sample from discrete depths using "biting" flutes, deep flutes with shallow pitch which hold material as the drill is extracted. As the drill is extracted a brush can deposit cuttings from the biting flutes to the surface in view of NIRVSS for a "quick assay" of the materials for water or other volatiles. If this quick assay shows indications of water or other volatiles, a regolith sample may be extracted for processing. Processing of the sample is performed by the Water

Analysis by Volatile Extraction system (WAVE). WAVE consists of a sealed oven to heat the sample first to 150°C, pause, then to 450°C. Any gases evolved from the sample are analyzed by a Gas Chromatograph/Mass Spectrometer system. This talk will provide an overview of the RP mission with an emphasis on mission goals and measurements, and will provide an update as to its current status.

B3.1-0015-18 THE DUST ENVIRONMENT OF THE MOON

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The Moon, as all other airless bodies in the solar system, is continually bombarded by interplanetary dust particles, and is also immersed in the solar wind plasma flow and UV radiation. There are several controversial observations from the Apollo era that can now be revisited due to new spacecraft data, and recent dedicated laboratory experiments. Hypervelocity dust impacts generate secondary dust ejecta particles, neutral and ionized gases, sustaining the recently discovered, permanently present dust cloud engulfing the moon, and contributing to the production of the dilute lunar atmosphere and ionosphere. UV and plasma exposure results in the electrostatic charging of the lunar regolith, that can lead to the mobilization, transport, and large-scale redistribution of the lunar fines. We focus on the recent results of in situ observations, as well as the latest laboratory results, a combination which resulted in a much improved understanding of the lunar dust environment.

This talk will summarize the LADEE/LDEX results identifying the permanently present and intermittently enhanced lunar dust ejecta cloud that is sustained by the continual bombardment by interplanetary dust particles originating form the sporadic background population, as well as the meteoroid streams. The measurements indicate no electrostatically lofted high-altitude dust density enhancements over the terminator regions, as was anticipated due to possible dust charging and strong electric fields in this region. However, there is strong supporting evidence for efficient dust mobilization and transport near the surface, due to electrostatic effects a process that is likely to be responsible to be responsible for the observed dust ponding on asteroids, and its full effect is yet to be investigated for the lunar surface.

B3.1-0016-18 HIGHLIGHTS OF SCIENCE AND EXPLORATION ACTIVITIES AT THE SSERVI TREX NODE

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The Toolbox for Research and Exploration (TREX) is a NASA SSERVI (Solar System Exploration Research Virtual Institute) node. TREX (trex.psi.edu) aims to decrease risk to future missions, specifically to the Moon, the Martian moons, and near-Earth asteroids, by improving mission success and assuring the safety of astronauts, their instruments, and spacecraft. TREX studies focus on characteristics of the fine grains that cover the surfaces of these target bodies their spectral characteristics and the potential resources (such as H2O) they may harbor. TREX also places an emphasis on ultraviolet measurements, in addition to visible and nearand mid-infrared studies, for thorough compositional analyses.

TREX studies are grouped into four Themes: lab studies, Moon studies, small bodies studies, and field work. The tasks and products of each Theme within TREX are connected. The Laboratory Studies Theme's products are inputs to the photometric and spectral studies of the Small Bodies and Moon Themes. The laboratory data will be used to validate models and as direct inputs for modeling spacecraft observations of surfaces. The models and lab data are inputs to the Field Studies Theme for use in creating autonomous decision-making software packages.

The TREX spectral library focuses on fine-grained (<10 micron) planetary materials measured over ultraviolet, visible/near-infrared, and mid-infrared (UV-VNIR-MIR) wavelengths under environmental conditions that mimic the surfaces of the airless targets (in vacuum, when possible, and at various temperatures). This library will be invaluable in interpreting spacecraft data (e.g. for the Moon and small bodies Themes) and will be made available to the larger community as well. Furthermore, the spectral library will be ingested into software used in autonomous sample selection in the TREX fieldwork. The lab measurements include a range of pure terrestrial minerals (including 6 samples previously measured in other SSERVI labs, for cross-correlations), lunar samples and meteorites, along with mineral mixtures and ice-mineral mixtures. A goal of performing measurements in a suite of labs is to harness both unique and overlapping capabilities to derive a robust set of cross-calibrated laboratory spectra. TREX labs are at PSI (Tucson), Univ. Colorado, Univ. Winnipeg, DLR, NASA/JSC, Univ. Illinois and Mount Holyoke.

The Moon is a primary focus of TREX studies, as the only Solar System body humans have visited, and a likely future human destination. TREX lunar investigations combine the lab measurements acquired under lunar conditions with lunar spacecraft data and modeling techniques to characterize particle size, mineralogy, thermal attributes, space weathering effects, and correlations with geologic features. The overarching goals of the lunar studies are to expand our understanding of the Moon scientifically and as a target for future human and robotic exploration, and to address ISRU and future instrument development needs. The TREX Small Bodies Theme delves into several topics, including photometry, spectral modeling, laboratory simulations of space weathering processes relevant to asteroids, the assembly of an asteroid regolith database, the dichotomy between nuclear and reflectance spectroscopy, and the dynamical evolution of asteroids and the implications for the retention of volatiles.

TREX field work focuses on improving science yield by delegating mission planning, data collection, analysis, and decision-making to an automated robotic explorer. The objectives of our field investigations are to test the accuracy of our autonomous selection software and UV field spectrometer, and to compare the science yield of current robotic exploration strategies with that of the semi-autonomous robotic exploration system. Fieldwork will be performed at small body analog sites containing fine-grained materials analogous to those expected on asteroids and the Moon. Two locations have been chosen: the Palouse glacial loess site in Washington and the phyllosilicate-bearing Hopi Volcanic Field in Arizona. Multiple instruments will be used during the field campaigns, including three spectrometers (UV, VNIR, FTIR), a gamma ray / neutron spectrometer with active interrogation (GNS), and a Raman spectrometer. These data (UV, XRD, GNS, and VNIR) will be the inputs for our Tetracorder autonomous decision making. The mineral and elemental data will provide a complete picture of the physical and chemical mineralogy of the surface.

TREX is based at the Planetary Science Institute. Roughly two-thirds of TREX scientists are with PSI, distributed at locations across the country and Europe, with co-investigators and collaborators at NASA/GSFC, NASA/JSC, Columbia Univ., Carnegie Mellon, LPI, Univ. Colorado, Univ. Winnipeg, Univ. Illinois, DLR and Smithsonian Institution: TREX thus represents a truly virtual team.

B3.1-0017-18 NARROWBAND ION CYCLOTRON WAVES IN THE EARTH'S MAGNETOTAIL OBSERVED BY MOON-ORBITING ARTEMIS SPACECRAFT

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Analysis based on Apollo surface magnetometer data has shown that narrowband ion cyclotron waves are often observed on the lunar surface when the Moon is in the Earth's magnetotail. The proposed generation mechanisms of these narrowband waves still require further confirmation by observations. This paper presents results based on ARTEMIS field and particle observations near the Moon and when the Moon is in the magnetotail. We find that the characteristics of narrowband waves near the ion cyclotron frequencies can be divided into three types: (1) Left-handed polarized waves in the plasma sheet; (2) Left-handed polarized waves outside the plasma sheet; (3) Right-handed polarized waves in the plasma sheet boundary layer. In Type 1 wave events, the ion velocity distribution shows a clear depletion in the direction toward the Moon, indicating that the Moon absorbs most ions traveling to it. The resulting temperature anisotropy is subject to ion cyclotron wave growth. In Type 2 events, the observed ion velocity distribution does not present a clear temperature anisotropy. Although spacecraft measurements of ions cannot confirm the mechanism of wave generation, it is possible that waves are generated elsewhere and propagate to the spacecraft. Type 3 waves are not evident in the Apollo surface magnetometer data examined in our previous study, but they resemble the right-handed waves observed by ISEE 3 and Geotail spacecraft in the distant magnetotail. These waves are generated through a resonant interaction with the ion beam in the plasma sheet boundary layer. This paper also discussed WHAMP analysis of wave excitation, the possible role of pickup ions in generating Type 2 waves, and the comparison with recent results of narrowband ion cyclotron waves based on Kaguya and Geotail observations.

B3.1-0018-18 FUTURE LOW-COST LUNAR AND PLANETARY MISSIONS ENABLED BY COMMERCIAL SPACE COMPANIES

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Introduction: Science missions to the Moon need not be seen as rare and expensive opportunities. Affordable, repeated access to lunar orbit and/or the lunar surface is being made possible by innovations by commercial space companies. Moon Express' vision is to open the lunar frontier with turn-key payload, data and services for missions to the Moon for a wide range of customers globally, including governments, NGO's, commercial enterprises, universities, and consumers. Like the Earth, the Moon has been enriched with vast resources through billions of years of bombardment by asteroids and comets. Unlike the Earth, these resources are largely on or near the lunar surface, and therefore relatively accessible. Moon Express is blazing a trail to the Moon to seek and harvest these resources to support a new space renaissance, where economic trade between countries will eventually become trade between worlds. All Moon Express expeditions will prospect for materials on the Moon as candidates for economic development and in-situ resource utilization.

One of the greatest practical space discoveries of our generation is the presence of vast quantities of water on the Moon. Water not only supports life but its constituents, hydrogen and oxygen, are energetic and clean rocket fuel. The discovery of water on the Moon is a game changer, not just for the economic viability of lunar resources, but for the economics of humans reaching Mars and other deep space destinations. Water is the oil of the solar system, and the Moon can become a gas station in the sky to fuel human space exploration, development and settlement of the solar system. Moon Express will begin prospecting for water resources on the Moon with its very first expedition.

The MX family of spacecraft: Moon Express has developed a family of flexible, scalable robotic explorers that can reach the Moon and other solar system destinations from Earth orbit. The MX spacecraft architecture supports multiple applications, including delivery of scientific and commercial payloads to the Moon at low cost using a rideshare model, or charter science or commercial expeditions to distant worlds.

The MX robotic explorer spacecraft are optimized for launch on existing and emergent rocket systems. The payload masses quoted below assume no launcher constraints. MX-1: A single stage spacecraft capable of delivering up to 30kg to the lunar surface. MX-2: A dual-stage spacecraft that doubles the capability of the MX-1 and can reach the moons of Mars. MX-5: A cis-lunar workhorse spacecraft that can deliver up to 150kg to lunar orbit or 50kg to the surface. MX-9: A lunar prospector/harvester that can deliver up to 500kg to the lunar surface, including an embedded MX-1R spacecraft that can launch from the lunar surface and return lunar samples to Earth. The MX spacecraft architecture supports multiple applications, including delivery of scientific and commercial payloads to the Moon at low cost using a rideshare model, or charter science expeditions to distant worlds. Designed for Scout Class exploration capabilities starting from low Earth orbit, MX-1 delivers flexibility and performance to revolutionize access to the Moon and cis-lunar space.

Dual stage flexibility drives more payload to the lunar surface or extends the reach to deep space. Compatible with existing and emergent launch vehicles, the MX-2 delivers Scout Class possibilities for exploration and commerce at low cost.

Designed as a workhorse that can deliver 150kg to low lunar orbit from low Earth orbit, with a range of configurations to support lunar landing and cis-lunar operations, the MX-5 can also be outfitted with MX-1 or MX-2 staged systems that can bring the entire solar system within reach. Available in orbiter, lander, deep space probe and sample return configurations.

Designed for Frontier Class exploration capabilities, MX-9 will support robust lunar sample return operations. Like it's MX-5 little brother, the MX-9 can also be outfitted with MX-1 or MX-2 staged systems that can deliver over 10kms V and extend its reach to span the solar system, and beyond.

Currently-Planned Lunar Missions: Our first expedition will utilize our MX-1E robotic explorer to deliver a diverse manifest of scientific and commercial payloads to the lunar surface. Our customers for this mission include the International Lunar Observatory Association, the University of Maryland, The National Laboratories of Frascati, Celestis and Google. Following our initial "Lunar Scout" expedition next year, we will offer payload accommodations on future voyages, planned at the rate of one per year. But we can also scale up and increase the frequency of our lunar flights to meet market demand and opportunity. Our second expedition in 2020, "Lunar Out-post", will enable the first commercial presence and exploration of the lunar South Pole. It may in fact be the first-ever soft-landing at a lunar pole. The primary goals of this mission are to set up the first lunar research outpost at a "peak of eternal light", prospect for water and useful minerals, and accommodate a variety of research instruments for our expedition partners. Our third expedition, "Harvest Moon", will take place by 2021 and includes the first commercial sample return, beginning our business phase of lunar resource prospecting and harvesting. The samples brought back will be the only privately obtained lunar materials on Earth, and will be used to benefit science as well as commercial purposes.

Collapsing the cost of lunar missions: The paradigm of what it takes to fly a lunar mission has begun to shift. Launch costs are rapidly decreasing with emerging commercial launch providers.

Commercial operators can reduce the cost of orbiters and landers by re-using designs and by innovating in ways that national space agencies are not mandated to do.

Although the current architectures for Moon Express missions involve going from Low Earth Orbit directly to Lunar orbit, then Lunar surface, or to other destinations in the solar system, integrating the MX family spacecraft into an architecture that involves the Deep Space Gateway presents new and exciting opportunities for science and for cis-lunar operations in general.

Mission concepts that assume that the DSG is available as a hub of operations in Lunar orbit can enable much larger landed masses on the lunar surface and/or continuous shuttle service for assets on the surface or for returned samples to DSG. The Deep Space Gateway can also be a starting point for repeat robotic science and exploration missions to Mars or its moons, or to other solar system destinations. One could imagine scenarios in which refuelling of MX spacecraft could occur at DSG.

Moon Express has been able to collapse the cost of Lunar missions, and the incorporation of DSG into mission scenarios enable even lower mission costs with a workhorse for small payloads to and from the surface of the Moon, and from the Deep Space Gateway itself.

B3.1-0019-18 ALPHA PARTICLE X-RAY SPECTROMETER ONBOARD CHANDRAYAAN2 ROVER

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Alpha Particle X-ray Spectrometer (APXS) is a well proven instrument for quantitative elemental analysis of the planetary surface through in-situ measurements. This technique involves measurement of X-ray fluorescence by irradiating the lunar surface with Alpha particles and X-rays using radioactive sources. The proposed landing site for Chandrayaan-2 lander is in the high latitude region in the southern hemisphere, which provides the first opportunity to explore the lunar surface with in-situ measurements. The objective of the APXS experiment is to analyze several soil/rock samples along the rover path. The plan is to image the Moon samples to be measured using navigation and imaging cameras onboard rover and traverse the rover towards the sample to carry out the fluorescence measurement. APXS uses Cm-244 radioactive alpha source which emits both Alphas and X-rays. The energy of alpha particle is 5.8 MeV and the energy of X-rays are 14.3 keV and 18.4 keV. It is well known that the PIXE is dominant for low Z elements while XRF is more prominent for high Z elements, allowing the determination of elements from Na to Br, spanning the energy range of 0.9 to 25 keV, for the K X-rays. We use six alpha sources, each with activity of 5 mCi (total activity of 30 mCi). The

Flight Model (FM) of the APXS payload has been completed and tested for various instrument parameters. The design details and the performance of the APXS instrument will be presented in the conference.

B3.1-0020-18 OLIVINE RICH EXPOSURES IN THE GRIMLADI BASIN ON THE NEARSIDE OF THE MOON: IMPLICATIONS FOR LUNAR ENDOGENIC PROCESSES

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Lunar magma ocean hypothesis suggests that the Moon was completely molten immediately after its accretion. As the magma ocean crystallized, anorthosite and cumulate pile of denser mafic minerals were formed as products of differentiated magma. Olivine is the primary mafic mineral crystallized in the early stages of magma evolution and represents a significant component of the lunar mantle. Detection of olivine on the lunar surface indicates the exposures of such deep seated materials. The deep seated rocks and minerals provide information on lunar interior. We investigated the Grimaldi basin (50S, 680W, on the western limb of the lunar nearside region and Pre-Nectarian in age) for the distribution and geological context of olivine exposures in the basin. This basin has been selected as it is located in the region where the crust is relatively thin. Crustally thinner regions on Moon are potential areas for the exploration of dense mafic mineral assemblages. Pure anorthosite on the peak ring, noritic anorthosite, anorthosotic norite and few occurences of gabbro have been previously reported in the basin using telescopic spectral measurements (Spudis et al., 1195, Geophys. Res. Lett., v. 22:3055-3058). Hyperspectral images from HySI and M3 (Moon Mineralogy Mapper) and high resolution panchromatic images from TMC and LROC have been utilized for the mineralogical and morphological analyses. Olivine with diagnostic triplet absorption bands at 0.85µm, 1.05µm and 1.25µm in NIR spectra have been identified at 68 locations within the basin; several of them are new areas of discovery. The olivine rich exposures have mostly been found to be occurring on the walls (locally on slumped walls) and rims of the fresh impact craters located on the concentric inner rings of the multi-ring impact basin while few occurrences are located on the sloped area of peaks within the basin. Orthopyroxene rich materials have also been exposed in association with olivine rich exposures. At two locations, olivine is associated with crystalline plagioclase on the crater wall indicating a crustal unit of pure anorthosite. Fe-Mg spinel has been detected in mature surfaces of outer facies of Havelius formation in the basin as well as on the sloped wall of impact craters and peaks. Fe-Mg spinel has also been found to be coexisting with the olivine rich sites on the crater walls. In addition to the olivine dominating spectra, olivine bearing Mare basalts as well as olivine rich localized pyroclastic deposits are also present in the basin. However, spectra from these areas exhibit a mixture of olivine and pyroxene, defined by the absorption features near 2µm in association with the 1µm band. The spectra of olivine exposed in peak ring craters don't exhibit the 2m band corresponding to the presence of Fe2+ in M2 site. Therefore, it can be inferred that olivine exposures concentrated in the peak ring craters of the basin represent deep seated material. The peak rings of the basin is believed to be formed by the upliftment of deep seated materials due to elastic rebound followed by the impact event. Subsequent impact cratering on the peak rings would have exposed these deep seated suites of rocks comprising olivine rich materials. Spectral modelling of the HySI and M3 data to determine the abundance and Mg no. of olivine would be done in future. These aspects undoubtedly will address the possible sources and origin of olivine and the nature of endogenic processes operated in the basin.

B3.1-0021-18 APPLYING MODERN ANALYTICAL TECHNIQUES TO THE APOLLO SAMPLES: A POTENTIAL MODEL FOR FUTURE SAMPLE RETURN MISSIONS

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Background: From 1969-1972 the Apollo missions collected 382 kg of lunar samples from six distinct locations on the Moon. Studies of the Apollo sample suite have shaped our understanding of the formation and early evolution of the Earth-Moon system, and have had important implications for studies of the other terrestrial planets (e.g., through the calibration of the crater counting record). Despite nearly 50 years of research on Apollo samples, scientists are still developing new theories about the origin and evolution of the Moon. In order to resolve these questions, scientists need access to new lunar samples, particularly new plutonic samples. Although no new large plutonic samples (i.e., hand-samples) remain to be discovered in the Apollo sample collection, there are many large polymict breccias in the Apollo collection containing relatively large (1 cm or larger) previously identified plutonic clasts, as well as a large number of unclassified lithic clasts. In addition, new, previously unidentified plutonic clasts are potentially discoverable within these breccias. The question becomes how to non-destructively locate and identify new lithic clasts of interest while minimizing the contamination and physical degradation of the samples. Results: The solution to the identification of new clasts within the Apollo samples while still keeping the samples pristine is micro-computed X-ray tomography (micro-XCT). The technique uses high energy X-rays (typically 180-320 kV) to make 3-dimensional images of a sample. These images highlight materials with different X-ray attenuation values, which are determined by the density and composition of the materials. Thus, lithic clast materials can be differentiated from the breccia matrix, and different types of lithic clasts can often be differentiated from each other [1-3]. The scans can also be used to estimate the volume and mass of clasts, which is useful in determining which studies they are most suited for. The high-energy nature of the x-rays allow for scanning of relatively large samples (up to 15 cm) while triply bagged in Teflon containing a dry-nitrogen atmosphere. This protects the samples from potential contamination. Once the XCT-scans have identified the location and approximate composition of the lithic clasts within the polymict breccia sample, this information can then be used to more precisely cut the samples into slabs, exposing the clasts of interest for sampling and further study. Although micro-XCT provides x-ray attenuation data for a sample, it does not give direct compositional or mineralogical information (although making reasonable assumptions and using standards during analysis allows for good estimations). Micro X-ray fluorescence (micro-XRF) uses a focused (25 micron) high energy (up to 50 kV) X-ray beam to produce semi-quantitative compositional maps of relatively flat surfaces. These maps can be used to better characterize clasts identified in micro-CT data, or to identify clasts that are compositional or textural outliers. Another technique, scanning laser-Raman analyses of cut slabs of breccias, has the potential to give direct mineralogical information that can be co-registered with the compositional data from the micro-XRF scans. Neither micro-XRF nor laser-Raman scanning can be easily done on samples contained in Teflon bags, but both scanning laser Raman and micro-XRF could be adapted to work in a standard nitrogen glove box. Future Missions: The original Apollo sample preliminary examination teams (PET) used binocular microscopy as they made their initial descriptions and observations of the samples. This was in part due to the technology available at the time, and in part, an effort to keep the samples as pristine as possible. Subsequent missions have used progressively more sophisticated techniques for PET, e.g., FTIR for Genesis or EDAX and laser-Raman for Hayabusa. Future sample return missions like OSIRIS-REx or South-Pole Aitken sample return are likely to incorporate micro-XCT, micro-XRF, and other sophisticated techniques into their PET analysis. References: [1] Almeida N. V. et al. (2014) MAPS, Abstract 5033. [2] Smith C. L. et al. (201s) MAPS, Abstract 5323. [3] Hyde, B. C. et al. (2013) MAPS, Abstract 5301.

B3.1-0022-18 TAPPING INTO THE LUNAR VOLATILE CYCLE WITH A SAMPLE RETURN MISSION TO THE SCHRODINGER BASIN

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The detection of water and other volatile species in Apollo samples has provided a new tool for assessing the accretion of the Moon, processing of volatiles during the magmatic evolution of the lunar interior, venting at the surface, and deposition in near-surface ice caches that may be harvested to support a sustainable exploration program on the lunar surface. Analyses of Apollo 17 glasses, norites, and a troctolite, for example, indicate that those types of samples can be used to measure OH abundances and isotope compositions that are key signatures of volatile sources and subsequent processing. Deciphering a volatile cycle from those samples is difficult, however, because they may not be derived from the same system in a Moon with a heterogeneous distribution of volatiles. The crystalline rocks were delivered to the Apollo 17 site as ejecta and, thus, come from a site tens to perhaps more than a 1000 km from the pyroclastic glass.

To address that complexity and evaluate the volatile cycle from accretional delivery, through processing in the lunar interior, to venting at the surface, we ideally want a set of samples that taps into that system at different depths in the same location on the Moon. We also ideally want to probe the lunar farside, for which we do not yet have any data except from meteorites without a known provenance. The Schrödinger basin is a geologically perfect site to address those issues and has already been identified as a high-priority landing site for robotic sample return missions and human sample return missions. In the Schrödinger basin, one can collect material from an immense pyroclastic vent that may be the largest indigenous source of volatiles in the South Polar Region during the past 3.7 billion years. Lava flows were also emplaced on the basin floor of Schrödinger, forming deposits that may provide evidence of a less-volatile rich portion of magma ascent from the same mantle source region as the pyroclastic vent or, if a different age than the pyroclastic vent, potentially of a different mantle source depth. Samples that record volatile abundances at a variety of crustal depths above the mantle can be extracted from the peak-ring, which was uplifted from depths down to 30 km, and from clasts in polymict impact breccias on the basin floor that contain excavated material from depths down to 19 to 24 km. Collectively, a suite of samples involving pyroclastic material, peak-ring lithologies, impact breccias, and mare flows would probe volatile abundances in the lunar interior at several different depths as they were being processed and eventually vented at the surface. A key advantage of the Schrödinger landing site over other sites is that it provides probes of the volatile cycle at different depths in the same location. This is an essential element of any study of the volatile cycle, particularly if volatiles are heterogeneously distributed laterally within the lunar interior.

B3.1-0023-18 HIGHLIGHTS OF SCIENCE AND EXPLORATION ACTIVITIES AT THE SSERVI VORTICES NODE

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The surface and near-surface of a planetary object is host to a wide variety of processes. It is the part of the body that interacts with impacts, solar and galactic energy to create or destroy volatiles, it is the part that we see with remote sensing instruments, and the part that will be sampled and tested by robots and astronauts. The Volatiles, Regolith and Thermal Investigations Consortium for Exploration and Science (VORTICES), a Solar System Exploration Virtual Institute (SSERVI) team headquartered at the Johns Hopkins University Applied Physics Laboratory, focuses on the entire volatile-regolith system occurring on small bodies and on the Moon. The team focuses on the sources, sinks and transport mechanism of volatiles (e.g., H2O, OH); the regolith and its properties and how it acts as a transport medium and storage reservoir; and how volatile and solar resources facilitate planetary exploration. At the time of selection, VORTICES had team members at 12 different institutions across the United States and its territories, at the current writing personnel movements have reduced that number to 10 institutions.

The work done by VORTICES team members involves interlocking themes considering the entire regolith-volatile system of the Moon and small bodies in the context of science and exploration. These themes are: 1) Volatiles in the Solar System: Sources, Processes, and Sinks: Understand how and where volatiles (e.g., OH and H2O) form, how they interact physically and/or chemically with regolith, how they are transported across and within the regolith, and their ultimate fate - be it sequestration in a cold trap or loss from the body. 2) Regolith: Origin and Evolution on Airless Bodies: Understand how regoliths are formed and evolve, and how those formation and evolution processes vary across the inner solar system. 3) Resources: Identification and Exploitation: Understand how volatile and solar illumination resources are distributed and how they enable robotic and human exploration.

In 2017, the group expanded modeling efforts of the thermal properties of the regolith, penetration of protons into the regolith and thermal fatigue of rocks and regolith generation. A new laboratory facility to examine how proton bombardment of regolith particles (solar wind bombardment of a surface) influences their ability to store and transport OH has been developed. This complements existing facilities that simulates micrometeorite impact to understand space weathering and the influence of micrometeor impact on ability to store and transport volatiles. The recent work builds upon work supported by VORTICES in the first three years of the institute, some highlights of which include: identification of lunar polar wander via regolith hydrogen signatures by Siegler et al., simulation of regolith creation by thermal stresses and calculation of the characteristic particle size created (El Mir, Ramesh et al.), modeling of impact gardening and its effect on lunar ice retention and burial (Hurley et al.), laboratory simulations of space weathering on carbonaceous asteroids (Kaluna, Gillis-Davis et al.), modifying an asteroidal shape/thermal modeling code to include additional features derived from Diviner thermal models (Magri, Hayne et al.), and measuring the desorption of water from lunar samples to understand the stability of surficial lunar water and the origin of the diurnal cycle seen from several spacecraft (Orlando, Hibbitts et al.).

We will provide an overview of the work done by VORTICES, including collaborations with other SSERVI teams.

B3.1-0024-18 INTRODUCTION TO THE LUNAR GAMMA-RAY SPECTROMETER FOR KOREA PATHFINDER LUNAR ORBITER

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Presently, KPLO (The Korea Pathfinder Lunar Orbiter)'s Gamma-Ray Spectrometer (KGRS) is being developed for an engineering model. The scheduled final KGRS development will be completed no later than mid-2019. The KPLO weighs approximately 550 kg and it will be launched in late 2020 by Falcon 9 rocket. The KPLO Gamma-Ray Spectrometer system is a compact low-weight instrument for the chemical analysis of lunar surface materials within a gamma-ray energy range from 10s keV to 10 MeV. The KGRS will collect low energy gamma-ray signals by either X-ray fluorescence or by natural radioactive decay in the low energy regions of spectrum and higher-energy gamma rays due to either neutron capture or inelastic scatter. The GRS system will determine the elemental compositions of the near surface of the Moon for investigation of the lunar geology and resources. The main LaBr3 detector of KGRS is surrounded by an anti-coincidence counting module of a boron-loaded plastic scintillator to reduce both low energy gamma-ray background from the spacecraft and housing materials and high energy gamma-ray background from cosmic rays. The main detector has high and low gain settings for gamma-ray energy ranges up to 3 and 10 MeV, respectively. One month of calibration and 11 months of a nominal mission period are planned with a minimum required GRS background measurement at anti-nadir direction. The planned altitude of KPLO in orbit is 100 ± 40 km, and KGRS data will be collected every 10 sec. The KGRS investigation will help to assess open questions related to the spatial distribution and origin of the elements on the lunar surface and will contribute to unraveling geological surface evolution and elemental distributions of potential lunar resources. This talk introduces the current development of KGRS and prospective scientific outcomes by KGRS data.

B3.1-0025-18 RADIO ASTRONOMY ON AND AROUND THE MOON

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The exploration of remote places on other planets has now become a major goal in current space flight scenarios. On the other hand, astronomers have always sought the most remote and isolated sites to place their observatories and to make their most precise and most breath taking discoveries. Especially for radio astronomy, lunar exploration offers a complete new window to the universe. The polar region and the far-side of the moon are acknowledged as unique locations for a low-frequency radio telescope providing scientific data at wavelengths that cannot be obtained from the Earth nor from single satellites. Scientific areas to be covered range from radio surveys, to solar-system studies, exo-planet detection, and astroparticle physics. The key science area, however, is the detection and measurement of cosmological 21 cm hydrogen emission from the still unexplored dark ages of the universe. Developing a lunar radio facility can happen in steps and may involve small satellites, rover-based radio antennas, of freeflying constellations around the moon. A first such step could be the Netherlands-Chinese Long Wavelength Explorer (NCLE), which is supposed to be launched in 2018 as part of the ChangE'4 mission to the moon-earth L2 point.

B3.1-0026-18 DEVELOPMENT OF THE NETHERLANDS - CHINA LOW FREQUENCY EXPLORER (NCLE)

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In radio astronomy, the very low frequency (VLF) range, below30 MHz, as one of the last remaining unexplored spectrum regions, plays an important role to understand comprehensively the physical processes of celestial sources by observing their emissions in the entire detectable EM spectrum. However, the artificial radio frequency interference (RFI), the cutoff frequency of the Earth's ionosphere, the AKR and QTN noise make it difficult or impossible to observe the sky VLF radio emissions with terrestrial telescopes. To open up this remaining spectral window virtually, a spaceborne telescope turns to be the only possibility.

Based on a space cooperation agreement signed between the Netherlands and China, a joint scientific team including Chinese researchers and Dutch researchers proposed a low-frequency scientific instrument, the Netherlands-China Low Frequency Explorer (NCLE). The NCLE will be hosted by the Chang'e 4 relay satellite, it will operates on an orbit at the Earth-Moon L2 point (around 64000 km behind the Moon), and serves as a reply between the Earth and a lander working on the far side of the Moon. The satellite is expected to be launched in 2018.

The NCLE will operate at the frequency band from 80 kHz to 80 MHz. It consists of three colocated, 5 m monopole antenna elements mounted on one side of the spacecraft body to receive the radio signals with three-dimension polarizations. These antennas are optimized to have a good sensitivity between 1 and 80 MHz where the priority science signals are expected. However, they are also able to extend down to the kHz regime with the decreasing sensitivity. The analogue signals sensed by the antennas are digitized by an ADC board, and then the data are processed in a Digital Receiver System (DRS) on which several dedicated science modes are implemented in a Field Programmable Gate Array (FPGA). These scientific modes perform such as fast Fourier transforms to create average radio spectra, triggering to capture a short segment of the digitized signal for transient radio events, and direction of arrival (DOA) finding with beam-forming or goniopolarimetry techniques. Raw time

traces can be stored for groundbased post processing and VLBI experiments. More detailed analysis will be done after the data are sent back to the Earth.

As described above, the man-made RFI is a big obstacle to observe the VLF radio sky on the Earth. Besides, for a space-based low frequency radio instrument, the RFI from the spacecraft itself should also be considered.

In this work, the development of NCLE project will be introduced and discussed including payload design, choices of the design, and RFI suppression, etc., some of them will be illustrated with the simulation and measurement results.

The NCLE scientific payload are mainly developed by the Radboud University, ASTRON, and Innovative Solutions in Space in Netherlands, in close collaboration with National Astronomical Observatories, CAS (NAOC), National Space Science Center, CAS (NSSC), and DFH Satellite CO.,Ltd in China.

B3.1-0027-18 THE CUBESAT LOW FREQUENCY EXPLORER (CLE) IN LUNAR ORBIT

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In radio astronomy, as in astronomy in general, a wide range of frequencies is observed, as each spectral band offers a unique window to study astrophysical phenomena. At the low-frequency part of the radio spectrum, telescopes such as LOFAR, GMRT and the MWA provide windows to study for example cosmology, pulsars, and (extra)galactic phenomena. Observing at even lower frequencies is very interesting as well, but, due to the influence of the Earth's ionosphere this is not possible from Earth. Thus, the only option to observe the lowest frequencies is a telescope in space.

In 2009 the OLFAR radio telescope based on a swarm of (50+) nano-satellites in lunar orbit was proposed. In order to assess the status of current-day technologies for OLFAR, the CubeSat Low Frequency Explorer (CLE) mission concept and technology study was conducted. This was done in the context of the SysNova "LUnar Cubesats for Exploration (LUCE)" challenge of ESA's General Studies Programme (GSP). The CLE mission concept is aiming at conducting radio astronomy below 30 MHz. This CLE radio mission and technology analysis is helping to pave the way towards deploying a larger scale distributed low frequency radio telescope in space, in the coming decades.

The Sysnova mission scope includes a circular lunar orbit requirement of >500 km altitude, a total mass of <60 kg, and data communication to a Lunar Obiter in elliptical polar orbit. The CLE study looked into astronomical science to be conducted, and also looked into technical feasibility with associated Technology Readiness Levels (TRLs). It turned out that for CLE with current-day technologies an instantaneous bandwidth of 10 MHz and 4 satellites with maximum baselines of 10 km can be supported with roughly 15% observational duty cycle. Given radio instrument space heritage and recent developments such as the Chang'e 4 NCLE receiver, it should be technologically possible to develop CLE in the coming decade. For a larger scale system such as OLFAR with more than 50 satellites, it turns out that the inter-satellite and downlink communication bandwidth (and associated mass) are currently the main limiting factors. However, novel optical communication links and novel RF communication schemes are currently being developed, and this give a promising outlook.

B3.1-0028-18 A UNITY OF PURPOSE IN EXPLORATION AND SPACE SCIENCE: HIGHLIGHTS FROM THE SSERVI NESS TEAM

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The Network for Exploration and Space Science (NESS) is one of the new teams selected in 2017 to be part of NASA's Solar System Exploration Research Virtual Institute (SSERVI). NESS conducts multifaceted and multidisciplinary research in the space sciences, including the areas of astrophysics, heliophysics, and exoplanetary science, that are enabled through human and robotic exploration of the Moon. Our team focuses on low radio frequency observations of the Sun, exoplanet systems, and the early Universe using the unique radio-quiet of the lunar farside and collaborative tools for exploration. The design of wide bandwidth receivers, prototype antennas, and arrays of radio dipoles on the lunar farside to investigate Cosmic Dawn, Heliophysics, and Extrasolar space weather are core activities within NESS, as well as the continuous research of theoretical and observational aspects of these subjects. NESS is developing designs and operational techniques for teleoperation of rovers on the lunar surface facilitated by the planned Deep Space Gateway in cis-lunar orbit. New experiments, using rover + robotic arms and Virtual Reality simulations, are underway to guide the development of deployment strategies for low frequency antennas via telerobotics.

B3.1-0029-18 PROTONS IN NEAR LUNAR WAKE: OBSERVATIONS BY SWIM/SARA ONBOARD CHANDRAYAAN-1

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When the super sonic solar wind plasma from the Sun interacts with the Moon, an airless body without a global magnetic field, it creates a void behind the Moon in the downstream. This void, known as the lunar plasma wake, was conventionally thought to be almost devoid any plasma especially at distances close to the Moon (few hundered lunar radii downstream), until the recent lunar missions revealed a competely different scenario. It was found that solar wind can access the near wake region (100-200 km altitude on nightside) by processes that are kinetic in nature. The SARA (Sub-keV Atom Reflecting Analyzer) experiment onboard Chandrayaan-1 carried an ion-mass analyser namely SWIM (Solar Wind Monitor), and the observations brought out new mechanisms for wake refilling and better understanding of the characteristics of plasma populations in near wake. SWIM observations showed for the first time that protons access the near wake even under a special scenario of magnetic aligned flow where the interplanetary magnetic field (IMF) is aligned with the solar wind velocity so that none of the known mechanisms can explain such protons. These were found to be the solar wind protons from the tail of the velocity distribution. Such protons have gyro-radii larger than lunar radii so that they enter the near wake region directly even under magnetic aligned flow. A new population of suprathermal protons (sim1.5–3 times the solar wind energy) were observed around the Moon. These protons have large initial velocity (>100 km s–1) and originate from a high altitude source (>500 km above the dayside lunar surface). Discovery of these protons calls for a new source feeding the plasma environment around Moon, which is yet to be identified. Whereas in most of processes protons access the near wake region by travelling perpendicular to the IMF, wake refilling parallel to IMF also has been observed. Comparison of the observed protons (energy sim700 eV) with the 1-D analytical model of an electrostatic plasma expansion into a vacuum showed the observed velocity to be higher by a factor of 2 to 3 and the observed density to be lower by a factor of 2 to 25 than the model predictions. Thus, the simple analytical models cannot explain the observed ion dynamics along the magnetic field in the vicinity of the Moon. The analysis of the complete data set from SWIM in near wake region showed the presence of several proton populations with distinct velocity distributions coexisting in this region. Based on the characteristic velocity distribution functions and the backtracing model, most of these populations could be explained by known mechanisms although there are a few populations whose sources are yet to be found out. The observations have showed an additional mechanism which involves the transport of the solar wind that is scattered from the small scale magnetic fields on the Moon (lunar magnetic anomalies) on the dayside to the near wake region. The understanding of the plasma environment and the electrodynamics on the lunar nightside is still evolving. These observations not only throw light on this aspect but also on the possibility of the interaction of such plasma with the lunar surface. The interaction can modify the surface charging, and also cause sputtering from the nightside surface that contributes to lunar nightside exosphere. The recent observations of energetic neutral atoms emitted from the lunar nightside surface supports this. Further explorations of the Moon is required to have a comprehensive understanding of lunar plasma environment.

B3.1-0030-18 HIGHLIGHTS OF THE FRANCE SSERVI PARTNERSHIP

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Overall context:

IRAP has become a SSERVI partner, with the official signing on May, 24th, 2016 of its affiliation, as the result of the submission of the proposal 'SSMMAC-France' (Space Studies of the Moon, Mercury, Asteroids and Comets in France).

A few science and future projects highlights:

Lunar Orbital Imaging Spectroscopy and Geology. Given the wealth of the dataset acquired by the imaging spectrometer M3 on board Chandrayaan-1 mission, advanced hyperspectral processing appears needed to explore the existing variability involving plagioclase and mafic crystal field absorptions, and better constrain the lunar crust lithology and cratering process. Laboratory data are used to improve the capability of MGM modeling to realistically model complex mafic mineralogies when considering rock slab surfaces with coarse textures, involving plagioclase and mafic crystal field absorptions. This strategy is tested on M3 spectra with the objective of documenting the petrology at Copernicus and Aristarchus craters through characterization of plagioclase and mafic crystal field absorptions, from exposed outcrops (e.g., central peaks, inner walls and rims).

Lunar Interior. Lunar seismic signals (Apollo data) are notably different from terrestrial seismic records: the energy rise at the onset of the signal is gradual, the S-wave arrival is difficult (or impossible) to detect, the maximum of energy is broad, and the energy decay in the coda is very slow. In 1974, Dainty et al. made the first attempt at modeling the scattering processes in the Moon using diffusion theory, and inferred a thickness of 25 km for the scattering layer. However, the modeling was limited to the planar case. Given the size of the Moon and the duration of seismic signals, spherical effects appear quite relevant. For the first time, stratification of scattering properties and spherical geometry are addressed. Using an advanced attenuation model, the depth of shallow moonquakes is determined by inversion based on the observed variation of the time of arrival of the maximum of energy with epicentral distance. They are found to originate from a depth of about 50 km ± 20 km, likely resulting from the failure of deep faults in the brittle part of the Moon.

Future lunar missions and instruments.

SELMA: IRAP is contributing to the SELMA (Surface, Environment, and Lunar Magnetic Anomalies) mission proposal submitted in response to ESA Cosmic Vision AO for M5 mission

Opportunity. SELMA is a mission to study how the Moon environment and surface interact. It focuses on the origin of water on the Moon, on how the “volatile cycles” and the lunar minimagnetospheres work, on the influence of dust on the lunar environment and surface. SELMA uses a unique combination of remote sensing via UV, IR, and energetic neutral atoms and local measurements of plasma, fields, waves, exospheric gasses, and dust. It will also conduct an impact experiment to investigate volatile content in the soil of the permanently shadowed area of the Shackleton crater. The spacecraft will carry an impact probe to sound the Reiner-Gamma mini-magnetosphere and its interaction with the lunar regolith from the SELMA orbit down to the surface.

DORN: Since the early stages of the lunar exploration, radon-222 and its progeny have been identified as key tracers of the present-day lunar seismic and venting activity. Long-term monitoring of the radon cycle on the surface of the Moon would thus provide valuable ground truth for orbital measurements and would help address several key issues related to the transport of lunar volatiles and dust, including the study of the transport of gases through the lunar regolith, cycles in the lunar exosphere, monitoring of the venting activity and identification of active outgassing spots. A prototype for an in situ instrument called DORN aimed at measuring both radon and polonium atoms around the lander, and the subsurface flux of radon at the landing site is being developed at IRAP.

LIBS: Since 2012, LIBS (Laser-induced Breakdown Spectroscopy) has been successfully used under low atmospheric pressure for exploring the geology of Mars at Gale Crater with ChemCam instrument onboard Curiosity. Laboratory studies have also demonstrated that LIBS can give accurate and precise results under vacuum conditions. Its potential for rapid and accurate in situ elemental analysis of lunar materials and characterization of resources is currently under study.

Small bodies plasma physics. IRAP is also deeply involved in ROSETTA and Dawn data analysis and interpretation, as well as in planetary plasma activities related to CDPP (Plasma Physics Data Center).

B3.1-0031-18 RADON-222 AND POLONIUM-210: TRACERS FOR VOLATILE TRANSPORT ON LUNAR SURFACE

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Samples returned from the moon have established that widespread lunar volcanism ceased around 3.2 Ga, and only impact craters reshaped the lunar surface over the last billion years. However, morphological and spectral evidence suggests recent outgassing activity at Ina structure, close to one of the regions where high 210Po alpha activity has been previously observed. Further, 222Rn (half life = 3.8 days) produced in decay chain of 238U, can be expected to be released from the upper layers of the hot sunlit side of the lunar surface by thermal diffusion and be trapped in the permanently shadowed regions of the moon and other cold traps in the polar regions. The mean free path of a radon atom's random walk is not determined by collisions with other gas molecules in the extreme lunar vacuum, but rather from collisions with soil grain surfaces. Subsequently, 222Rn decays to 210Pb, and a thin layer of 210Pb and 210Po is expected in the permanently shadowed regions of the lunar surface. We propose to develop an alpha particle spectrometer for a lunar lander/rover mission using ion-implanted silicon detectors for measuring signals from alpha particles produced by the decay of 222Rn (5.490 MeV) and 210Po (5.304 MeV) at permanently shadowed regions of the lunar surface. Alpha spectrometers on Surveyor landers and Apollo orbiters measured 222Rn and 210Po in lunar rocks and soils and suggest temporal and spatial variability in their concentrations. Several models have been proposed for transport of radon from the lunar interior to the lunar surface and then across the terminator to the colder regions. Permanently shadowed regions near lunar poles should have high concentrations of 222Rn, 210 Po and an alpha particle spectrometer and a cooled HPGe gamma ray spectrometer (for 210Pb measurements using 46.5 keV gamma line) on a future lunar lander/rover mission should be able to determine their concentrations and help us understand the transport and deposition of volatiles on the lunar surface.

B3.1-0032-18 LUNAR SIMULANT IN LOW TEMPERATURE VACUUM TESTING FOR OUTGASSING CHARACTERISATION

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Nowadays interest towards ice in space is increasing. One of the reason why stays in the great importance icy the volatiles elements play in the exobiology and pre-biotic components potential existence. The ESA Juice mission towards the Jupiter icy Moons, in preparation for flying in 2022 is just an example, as well as the on going, proposed and future missions focusing on asteroids with samples return. More nearby in time, the first incoming challenge is represented by the lunar 27 ESA-Roscosmos mission, supposed to land n the Moon south Pole to collect and analyze in situ icy volatiles. Icy volatiles sampling in vacuum is quite a tough operation: icy gases immediately sublimate as soon either the pressure decreases - because of the extraction - or the temperature increase - because of the friction provoked by the mechanical energy injected in the soil to crack it and collect the specimen. The risk is, therefore, to penetrate the soil, collect subsurface samples supposed to have the volatiles content required to run scientific analysis and to release to the instruments soil with no volatiles at all inside, because of the occurred sublimation in vacuum. Currently, no validated model exists on sublimation phenomenon for gases trapped in a soil composite while in vacuum. Therefore experimental tests would be beneficial to characterize it and tune both the tool to sample and the operations to run while sampling the icy planetary soil. At Politecnico di Milano-Aerospace Science Technology Dept. the design and setup of a dedicate experimental facility to assess the gasses and icy volatiles sublimation phenomenon in vacuum is under development. A vacuum chamber, equipped with soil inside - either dry or wet - which correctly reproduces the polar Moon conditions is a challenge also in the setting up activities: soil is prepared in air at sea temperature, therefore, even the dry soil traps air molecules which contribute to the sublimation as soon as the soil undergoes a vacuum creation procedure; the amount of gases coming from trapped air has to be distinguished from gases being part of the simulated icy volatiles purposely inserted in the soil to run the scientific test. Previous tests, performed at Glenn Research Center, have identified how lunar soil simulants, inserted in a thermal vacuum chamber, increase the time needed to reach the target pressure because of the gas load, coming from the simulant, provoked by the air trapped between the soil particles, and the water vapor absorbed by the simulant when exposed to atmospheric conditions. Therefore, to correctly support the design of a planetary icy soil sampler the terrestrial infrastructure must firstly quantify the gas load produced by the soil during the chamber pressure decreases and provoked by the trapped air; then it must be equipped to monitor and measure the gas load, in vacuum, provoked by the tool-soil energy exchange. The NU-LHT-2M is here used as Moon highlands simulant. A scaled experimental set up, made up of a soil chamber and a vacuum chamber, connected by a pressure regulated line has been realized. The two chambers scheme allowed characterizing and

controlling the experienced soil sputtering and boiling as soon as the pressure starts decreasing. This is a critical phenomenon to be avoided to keep the soil characteristics known and as desired to correctly simulate the planetary soil during any functional testing of tools interacting with the soil itself (e.g. drilling, sampling, impacting, etc). The adopted two chambers scheme is required to keep the experiment completely independent from a classical TVAC internal chamber with suffer from any particle which can enter the pump line, jeopardizing the complete plant because of pump failure; the system can be easily cooled down just inserting the whole in a freezing plant, decoupling the vacuum creation from the temperature regulation process. A 10-5 bar pressure conditions can be obtained; The lunar simulant NU-LHT-2M has been prepared setting up a compaction procedure based on a layered vibrations campaign to reproduce at the best the lunar soil bulk density. The experimental campaign run so far revealed the significant air content in the compacted soil while getting to the correct vacuum level in the soil chamber, confirming the need of a standardized procedure to prepare the soil in vacuum to be not only chemically but also physically representative of the planetary soil as soon as any technological or scientific experiment involving interaction with low temperature, maybe icy, soil in vacuum is conducted. The facility design, implementation and calibration will be critically discussed and presented, together with the results of the tests which led to the soil behavior characterization (dry and wet) and to the soil preparation procedures definition.

B3.1-0033-18 METEOROID BOMBARDMENT AND IMPACT GARDENING IN THE LUNAR POLAR REGIONS

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The Moon is continually bombarded by interplanetary meteoroids. While meteoroids turn into shooting stars at Earth due to our thick atmosphere, airless surfaces like the Moon's are completely exposed to meteoroid impacts. The surface of the Moon is covered with a layer of loose rocky material, including fine dust particles. This regolith has been formed, and remains continually reworked, by the intermittent impacts of comets asteroids, and the continual bombardment by meteoroids. Each meteoroid impact produces orders of magnitude more ejecta mass compared to the primary impactor mass, most of which is bound and returns to reblanket the lunar surface.

Water is thought to be continually delivered to the Moon through geological timescales by water-bearing comets asteroids and produced continuously in situ by the impacts of solar wind protons of oxygen-rich minerals exposed on the surface. Meteoroids are an unlikely source of water due to their long UV exposure in the inner solar system, but their high-speed impacts can mobilize secondary ejecta dust particles, atoms and molecules. Other surface processes that can lead to mobilization, transport and loss of water molecules and other volatiles include solar heating, photochemical processes, and solar wind sputtering. However, since these drivers are minimized at high latitudes, particularly in Permanently Shadowed Regions (PSRs), dust impacts are an important driver governing the evolution of volatiles in these regions.

The meteoroid environment at the lunar polar regions has been difficult to constrain, given the paucity of available data. However, recent Earth-based observational and modeling efforts have revealed a persistent, high speed and high inclination source of meteoroids at 1 au that continually bombard the lunar polar regions. In-situ ejecta measurements were made at the Moon by the Lunar Dust Experiment (LDEX) onboard the Lunar Atmosphere and Dust Environment Explorer mission. LDEX observations enabled a detailed understanding of the structure of the impact generated, permanently present lunar ejecta cloud and subsequent gardening rates near the lunar equatorial plane. Here, we extend those equatorial measurements to the lunar polar regions using advanced models of meteoroid impactors at the Moon to constrain the associated impact gardening rates.

B3.1-0034-18 A TENTATIVE PLAN OF CHINA TO ESTABLISH A LUNAR RESEARCH STATION IN THE NEXT TEN YEARS

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upChina successfully implemented the missions of Chang'E-1 in 2007, Chang'E-2 in 2010 and Chang'E-3 in 2013 respectively, and Chang'E-4 will be launched in 2018 to achieve landing and inspection on the far side of the Moon. And later, Chang'E-5 will be launched in 2019, with an attempt to collect lunar samples and return them to the Earth. On this basis, through years of study and discussion, Chinese scientists have proposed a preliminary plan for establishing a lunar research station on the lunar South Pole by implementing 3-4 missions between 2021 and 2030. The first mission is designed to carry out geological investigations on the landing site and the detection of water ice in the permanently shadow crater. The main scientific task of the second mission is to collect lunar rock and soil samples and return them to the Earth for further analysis. The third mission is focused on the test of insite utilization of lunar resources on the Moon.

B3.1-0035-18 TOWARDS THE INTERNATIONAL LUNAR DECADE

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Vidvuds Beldavs, David Dunlop, Jim Crisafulli, Bernard Foing

In November, 2014 an international group gathered in Hawaii at the conference "Next Giant Leap: Leveraging Lunar Assets for Sustainable Pathways to Space" issue the International Lunar Decade (ILD) Declaration. The central premises of ILD are: 1. The inspiration for ILD is the International Geophysical Year 1957-8 that marked the first global effort to understand the Earth. ILD is proposed as framework for international cooperation towards permanent presence of humankind on the Moon and beyond. Initially proposed by COSPAR to start on the 50th anniversary of IGY in 2007, global conditions were not favorable. Now, with many countries planning missions to the Moon the decade of 2020-2030 would be appropriate to work towards the strategic goal of making possible permanent presence on the Moon. 2. Economic use of lunar resources is a precondition for sustainable research and commercial activities on the Moon. There is speculation about lunar water and asteroid resources, but no business case for use of space resources has so far been offered. Markets for space resources do not exist. Technologies to mine and process space resources need to be developed. Even the legal right to use space resources within existing space law is uncertain. Recent developments suggest that a business case for lunar resources can emerge over the next few years. Lunar regolith includes significant basalt content from which basalt fibre could potentially be produced by melting regolith at about 1500C with concentrated solar energy. Uses could include thermal barrier shields as well as impact shielding for spacecraft and structural and body parts of spacecraft and rovers and haulers on the lunar or Martian surface thereby generating major savings in lunar and planetary exploration. Space Solar Power is another development where technical designs promise electrical costs competitive with other alternatives with zero CO2 emissions. An early application with commercial potential could be a Lunar Power Utility that could lower costs and speed up lunar development. Lunar water is another promising resource. Low cost launch from the lunar surface is key to realizing the economic potential of lunar resources. Additionally, the issue of rights to use lunar resources, particularly as commercial products, remains to be addressed.

Moon Village provides a structure to link between exploration and research and commercial developments into a mutually augmenting whole. Moon Village is a bottom-up, open, evolutionary concept for development on the Moon and in cislunar space by an international community including scientific research, business and cultural interests, as well as space agencies and international organizations. Moon Village, however, does not address the policies required to enable use of lunar resources or to engage the global research community, the UN, and other international organizations such as the International Science Council, which coordinated the IGY. Moon Village and other

developments can benefit from the framework for strategically directed international cooperation from 2020 to 2030 provided by the ILD to: develop internationally accepted policies for use of space resources, foster innovation and the development of enabling technologies and infrastructure aimed at driving down the costs of activities in cislunar space and on the Moon, and facilitate the creation of markets for space resources. Adoption of the ILD framework by UN COPUOS, COSPAR, International Science Council, ILEWG, ISECG and other forums for international cooperation in outer space can lead to greater progress in the 2020-2030 period for all participants individually and jointly through initiatives such as Moon Village and the Deep Space Gateway. The ILD framework can also provide mutually agreed to strategic direction to meet UN Sustainable Development Goals through lunar exploration and development. The use of lunar and asteroid resources can create economic activities that do not damage the environment while expanding wealth and opportunities for people on Earth.

B3.1-0036-18 FLASH ORAL PRESENTATION OF POSTERS (2 MINUTES /POSTERS)

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Flash oral presentation of posters (2 minutes /posters)

Lunar science and exploration are having a renaissance with as many as twelve missions (and 18 vehicles) sent to Moon during the last "International Lunar decade". This session is aimed at discussing new progress in lunar science from recent missions, latest science results, newer insight into our understanding of Moon, modelling and synthesis of different scientific data, future missions, and science questions. It will include inv ited, contributed, and poster papers. Papers on new lunar mission concepts, instrumentation for the future missions, the upcoming lunar decade of landers and lunar robotic village, and preparations for human lunar exploration are also welcome in this session. COSPAR-18-B3.1 will also be ICEUM13A, part of the 13th International Conference on Exploration and Utilisation of the Moon from the ILEWG ICEUM series started in 1994.

B3.1-0037-18 IN SITU PYRO-GCMS CHEMICAL ANALYSIS OF LUNAR SOIL WITH THE GAS ANALYTICAL COMPLEX EXPERIMENT OF THE FUTURE LUNA-RESURS MISSION

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The chemical analysis of lunar samples collected in the regolith or rocks is of primary importance to assess their content in volatile species. These volatiles could reveal, for instance, part of the nature of: materials delivered to Earth from exogenous sources, minerals present in the Lunar regolith and surface rocks, and Lunar indigenous organic material. These are key information to improve our knowledge on the origin and evolution of the Moon, but also on important processes for the prebiotic chemistry that took place on Earth. Even if the accuracy and sensitivity of the analytical instrumentation used in the laboratory are very high to characterise the chemical content of samples brought from the Moon, the journey of these samples in space, as well as their transportation to the Earth environment, could change the nature in the volatile content of the samples (e.g. loss of chemical species, possible chemical reactions or contaminations). For these reasons, in situ chemical analysis, in addition to provide direct information on the chemical composition of the Lunar regolith, could be of precious help for the interpreting the results obtained in the laboratory, and their transposition to the Moon surface environment. This is the reason why our team proposes an instrumentation to characterize in situ the content of volatiles in the lunar soil and rocks. This instrumentation is part of the Luna Resurs payload. This space probe should land near the lunar South pole, thus giving for the first time the opportunity to characterise this region which is thought to be rich in volatiles from remote sensing, whereas the previous lunar missions were all constrained to land near the equator. Our instrumentation is based on pyrolysis coupled with gas chromatography and mass spectrometry. It has the capability to: extract volatile materials (either condensed or present in the minerals) from the solid samples; separate the volatile and analyze their structure for identification and quantification; and analyze isotopic ratios in a certain extent. With this aim, the instrument is composed of: i. a pyrolyser capable to heat the samples up to about 1000°C; ii. a gas chromatograph devoted to separate and detect the volatile species released from the samples. The chromatograph includes two analytical channels, one devoted to separate the noble gases and the most volatile molecules, and one devoted to analyse very volatile organic molecules;

iii. a time of flight mass spectrometer for the structural identification of the molecules. This instrumentation should allow the identification of inorganic volatile molecules and small organic molecules (up to about benzene). This communication aims at presenting this instrumentation of the Luna Resurs space probe, and results obtained from calibration of individual parts and qualification model that give an overview of the analytical performances of this instrument.

B3.1-0038-18 LUNAR ICE LOCATION EXPLORATION

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The main objective is to show a detailed trade study on the potential water deposit locations for future exploration missions. Large quantities of resources are required to enable any crewed exploration missions to successfully explore and live away from earth. The basic need of any crewed mission is water, and the idea of extracted it from celestial bodies or utilization of water from in-situ locations could potentially increase the performance and reduce the cost of exploration missions is highly considered today. Also, water is a combination of Hydrogen and oxygen molecules which can be further used to serve as propellants for the propulsion system. NASA plans to establish systems in the cis-lunar space, therefore Moon is an excellent potential location for the collection of in-situ resources. Several Lunar probes such as INDIA's Chandrayaan, NASA's Lunar Prospector, Japan's Kaguya have shown evidence of water on the lunar surface.Water is likely to be in the deep impact craters and polar regions.

This paper investigates the locations of the highest concentration of water, comparison of these target locations for future missions, and a brief discussion on solar heating's impact on these locations. After analyzing all the requirements necessary for the water exploration landing site such as zone of direct radio communication, density of water ice, Circular Polarization Ratios from the Mini SAR observations, degree of illumination and many other factors, our research concludes that The Peary Crater (88.5°N, 30°E) located in the Northern Polar Region is the best suitable location for finding water on the moon. The crater floor of peary is permanently a shadowed region(northern rim of Peary crater, Peary B and Peary W experience permanent shadow, as cold as -248°C) whereas it also has areas along its rim that are permanently illuminated by the Sun that can be further used as a crucial solar energy source for the exploration rover. Peary is a location in constant sunlight still near the suspected stores of water ice.

B3.1-0039-18 POSSIBLE LANDING SITES NEAR THE NORTH POLE OF THE MOON

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Currently, a number of areas in the southern polar region of the Moon have been selected as the proposed landing sites for the future mission of the Luna-25. When choosing potential landing sites, one of the criteria was the enhanced abundance of hydrogen at a given location. The enhanced abundance of hydrogen in the polar regions of the Moon is generally attributed to the presence in these regions of deposits of volatile compounds, in particular water ice. Also, the proposed landing sites must meet certain criteria: 1. the dimensions of the landing ellipse should be 15 × 30 km, with the semi-major axis of this ellipse should be located in the direction of the meridian. 2. the surface slopes at the landing site must not exceed 7º. 3. illumination at the landing sites should be maximum. The increased hydrogen content in the regolith in the northern polar region of the Moon was detected by the neutron spectrometer of the probe Lunar Prospector (LP). More accurate information about this phenomenon was obtained by the LRO probe. According to the data of the neutron spec-trometer LEND onboard LRO probe in the region of the north pole of the Moon, three regions are distin-guished in which the hydrogen content is signifi-cantly higher than in the surrounding terrain. These areas are located near the craters of Peary, Nansen F and Rozhdestvenskiy U. Siegler et al., (2016) analyzed in their work the features of the motion of the Moon and showed that more than 3 billion years ago the north pole of the Moon was located in the crater of the Rozhdestvenskiy U (84,9° N, 152° E). During this period, the south pole was located in the r of Kabeo crater (85,5 ° S, 45 ° W), where sig-nificant deposits of a number of volatile compounds were discovered. So, it can be expected that the excess hydrogen found in this region can be associ-ated with the deposition of volatile compounds. simi-lar to those found in the southern polar region. In this paper, we have studied the area of the Rozhdestvensky U crater in order to search for pos-sible landing sites for future lunar missions in the area. We used the data of the DEM altimeter LOLA onboard LRO probe for the study of the relief in the area of Rozhdestvenskiy U crater. We calculated the slopes and aspects of the surface in a given re-gion using the method of. Using the obtained results, we investigated the illumination conditions and the thermal regime on the surface and in the sub-surface layer of the regolith in this region. As a result, we have identified a number of areas that meet the criteria of landing sites.

B3.1-0040-18 MOON-SOLAR WIND INTERACTION AND CORRESPONDING WAVE PHENOMENA

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The latest observation revealed that the significant deflected proton fluxes exist over magnetic anomalies at lunar surface and these observations gave possibility to imply that the magnetic anomalies may act as magnetosphere-like obstacles (mini-magnetospheres). Such obstacles modify the upstream plasma and number of many models was developed to describe such formations. Also on the Wind spacecraft across the lunar wake number of different types of electric fluctuations were observed: langmuir waves, electrostatic modes above electron cyclotron frequency, whistlers. The investigations revealed emissions on plasma frequency and its first harmonic. Electron reflection at quasi-shock at leading edge of magnetic anomaly could drive the electric field oscillations. The generation mechanism is similar to that known for foreshock of planetary bow shock.In KAGUYA and Lunar Prospector missions the monochromatic whistlers near the Moon were observed as narrow band magnetic fluctuations with frequencies close to 1 Hz, and are mostly left-hand polarized in the spacecraft frame. We present the review of actual observations and different mechanisms of wave and magnetic disturbances generation in plasma environment around the Moon: in solar wind closely to the Moon, over the magnetic field anomalies at its surface, in the lunar wake and around its boundaries. The generating mechanisms, propagation and other characteristics of waves are presented. Particular attention is pointed on Electrostatic Solitary Waves (ESWs), monochromatic whistlers, large-amplitude monochromatic ULF waves and non-monochromatic whistler waves. However all these questions remain open and require further experimental confirmation as on the basis of already available data (the Kaguya and Chandrayaan missions) and data to be obtained in advanced scientific projects of the Moon's exploration (the project LunaResursOrbitalInyapparat).

B3.1-0041-18 RESTORED APOLLO MAGNETIC FIELD RECORDS

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Between 1969 and 1975, several Apollo missions measured the magnetic field at the Moon either on the lunar surface by the Apollo Lunar Surface Experiment Packages (Apollos 12, 15, and 16) or at low altitudes by orbiting sub-satellites (Apollos 15 and 16). As of today, these data still represent the only joint surface-space magnetic field observations in the lunar environment. For decades, Apollo's magnetic field data were stored on magnetic tapes in an obsolete data format. An effort has been made in recent years to restore these precious digital records. This poster summarizes the data restoration efforts to date and the new findings based on the restored Apollo magnetic field data.

B3.1-0042-18 A NEW POLAR COORDINATE EXPRESSION FOR MOON-BASED EARTH OBSERVATION IMAGES

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The moon, as the unique natural satellite of the earth, is an ideal earth observation platform for obtaining consistent and continuous global-scale earth observation images compared with observation from artificial satellites. As a result, the Moon-based earth observation (MEO) already has aroused many scholar's interests for its advantages in observing the large-scale geoscience phenomena chronically and continuously. However, it is difficult to build the coordinate mapping relationship between the MEO images coordinates and the geographical coordinates directly, due to the change ranges of sublunar point caused by variation relationship of the moon and the earth, the geometric distortion of MEO images caused by curvature of the earth, and so on.

In this paper, a polar coordinate expression (ρ,ϑ) on the projection surface related to the sublunar point is designed and used to express the MEO large scale hemisphere image, that is applied as a mid-coordinate between the original image coordinate and geographical coordinate. The MEO image with polar coordinate expression on the projection is similar to original acquiring image and it is easy to register them with less information lost and geometric deformation. In addition, an analytical relationship can be built easily between the proposed polar coordinate and the geographical coordinate. Therefore, the polar coordinate expression for MEO images can effectively deal with the geometric deformation caused by the varying sublunary point and the earth curvature, and improve the geometric correction accuracy.

B3.1-0043-18 SOLAR X-RAY MONITOR (XSM) ONBOARD CHANDRAYAAN-2 ORBITER

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The remote X-ray Fluorescence spectroscopy is a powerful technique to investigate the elemental abundances in the atmosphere-less planetary bodies. The experiment involves measuring spectra of fluorescent X-rays from lunar surface using a low energy X-ray detector onboard an orbiting satellite. Since the flux of fluorescent X-ray lines critically depend on the flux and spectrum of the incident solar X-rays, it is essential to have simultaneous and accurate measurement of X-ray from both planet and Sun. In the context of moon, this technique has been employed since early days of space exploration to determine elemental composition of lunar surface, however the elemental abundance measurements are available for only 15 % area of the lunar surface. Hence, it is planned to continue the remote X-ray fluorescence spectroscopy experiment on-board Chandrayaan-2 which includes both lunar X-ray observations and solar X-ray observations as two separate payloads. The lunar X-ray observations will be carried out by Chandra Large Area Soft x-ray Spectrometer (CLASS) experiment; whereas the solar X-ray observations will be carried out by a separate payload, Solar X-ray Monitor (abbreviated as XSM). The XSM will provide high energy resolution (3% @ 5.9 keV) and high cadence (at every second) measurement of the solar X-ray spectra, which will also be greatly helpful for independent solar studies. The Flight Model (FM) of the XSM payload has been completed and tested for various instrument parameters. The design details and the performance of the XSM instrument will be presented in the conference.

B3.1-0044-18 LUNAR CORE EFFECTS ON LOW-ALTITUDE MAGNETIC FIELD

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Magnetic sounding of the lunar interior can be carried out in at least two different ways. A popular approach is to measure the transfer function, which compares the magnetic field fluctuations on the lunar surface with those from external sources. An alternative approach is to use low-altitude magnetic field measurements to detect the induced magnetic moment due to a conducting core. The second approach requires only spacecraft measurements and has successfully been applied to the data from Apollo subsatellites, Lunar Prospector, and Kaguya for estimating the size of the lunar core.

This paper considers both theoretical and measurement aspects of the second approach of magnetic sounding. We perform 3-D finite-element calculations of the magnetic field, including the crustal magnetic fields and the core effects, to examine expected magnetic field at low altitudes. We also examine the feasibility of using ARTEMIS magnetic field measurements in the Earth's magnetotail to estimate the magnetic moment induced by the core. Since the start of its lunar orbit in 2011, ARTEMIS has been making many low-altitude passes to tens of km from the lunar surface, where the induced magnetic moment is observable. We find that measurements from the more distant probe can represent the external fluctuations, reducing the uncertainty in measuring the core-induced magnetic field at the close approach by the second probe.

B3.1-0045-18 SUBLIMATION RATE OF VOLATILES IN PURE AND MIXED ICES

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Volatile molecules are found in ices on Solar System bodies. For example, H2O, H2S, NH3, CO2, or CH4 have been detected and quantified in the Cabeus crater on the moon by LCROSS [1]. Some super-volatiles have even been detected, despite lukewarm surface temperatures at which they should not be in the condensed phase if they were pure. Current surface models that employ sublimation rate inputs to predict ice composition do not account for the existence of entrapment mechanisms by the more abundant water molecules [2]. Moreover, most sublimation rates applied to surfaces at cryogenic temperatures encountered in the Solar System are extrapolations based on vapor pressure measurements performed at higher temperatures.

Here we present measurements of the H2O and CO2 sublimation rates at cryogenic temperatures for pure ices and preliminary results for CO2 mixed with H2O. These measurements have been obtained by depositing ice films onto a gold coated electrode of a quartz crystal microbalance cooled at low temperature (T 10K) under ultra high vacuum. The ice is further warmed up and the rate at which molecules sublimate is measured by the microbalance for various temperatures. A mass spectrometer is employed in the case of mixtures to decompose the microbalance ice loss rates into species specific components.

Small temperature shifts due to phase changes are observed for pure ice sublimation (e.g. for amorphous vs crystalline H2O ice), which emphasizes the impact of the ice structure onto its thermodynamical parameters. In the case of volatiles mixed with H2O ice, a fraction of the volatiles stays trapped at high temperature until the H2O matrix desorbs. Preliminary results on entrapment parameterization as a function of the mixing ratio is presented. Such parameterization could be included in models to contribute to a better ice composition prediction as a function of surface temperature.

A. Colaprete, P. Schultz, J. Heldmann, D. Wooden, M. Shirley, K. Ennico, B. Hermalyn,

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B3.1-0046-18 RELATIVE DYNAMICS IN NON-KEPLERIAN ORBITS FOR PROXIMITY OPERATIONS AT CISLUNAR OUTPOST

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The near future sees a strong cislunar environment exploitation as a key element to develop and test several new enabling technologies to support more challenging science and exploration missions and the human presence beyond Earth. .The realisation of these forthcoming space programmes entails setting up space infrastructures in lunar vicinity, to be exploited as outposts for different manned and robotic activities. Moreover, risk mitigation, safety and robustness maximisation ask for a gradual robotized construction of those gateways to be ready to host the human presence. This milestone of near future future space roadmap opens interesting and multidisciplinary challenges from a space system engineering perspective. The knowledge of the spacecraft dynamics in cislunar space is well known thanks to studies about restricted Three-Body Problem (R3BP), which became relevant for engineering applications with the development of numerical computing capabilities. However, these studies are often focused on point mass dynamics and applied to find low-energy transfers between different locations in space. The paper presents results of the 6DOF spacecraft dynamics investigation in cislunar environment, with particular attention to the relative dynamics between approaching spacecrafts moving on non-Keplerian orbits; such dynamics understanding and precise modelling is fundamental to practically support forthcoming autonomous rendezvous and proximity operations for on orbit assembly in outer space. High-level 6DOF GNC strategies shall be settled, based on high fidelity dynamics modelling. The relative dynamics based on a Circular Restricted Three-Body Problem (CR3BP), on an Elliptic Restricted Three-Body Problem (ER3BP) and on a full Ephemeris model, including the presence of the Sun are critically compared to show the need for a high fidelity modelling whenever dealing with the relative guidance design in such domains. In particular, attention is focused on finding whether non-Keplerian orbits branches exist on which simplified models may still be valuable with respect to the accurate dynamical model. Sensitivity analyses are carried out to understand the effects that the features of the different modelling approaches separately have on the relative dynamics (e.g. influence of the Sun, influence of the eccentricity of the Earth-Moon orbit, influence of the out-of-plane force components). Analyses are presented according to the non-Keplerian orbits classes evaluated as the most suitable for a cislunar space station location: NRHO, Halo and DRO. Finally, the best modelling approach to study relative dynamics in cislunar space is highlighted and use case scenario is discussed.

B3.1-0047-18 ON THE FORMATION OF THE LUNAR SURFACE HYDRATION IN THE EARTH'S MAGNETOSPHERE

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Evidence of discoveries involved with lunar water (e.g., polar ice and OH−/H2O) have been observed in recent years. The dynamic H2O loss and rehydration cycle over a lunar day

indicated solar wind hydrogen should be an important source of lunar surface water. In this study, we investigate the influence of the Earth's magnetosphere in the formation of the lunar surface hydration. Based on Moon Mineralogy Mapper (M3) data onboard Chandrayaan-1, we perform a statistical study of the lunar hydration distribution at high latitude regions. The lunar surface OH−/H2O abundance increases with latitude toward the polar regions, which is consistent with previous studies. When the Moon entry into the Earth's magnetosphere, the lunar surface hydration can also be formed and the magnitudes are of the same order inside/outside magnetotail. We will discuss the physical mechanism in this work.

B3.1-0048-18 STRUCTURAL MEMBERS PRODUCED FROM UNREFINED LUNAR REGOLITH SIMULANT

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Introduction: The potential of utilizing lunar rego-lith as the raw material for manufacturing structural members is very appealing for future exploration of the Moon [1,2]. Future lunar missions will depend on in-situ resource utilization (ISRU) for structural components. Manufacturing structural components directly from unrefined lunar regolith would have the advantage of needing less specialized material processing equipment in comparison with refining the lunar regolith for its raw elements. Sintering lunar regolith has been proposed as a structural material by previous researchers but has not been evaluated for its elastic material properties. Sintering can be a highly variable process and only with the material constants can a structure be designed from this material.

Background: Sintering of actual lunar regolith has been accomplished by Taylor and Meek using mi-crowaves. However, there is not enough lunar regolith available for destructive testing to accurately quantify the mechanical material properties of sintered regolith. Lunar simulant substituted for lunar regolith in exper-iments then becomes the commonplace. The lunar simulant JSC-1A has become the standard for re-searchers in the topic of structural ISRU. Through a geothermic reaction produced by the inclusion of addi-tives, JSC-1A has been used to fabricate bricks for constructing a voissoir dome as performed by Faierson et al. [4]. In addition, Balla et. al. [5] has utilized JSC-1A, filtered for particle size, as the base material in a selective laser sintering (SLS) machine to prove the simulants additive manufacturing potential. As a proof of concept, fabrication of small solid cylinders was performed and the parameters for the SLS machine were evaluated. Focusing on developing an optimal method of sintering lunar simulant, Allen, et al. [6] compared the fabrication of bricks with two unrefined simulants, JSC-1and MLS-1.

Test Results and Data Analysis: Two batches of sintered lunar regolith simulant, JSC-1A samples with porosities 1.44% and 11.78% underwent compression testing. Analysis of the data sets were evaluated based on the comparative material density. Compressive strength compared to the shows two clear classes of material quality. The average compressive strengths of the 1.44% porosity material were 219 MPa, and 85 MPa for the 11.78% porosity material. Material properties were evaluated from the load vs. deflection data acquired. Stress, strain, modulus of elasticity, toughness, the compression strength, bulk modulus. By comparing these values with other ISRU derived structural mate-rials, sintered lunar regolith is expected to be one of the strongest material derived from lunar sources.

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B3.1-0049-18 RUSSIAN LUNAR ORBITER MISSION LUNA-26

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Russian Lunar orbiter mission Luna-26 (Luna-Resource-1 Orbiter) will have onboard 160 kg of science instrumentation to probe lunar surface and subsurface with radio waves, infrared, neutron and gamma ray emissions as well as exosphere, with UV remote sensing and full-set in-situ plasma package. The core experiment is lunar stereo-camera, which will provide images with 3-6 m resolution. The orbit scenario includes one year with near-circular orbit 60-80 km and later, which requires periodic correction maneuvers and later more permanent orbit with initial height of 140 km.Expected launch date is 2022. We present information on instrument package and mission planning

B3.1-0050-18 THE MOON ANTIPARTICLE ASTROPHYSICS STUDY

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The study of cosmic ray antiparticle fluxes and the search for antimatter in space as well as the question of the nature of "dark" matter is today one of the highest priority tasks of astrophysics which will undoubtedly continue to be actual for the next decades. In the PAMELA and AMS02 satellite experiments the energy spectra of positrons and antiprotons were measured and the upper limits of the existence of antihelium nuclei were found. However these experiments have already reached the limit on particle energy measurement. To continue the search and study of antimatter in the Universe instruments with a large aperture (also mass) and a long observation time (more than 10 years) are required. The main part of such type instrument is superconducting magnet requiring rather low temperatures. Detectors of AMC-02 and PAMELA type could be installed on the Moon. They could have a much larger aperture and a superconducting magnet at the base part of spectrometer. They will measure antiparticle fluxes up to extremely high energies with unprecedented statistics. Measurements on the Moon have a number of indisputable advantages. Small magnetic field of Moon magnetosphere and the absence of the atmosphere allow to simplify obtaining of the scientific results. The experimental setup can use large area detectors. The constant temperature at a depth of 1 meter under the surface is about -35°C that helps to cool the superconducting magnet. Furthermore there are craters (including at the south pole) where the temperature is constant -150°C and even -240°C. In this case the possibility of maintenance since long-term measurements and replacement of the failed unit of the scientific instrumentation could be preview.

B3.1-0051-18 WATER AND MINERALS EXPLORATION USING AVAILABLE TECHONLOGY ON MOON AND PLANNETS

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Choices made today, decides our tomorrow. When human are cursive to become multi-planetary species, the exploration of the planets with proper resources are crucial. The paper deals with study of available technology ready to use for the space mission to determine the quantity and mapping of one of very fundamental need for human survival, i.e. water on various planets and moon. The study deals with the selection of the available technology and instruments, on basis of efficiency, power required and cost-effectiveness. The paper also deals with the study and implementation of the instruments used in various space mission like Gamma ray Spectrometer which was used in Lunar Prospector and ODESSY mission and its trade study with neutron spectrometer and LCROSS on the basis of the power, size and efficiency ratios. Devolving an algorithm of mapping of the planet in terms of the water density. Hence determining the locations of the rich hydrogen and water content which can be a potential site of water and hydrogen extraction. The design of the equipment discussed in paper is based on the moon but could be implemented on any planet with minimal changes. The paper is an eye opener for the establishment of the humans on the different planets. It discusses about the equipment which can detect the water from the maximum altitude of 100kms above lunar surface. It demonstrate the difference of the different mapping that can be done using different equipment and hence help to select the best suitable and efficient equipment.

B3.1-0052-18 MOON GALLERY: AN EDUCATIONAL PROGRAM TO BUILD STRATEGIES FOR IMPLEMENTING AN INTERNATIONAL ART GALLERY ON THE MOON.

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Introduction - A short History of Art on the Moon:

The Moon Museum is a small ceramic wafer three-quarters of an inch by half an inch in size. The artists with works in the "museum" are Robert Rauschenberg, David Novros, John Chamberlain, Claes Oldenburg, Forrest Myers and Andy Warhol.

https://en.wikipedia.org/wiki/Moon_M useum

Fallen Astronaut: 8.5 cm aluminium sculpture by Paul Van Hoeydonck.

https://en.wikipedia.org/wiki/Fallen_Astronaut

A Gallery on the Moon project: Concept:

An international collaborative art work and Moon village promotion structure.

A crowd sourced online gallery of images created by an international group of participants.

A 10 by 10 cm patch of Lunar Rover exterior paneling is one intended venue for this Gallery.

A robust online presence, promotion structure and dissemination of information/teaching materials related to the program along with the potential of realising an art work on the moon.

Format:

A 10 x 10 cm square can be split into 100 cels of 1 cm x 1 cm. It can be split into even more equal sizes down to the pixel. A hi definition 10 x 10 cm printed image could have 1000 x 1000 pixels. That is 1 million pixels. The current initiative is to define and develop the aesthetic approach to this structure.

Digital Format:

Through an online interactive web platform individuals could input their designs into the grid.

Over a set time period and with multiple submissions from the public a variation of designs could be collected into an archive representing a broad spectrum of aesthetic approaches to a set of guidelines

Project outline/structure:

1] Research, concept development, collection of informative materials.

2] Design Implementation of website international call for artistic proposals/submissions. 3] Selection Process of submitted works and management of aesthetic organism online.

4] Potential implementation of gallery on the moon via ESA lunar rover or other craft destined for the moon.

Project Abstract:

The Moon Gallery is a proposal for defining and promoting the evolution of an aesthetic organism. The three main components of this project are research, collaboration and archive. The Research component is directed toward the development of context, informative materials and structure for the promotion of a call for artistic submissions. The Collaboration component is the implementation of the online creative tool and website designed for collecting submissions and showing a realtime evolution of the 'aesthetic organism'. The Archive component is both the dissemination of an online resource of images and artist proposals along with a possibly random selection of proposals fabricated into an actual material installation on the moon surface in the 10 x 10 cm grid format. What is an 'aesthetic organism'. A petri dish is good for growing bacteria cultures while a website is good at growing visual cultures. The 10 cm x 10 cm grid structure along with an online signup and submit image structure could develop a large amount of submissions over time with good promotion. Each section of the grid relates to both the biological concept of cells and the understanding of perspective. As the grid is filled with more and more input / imagery, the more it evolves. Over time an expanding stack of grids will create a 3d space of aesthetic intentions. What can we find out by such a construction of content. What is there to gain from studying the outcomes of such a visual social experiment? At the very least the intention of this endeavour is to raise awareness and interest in space and the moon village project along with attempting to develop a program which can have the potential to inspire new explorers of the imagination, perspective and space through a collaborative, interactive and evolving web project.

Additional Information - Current progress:

This Initiative of implementing a strategy for an International Art Gallery on the Moon is in a preliminary phase of sketching out ideas and methods while building a resource of information and developing a platform on the web for an international call to participate. In February 2018 Sitnikova and Zaklynsky have participated in meetings at Estec with MoonVillage Colleagues and have begun preparations for collaborations.

Sitnikova and Zaklynsky have initiated the residency with the MoonVillage project at Estec and will be working at Estec on a weekly basis for the next 6 months to year. We have tentatively scheduled presentations at The Royal Academy of Art and Willem De Konig Academy to engage younger artists into the project. We are in Planning stage for developing a series of presentations and Lectures at Pulchri Studio in Den Haag from May 19 to June 12, 2018. The Moon Gallery Project has been accepted into the 6th European Lunar Symposium in Toulouse, France. We have also begun a collaboration with the EuroMoonMars Team to develop a test launch of the general moon gallery project and to explore its physical implementation and interaction with moon villagers.

Connected to the research and conceptual development of this initiative we are producing a series of large scale 2 x 2 m paintings which utilise custom built drawing machines. These paintings will show a study of the grid format mentioned previously in various abstractions. We will also use these machines to plot the paths of satellites around the earth with via a collaboration with computer programmers at Estec. An Exhibition of this work along with a presentation on the initiatives development will be presented at Pulchri Studio in Den Haag on the 19th of May and run until June 12th, 2018. - http://pulchri.nl/

Other inspirations / conceptual-structural guides:

The Magic Square - https://en.wikipedia.org/wiki/Magic_square Map of the moon: - https://moontrek.jpl.nasa.gov/

Interactive Web Art Models: Generative Crowdsourcing.

http://www.thesheepmarket.com/ http://www.swarmsketch.com/

Galileo experiment on the Moon: The Hammer Feather Drop. https://history.nasa.gov/alsj/a15/a15.clsout3.html References:

The "Moon Village" Concept and Initiative. https://www.hou.usra.edu/meetings/leag2016/pdf/5084.pdf

Space is the Place - MoonVillage ArtScience Residency. http://meetingorganizer.copernicus.org/EPSC2017/EPSC2017-982.pdf

Launch Your Design With Cheops - ArtScience@ESA. http://blogs.esa.int/artscience/2017/11/02/launch-your-design-with-cheops/ Visual Material:

The below images and art work show an evolution in concepts of perspective and space. The invention of techniques to aid in the accurate reproduction of our landscape and environment led to philosophical advancements in concepts of our aesthetic and spiritual nature on one hand while on the other it led to the ability of our species to infer a map of the observable universe we exist in. Our perspective has taken us from the terrestrial to the celestial while solidifying the understanding of our place in between. The images aim to illustrate the evolution of our human perspective and our capacity for the exploration of the space within and around us.

Brunelleschi's mirror. Filippo Brunelleschi was one of the founding fathers of the Renaissance and is generally known for developing this technique for linear perspective in art.

https://en.wikipedia.org/wiki/Filippo_Brunelleschi http://farm5.static.flickr.com/4147/5051886066_86dd4b1b00.jpg

Wassily Kandinsky (Russian, 1866-1944). Thirty (Trente), 1937. Oil on canvas. 31 7/8 x 39 5/16 in. (81 x 100 cm). Musée national d'art moderne, Centre Pompidou, Paris.

http://www.wassilykandinsky.net/work-273.php

Ellsworth Kelly, 1951. Spectrum Colors Arranged by Chance II, Collage on paper. http://www.tate.org.uk/context-comment/articles/sixty-years-full-intensity

Sloan Digital Sky Survey map of the known universe. At this scale, no stars are visible. Individual galaxies like the Milky Way are also invisible. Only clusters of galaxies, super clusters and filaments containing millions of galaxies can be seen. http://www.sdss.org/

B3.1-0053-18 MOON-BASED EARTH OBSERVATION GEOMETRY ANALYSIS

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Currently most developing platforms are satellite, in contrast carry out systematic observations with moon based Earth observation platform is still a new concept. The Moon is the biggest satellite of our planet Earth, and it is the only natural satellite of the Earth, moreover it is the only place other than Earth, where humans could arrive and have arrived. Prior exploration mission orbiting or passing or landing the moon has showed the feasibility to observe the earth from the moon. Earth observation from the moon will give people different perspectives when observe the earth with sensors from the moon.

This research will discuss key issues of observation geometry of the moon-based sensor. We first designed a coordination system transformation conception from fixed seleno-centric coordinate systems to terrestrial coordinate systems, where the position, liberation and attitude of earth and moon will be obtained, and the position of the moon-base sensors is obtained by coordinate transformation. Based on these the main frame of the lunar based earth observation geometry simulation system is realized, and with the simulation system we analyzed the geometric features, overall coverage, and ground observation angle and observation time. We found that the on the moon the complete observation area (80 degrees north and south latitude, east longitude 80 degrees between the earth) have optimal space coverage, the earth target time coverage, angle of coverage; high latitudes of earth observation in this interval can be as much as possible to reduce the influence of pointing error. The aberration caused by the motion of the moon cannot be ignored. But the quadratic term of the aberration is one percent of the first item. The influence of the additional aberration caused by the relativistic effect is 10 of the negative eight power. It can be neglected in the application of lunar base to earth observation.

B3.1-0054-18 LINEAR AND NON-LINEAR WAVES NEAR THE SURFACE OF THE MOON

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Linear and nonlinear waves in a dusty plasma over the lunar dayside are considered. It is shown that the relative motion of the solar wind with respect to the photoelectrons over the lunar surface leads to the excitation of high-frequency oscillations with frequencies in the range of Langmuir and electromagnetic waves. The dust acoustic wave excitation is possible in the vicinity of the lunar terminator. The parameters of the dust acoustic solitons in the dependence on the height over the lunar surface are determined. Solutions in the form of dust acoustic (DA) solitons corresponding to the parameters of the lunar dusty plasma system have been found [1]. In [1, 2] adiabatic trapping of electrons when considering the solitons has not been taken into account. However, DIA localized wave structures (in particular, solitons) can be accompanied by either positive or negative electrostatic potential, the positive being the potential well for electrons. The localized wave structure properties with taking into account the influence of the effect of adiabatic trapping are determined.

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B3.1-0055-18 LOW-HYBRID WAVE TURBULENCE IN THE INTERACTION REGION OF THE EARTH'S MAGNETOTAIL WITH DUSTY PLASMA NEAR THE MOON

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The lower-hybrid wave turbulence that take place under the interaction of the Earth's magnetosphere with dusty plasma near the lunar surface is considered. It is shown that the lower-hybrid waves can be excited due to the onset of linear hydrodynamic instability, which is caused by the relative motion of the magnetosphere and charged dust grains. The dynamics of the development of lower-hybrid wave turbulence is investigated. It is described in terms of strong turbulence theory, where the modulational interaction is important. The energy density of oscillations, the effective collision frequency, and the electric fields arising in the system are determined for lower-hybrid wave turbulence. The obtained effective collision frequency should be taken into consideration when deriving hydrodynamic equations for dusty plasma particles with allowance for turbulent plasma heating.

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B3.1-0056-18 GROUND CALIBRATION AND UPDATED QUANTITATIVE ANALYSIS RESULTS OF CE-3 APXS

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The Active Particle-induced X-ray Spectrometer (APXS) is one of the payloads on board the Yutu rover of Chang'E-3 mission. During the operation on the Moon, two in-situ measurements of the lunar regolith were conducted in the northern (19.51W, 44.12N) of Mare Imbrium.The abundance of major (Mg, Al, Si, K, Ca, Ti, Fe) and mirror (S, Cr, Sr, Y, Zr, Nb) element was achieved using the fundamental parameter method based on ground calibration of geochemistry reference samples. The results show that the regolith around the landing site contains abundant Fe, medium Ti and relatively high Al.

B3.1-0057-18 LUNAR DUST ACCUMULATION ANALYZER

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The Human race is on it hastens to be a multi-planetary species and the primary destination would be the Moon for obvious reasons. While colonizing the Moon comes into the picture, many aspects have to be taken into account and the most important factor is the lunar dust. Studying the Lunar dust deals pivotal figure in finding a sustainable livelihood in the lunar surface. As of now, it is known that lunar dust is abrasive and clingy as well as it is the fine powder glass with magnetic behavior. These properties of lunar dust make it extremely hostile for life as well as dangerous for the life-supporting equipment because of clogging up. However, there are still some advantages such as the lunar soil can be easily microwaved into flat surfaces, meaning roads and landing/launching pads can easily be created for future missions. Therefore the main mission objective is to design, build and operate a dust analyzer package which mainly consists of two parts, a magnetometer, which will answer to the magnetic properties of the lunar dust, and a set of solar cells, which are used in determining how fast is the dust accumulation takes place in moon on a solar panel, by calculating the net current drop from the solar cells. The main reason for this experiment is that we need to get an idea about the possible effects of lunar dust in the future of energy production and the feasibility of electricity generation for a long-term from using solar power plants. Using the magnetic flux obtained reading we will develop a microwave sintering process that can be used for converting lunar dust into flat surfaces, which can be used to develop Infrastructure on the moon in future. Keywords: multi-planetary, lunar dust, magnetic, microwave, magnetometer, solar cells, energy, electricity, magnetic flux, microwave sintering, Infrastructure.

B3.1-0058-18 WATER MINING IN THE SPACE

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Water appears the highly sought product in space. There is hope to find water ice under ever shadowed lunar polar regions. But even this hope will be proved, it does not mean that water mining on the Moon will be successful, because hardness of water ices at extremely low temperature is comparable with diamond hardness. As ever shadowed territories have lack of solar energy, the water mining on the Moon may become unreliable desire. At the same time our Solar System has a lot of water ice in its outer parts. All satellites of giant planets as well as all Kuiper Belt objects consist mainly of water ice. Comet nuclei contain water ice too, and they often have orbits with perihelion distance less then 1 a.u. Some of comets are on orbits that even cross the Earth orbit. Loosing volatiles and being decayed, they produce meteoroid streams. Among tiny refractory particles that burn in the Earth atmosphere when collide it, there are some larger fragments of dispersed parent comet nuclei. These “minicomets” blast in the Earth atmosphere from 10 to 20 times each year, so the total number of minicomets that cross Near-Earth space may be up to 40000 a year. If average diameter of minicomet poses to be 3 meters, it is about 15 m3 of snow or ices and contain at lest 10 ton of pure water. Earlier we proposed to use such mimicomets as kicking bodies to push away dangerous asteroids. It is not hard technical problem to deliver to a minicomet simple vapor rocket engine (“Gheron mahine”). This jet will use unlimited solar energy for heating of cometary material to high temperature an use it as propellant body. Just the same device may be used to capture minicomets in the vicinity of the Earth and to deliver them to Near-Earth orbits or even to the Moon surface. Rocket engines that use solar energy and material of captured bodies can be used many times in space. This allows water mining in space in any necessary amounts without supply from the Earth.

B3.1-0059-18 ORBIT DETERMINATION OF CE-5T1 IN EARTH-MOON L2 LIBRATION POINT ORBIT WITH GROUND TRACKING DATA

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The CE-5T1 extended mission is the first of China to fly spacecraft in the Earth-Moon Lissajous regions. It stayed at the L2 region for about 40 days from Nov. 2017 to Jan. 2018

. The Shanghai Astronomical Observatory (SHAO) team utilizes the SODP (SHAO Orbit Determination Program), using a batch least squares method, to process range, Doppler and VLBI tracking measurements from ground stations. The tracking accuracy for range, Doppler, VLBI delay and rate are typically 1 m, 1 mm/s, 1 ns and 1 ps/s. The typical accuracies of orbit determination solutions are on the order of several hundred meters in position and 1 cm/s in velocity with 5-7 days tracking data. The combination of VLBI data with range/Doppler data can improve the orbit accuracy in the L2 region comparing with the range/Doppler data only. The technique and analysis method used can provide a baseline for future Earth-Moon libration point spacecraft mission, including CE-4 relay satellite in the L2 region.

B3.1-0060-18 PROTECTED ANTIPODE CIRCLE (PAC) ON THE MOON FARSIDE AND AWAY FROM THE MOON VILLAGE

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The Moon Farside is the only place in space, and not too far from the Earth, where radio transmissions and noises produced by Humanity on Earth may not reach since the spherical body of the Moon blocks them, acting like a shield. Thus, protecting the Moon Farside from all kinds of non-scientific future exploitations (e.g. real estate, industry and military) has long been a concern for many far-sighted space scientists as well as for several IAA Academicians.

We started facing this problem in the 1990s, when the French radio astronomer Jean Heidmann (1923-2000) of the Paris Meudon Observatory first promoted an IAA Cosmic Study about which areas of the Moon Farside should be reserved for scientific uses only. But Heidmann passed away on July 3, 2000, and his work had to be continued by others. This author took over his IAA Cosmic study and a paper describing both the scientific and legal aspects of the problem was published in 2008.

Later, on June 10, 2010, this author was the first scientist to present the case for the Moon Farside Protection at the United Nations Office of Outer Space Affairs in Vienna during a meeting of UN-COPUOS, the United Nations Committee on the Peaceful Uses of Outer Space. Unfortunately, the undeclared but quite real “current, new race to the Moon” complicates matters terribly. All the space-faring nations now keep their eyes on the Moon, and only the United Nations might have a sufficient authority to Protect the Farside and keep safe its unique “radio-noise free” environment.

But time is money, and the “Moon Settlers” may well reach the Moon before the United Nations come to agree about any official decision concerning the Farside Protection. Quite an urgent issue.

In this paper, we propose that the new “Moon Village” supported by the vision of the ESA Director General, Jan Woerner, be located outside the PAC (obviously not to interfere with the detection of radiation coming from space) but also south of the PAC, to be “close” to the South Pole as much as needed to benefit of water there.

It thus appears the best venue for the “Moon Village” would be on or around the 180 degree meridian and south to the -30 degree in latitude of the PAC, possibly much more south of that, almost at the South Pole, thus resolving Moon Village location issue.

B3.1-0061-18 GEOLOGICAL MAP OF LUNAR IMPACT BASINS

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Abstract According to the requirements of 'Chinese 1:2.5 M Geologic Mapping of the Global Moon' project the whole impact basins were divided into five geological units which mainly identified by morphological characteristics and formation mechanism: central peak ring formation, basin rim formation, basin wall formation, basin floor formation, ejecta formation. It is much more normalized, unified and practical than others' work about mapping impact basins like some map in research articles and the American geological map in which every impact basin contains many geologic units with rock composition and geological age. Its attribute table contains basins' names, age, apparent diameter, apparent depth, each impact ring diameter, gravity anomaly, unit type, unit area. enditemize beginitemize

The whole lunar work was done in ArcGIS. Combining the formation theory of impact craters and interpretation results from LRO image, LOLA, M3 and IIM, the lunar impact crater whose diameter was greater than 200km and not have central peak was chosen as the impact basins. Then, 76 impact basins were interpreted out in our work. enditemize beginitemize

Key Words lunar impact basin; 200km; five geological units enditemize

B3.1-0062-18 HIGHLIGHTS OF THE ITALY-SSERVI PARTNERSHIP

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The Solar System Exploration Research Virtual Institute (SSERVI) is a NASA research entity with scientific focus on celestial bodies of the Solar System that can be considered as intermediate steps in the roadmap for human exploration, namely the Moon, Near Earth Asteroids, the Martian moons Phobos and Deimos and their surrounding environments. The SSERVI central office is at NASA Ames Research Center and, as virtual institute, SSERVI funds investigators at a broad range of domestic institutions, bringing them together via virtual technology, along with international partners, that can be involved at different levels. In this frame, the "SSERVI Italian node" was established in September 2014, when the Istituto Nazionale di Fisica Nucleare (INFN) of the Italian Republic became an Affiliate partner, with the main research topic on retroreflectors for planetary exploration. The Italian partnership in SSERVI's international program evolved to the Associate level, when the NASA and Italian Space Agency (ASI) signed a dedicated Implementing Arrangement, during the Workshop held on 14th June 2017, at the Italian Embassy in Washington DC. Since then, ASI has taken the role of Italian Principal Investigator and coordinator of the national scientific community involved in Exploration scientific activities, with particular reference to the above mentioned target in the Solar System. The Associate Partnership has been based on the "Italian Proposal for the participation to the NASA SSERVI International Partners Program -Associate membership Application", issued by ASI in June 2016 and reviewed and accepted by NASA in the following months. The Proposal summarize the main research areas where the Italian scientific community, mainly composed by research institutes like INFN and Istituto Nazionale di Astrofisica (INAF) and national Universities, is active. This paper describes the premises and perspectives of the Italian partnership in the SSERVI International Program, based on common research interest, in order to promote joint scientific activities, in preparation of the collective challenge to bring humans to Lunar and Martian surfaces.

B3.1-0063-18 ORBIT DETERMINATION USING VARIOUS MEASUREMENTS FOR INTERPLANETARY MISSIONS

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For the interplanetary navigation, the regime offers little dynamics thus requiring an extensive amount of time and tracking data to attain a solution. In order to increase the accuracy of the interplanetary orbit determination, it is necessary to use the S/C-based observations as well as the Earth-based data, such as the optical data taken by the onboard camera, the GNSS data and so on, which offered different information of the spacecraft (S/C) besides the line of sight direction. The results shown that the optical data taken by the onboard camera could improve the accuracy of the mars-transfer orbit determination by 1 magnitude. The measurement data of the GNSS receiver with high sensitivity on CE-5T1 spacecraft was also analyzed. The position error using GNSS single-difference pseudo range in the 1.5 hour arc is less than 109 m.

B3.1-0064-18 HOW TO IMPROVE THE QUALITY OF HXI IMAGING

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The Hard X-ray Imager on board ASO-S(Advanced Space -based Solar observatory) is a fouriersynthesis-type imager for solar flare observations;it measures a set of spatially modulated photon counts with one hundred,idependent,bigrid modulation collimators and an image is reconstructed from these data using sophisticated image synthesis procedures,such as the Maximum Entropy Method(MEM) and PIXON.In order to ensure the quality of the image, we take measures from the following aspects: 1, Fully understand the impact of the shift between the top and the bottom grids through the simulation on the image and the corresponding correction effect; 2, Fully understand the impact of the twist between the top and the bottom grids through the simulation on the image and the corresponding correction effect ; 3, intends to use the MEM method to improve the quality of HXI on orbit data, The quality of HXI imaging can be guaranteed from the result of the simulation.

B3.1-0065-18 IS THE SPHEROIDAL APPROXIMATION OF THE MOON IMPORTANT FOR HIGH-RESOLUTION GLOBAL GRAVITATIONAL FIELD MODELLING?

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Global gravitational field models for terrestrial planets and small bodies are usually developed in terms of a series of spherical harmonics. The corresponding expansions are strictly convergent only on or above the Brillouin sphere, i.e., the sphere enclosing all gravitating masses. However, when modelling gravitational fields of oblate or prolate planetary objects, the spheroidal approximation and the corresponding spheroidal harmonic expansion are more appropriate, particularly for high-degree gravitational models from Gravity Recovery And Interior Laboratory (GRAIL) and for precision navigation of satellites orbiting closely around the small bodies like OSIRIS-Rex. In this contribution, we consider a realistic spheroidal shape of the Moon and examine its consequences to the lunar global gravitational fields. The lunar Brillouin spheroid fits the shape of the Moon much better than the Brillouin sphere. In particular, the lunar Brillouin spheroid differs from the Brillouin sphere by 600 m at the poles, where improved gravitational models are expected from the spheroidal modelling and analysis. For the purposes of this study, we derive the spectral form of the Newton integral in the spheroidal approximation and develop an efficient computer algorithm for the global gravitational field modelling. Accuracy of the numerical algorithm is tested with known analytical solutions of the spheroidal gravitational potential. We next calculate spheroidal Bouguer gravity disturbances on the surface of the lunar Brillouin spheroid. The results are compared with those synthesised from spherical harmonics on the Brillouin sphere. The differences are investigated and quantified for different spectral bands and at different spatial regions to examine our new spheroidal gravitational models for the Moon.

B3.1-0066-18 MEMORANDUM IN OPPOSITION TO PROPOSAL TO WEAKEN THE MOON TREATY

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Memorandum in Opposition to Proposal to Weaken the Moon Treaty (keywords: moon, treaty, law, commerce, chm)

by Dennis O'Brien The Space Treaty Project Abstract

In two recent articles in The Space Review, Vidvuds Beldavs of the University of Latvia argues that the Moon Treaty must be revised so that investors in a future space economy can achieve a sustainable return on their investments. Although creation of a sustainable economic model in outer space is essential for humanity's future there, his proposed revisions throw out the baby with the bathwater.

Mr. Beldavs' main concern, shared with many others, is that the declaration that outer space is the "common heritage of mankind" (CHM), made in both the Moon Treaty and the original Outer Space Treaty of 1967, precludes the establishment of property rights sufficient to establish and sustain a space economy

Mr. Beldavs' proposal:

"The moon and other cosmic bodies and their natural resources are the common heritage of mankind to explore and to use. While the moon is a subject of interest for mankind as whole this does imply that the moon and its resources are the property of mankind or that rents should be collected by an international authority for their use, which finds its expression in the provisions of this Agreement, in particular in paragraph 5 of this article." (change highlighted)

(Note: It appears that Mr. Beldavs intended to say, "this does not imply that the moon and its resources are the property of mankind or that rents should be collected. . ." Otherwise the paragraph and his entire argument do not make sense.)

The short answer to these concerns is that the international regime of laws will provide private enterprise the necessary legal rights and protections while ensuring that the benefits of commercialization are realized by all of humanity. But that legal structure and the agency that implements it must have the underlying legal and moral authority that the CHM and the Moon Treaty provide.

The real issue at this time is how such payments would be collected and distributed. A new agency, perhaps an Agency for International Development of Outer Space, could be created to receive such revenues and determine their best use, including distributing them to lessdeveloped countries. The structure, policies, and procedures of any such agency would need to be determined as part of the "international legal regime" created by

the parties to the action. But if the authority to collect revenues was specifically removed from the Treaty, then there would be no legal basis for such an agency and no incentive for the space-faring nations and companies to create a mechanism to share the economic benefits of space commerce with the rest of humanity. For all practical purposes, the Treaty would be dead.

Although some oppose such a regime of laws and regulations on a philosophical basis, most businesses want a legal regime that they can rely on to reduce the uncertainty that investors deplore.

The proposed solution is to allow the private ownership of property in outer space. But the right to economic benefits does not require private ownership. Such rights can be guaranteed by the leases, use permits, etc. provided by the international agency that is established by treaty. That is the kind of certainty that allows for rational economic decision-making.

Using the revenues created to assist developing countries is not just theoretical. It is already possible to fund a space mission that directly engages such countries. The United Nations recently announced an agreement with Sierra Nevada Corporation to use SNC's Dream Chaser reusable space plane to carry the experiments of dozens of countries to orbit and safely return them when their science is complete. Only the funding is needed, funding that could come from benefits of space commerce that other countries/companies are beginning to realize.

The weakening of the CHM in the Moon Treaty would destroy not only its legal authority for an international regime of laws, but also its moral authority to affect customary international law. Humanity would cede control of its own destiny to the unseen hand of economic forces and political power. This would be a far greater "loss of sovereignty" than any claimed by individual nations.

The proposed solution is not only harmful to humanity, but also to free enterprise. Businesses need the certainty that a legal regime provides to make rational economic decisions. Humanity needs the protections that a legal regime provides so that everyone will share the benefits realized from the exploration and use of outer space.

We are currently living in an age when war, violence, and neglect are weighing heavy on the human spirit. People are increasingly feeling out of control of their own lives and are losing hope for the future. Our mission, the mission of the Moon Treaty, is to restore that hope, to create that shining city on the hill that will light the way for all.

This is not the time to shy away from our responsibilities. There will be only one time when humanity leaves its home planet, one chance to establish a pattern that will ripple far into the future. Full implementation of the Moon Treaty will protect businesses, big and small, and will free up the creativity and innovation that have long been the hallmark of free enterprise. At the same time, it will ensure that all of humanity benefits from space exploration and commerce, that no one is left behind.

As Klaatu reminded us, the choice is ours.

B3.1-0067-18 HUNGARIAN TEAM PULI TOWARDS LUNAR SCIENCE AND EXPLORATION

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Moon, our nearest neighbor in space which ignited our efforts towards outer space exploration in the 1960s and that led to several manned and unmanned missions in quick span of time to explore it and search for the sources of life and environment on a outer space body, is presently again in the spotlight as we are preparing to go to Mars and beyond. It is believed that most likely before humans go to Mars, manned mission to Moon in the 21st century is most certain. Not only using Moon as a base camp or a stopover towards manned Mission to Mars but Moon has several mysteries hidden in it, which, if found and explored, can be utilized to help in establishing the human colonies on Moon. In this direction several organisations around the world are preparing towards future exploration of Moon using Landers, Rovers and Orbiter Missions. Puli Space Technologies is a Hungarian startup which was founded in the year 2010 to participate in the Google Lunar XPRIZE Competition. The GLXP's objective was to design, build and send a craft to Moon to take panoramic pictures of the Lunar surface and transmit it back to Earth. Team Puli developed a unique rover with its "whegs" (Pentagon shaped wheel+legs), designed in such a way that the whole Rover can flip 360 Degree and stand back to its normal position if the Rover is obstructed by any rock or similar object.The Puli Rover was succesfully tested in various field simulation missions in Morocco [1], Hawaii and Austria [2]. Puli Space Technologies continues its journey on to the Moon after the GLXP to become the first Hungarian organisation to reach to Moon

B3.1-0068-18 LUNAR LAVA TUBES: A POTENTIAL OPTION FOR FUTURE HUMAN HABITATION ON THE LUNAR SURFACE

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Introduction: For the past several years it has been suggested that the next manned mission to the Moon could make use of lunar lava tubes as habitable shelters and/or storage areas. The lava tubes on the moon would provide protection against cosmic radia-tion, micrometeriods, meteorites, and other natural hazards while also providing a habitable environment with relatively stable temperatures compared to the wildly fluctuating day/night temperatures on the Moon's surface.

Benefits: There are numerous potential benefits to building a manned lunar base inside a lava tube. Due to the more stable temperatures in the tube, space suits and base modules would not require as extensive of temperature regulation systems as on the surface of the moon. This would allow astronauts a greater de-gree of freedom of movement while inside the tube. Eliminating the need for bulky insulation also means a lunar base only requires pressurization, therefore im-proving the size and portability of base components (this is assuming that the risk of debris falling from the roof of the tube is negligible). The protection from cosmic radiation inside the tubes presents the possibil-ity of a long-term manned lunar mission without the need for as extensive of shielding from radiation. Lu-nar lava tubes may also provide the opportunity for mining operations and geological study from directly beneath the Moon's surface. Study of the tubes them-selves may provide clues as to how the Moon was formed.

Further Study: More information on the exact structure and location of lunar lava tubes is required. At the present moment, only observational evidence has been found to support the existence of lava tubes on the Moon. Unmanned missions using lunar rovers and/or probes must be conducted in advance of a manned mission in order to determine the suitability of a tube for human habitation. Research must also be conducted in order to determine safe and efficient methods of moving supplies, astronauts, and other equipment in and out of the tube. Due to a lower gravi-ty and absence of atmosphere, lunar lava tubes could be significantly larger than lava tubes on Earth.

Seismic Activity: The exact cause and intensity of seismic activity on the moon is currently unknown. Therefore, study on the seismology of the Moon must be conducted in order to measure the potential risk of a lava tube collapsing or debris falling from the ceiling of a tube. Methods for safely clearing the floor of a tube of debris, boulders, or other potential obstructions must also be looked into.

Power: Considering the scenario where the main base and living quarters are located inside of a lunar lava tube, options for power generation and storage would have to be examined. If the power is generated from outside the tube (e.g. solar panels), an appropriate power transfer system and backup system must be established inside the tube, or vice versa if power is generated inside the tube.

Conclusion: The usage of lunar lava tubes for human habitation and/or storage in future manned missions to the Moon is largely theoretical at this point in time. There are unquestionably great potential bene-fits to the concept, however a considerable amount of study and further unmanned missions to the Moon will be required before any conclusions regarding the via-bility of the tubes can be reached.

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B3.1-0069-18 NEW CONSTRAINTS ON THE ESCAPE OF SODIUM AND POTASSIUM FROM THE MOON

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Recent measurements and models of the lunar alkali exosphere enable us to better understand the effect of the Sun on the escape of the Moon’s weak atmosphere. Sodium and potassium gases are important tracers of microphysical processes on the Moon because they can be easily observed from Earth as well as from lunar orbiters. Comparing exospheric transport models to recent high-resolution spectroscopic measurements from Earth, we may significantly constrain the velocity distribution of alkalis liberated from the lunar surface and the surface release processes. We find that a systematic increase in Doppler width towards full Moon phases is consistent with photon stimulated desorption with a high speed tail. Additionally, residual Doppler widths correlate to the solar wind flux measured by ARTEMIS, a finding that suggests non-negligible contributions by sputtering.

B3.1-0070-18 REGIONAL RECOVERY OF THE LUNAR GRAVITATIONAL FIELD BY INVERTING GRAIL LINE-OF-SIGHT GRAVITATION OBSERVABLES

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The Gravity Recovery And Interior Laboratory (GRAIL) satellite mission mapped the global gravitational field of the Moon with unprecedented accuracy (several mGal) and resolution (12 km). The fundamental inter-satellite tracking data have been exploited for estimating various lunar global gravitational field models. However, such global models in terms of spherical harmonic coefficients make use of a constraint (also known as Kaula's rule). This may lead to undesirable smoothing over different regions. In this contribution, we discuss a new approach for high-resolution regional recovery of the lunar gravitational field by integral transforms. Firstly, we derive integral estimators relating the GRAIL line-of-sight gravitation to the disturbing potential and gravity disturbance on the lunar surface. The integral estimators are composed of two terms, i.e., the truncated integration and the effect of the distant zones. Secondly, we validate the accuracy of the integral estimators in a closed-loop simulation. We investigate the optimal parameters for the integration radius and the maximum degree/order of a priori gravitational field model. The numerical stability of our regional integral inversion is studied. Thirdly, we determine the disturbing potential and gravity disturbance at different regions of the lunar surface. We use GRAIL Level-1B and SPICE orbital data combined with a priori gravitational field model. Finally, our regional solutions are compared with other GRAIL global lunar gravitational field models.

B3.1-0071-18 LUNAR SETTLEMENT BASED ON ITS CRATERS' CHARACTERISTICS

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Moon has been one of most considered subjects of space research since 20th century. It is because of different reasons such as its close distance to earth, concerns about future climatic conditions of earth in order to have living camps on moon, and its potential characteristics for general and particular space researches. If we want to focus on living camps and conditions on the moon, we must consider various important factors such as water and other resources discoveries and conditions, air pressure, and low gravity of the moon. In this way, one of the potential and effective places on the moon could be the edge of lunar craters because of protections from rays and meteoroids, craters' inside-moon surface views, two sides access for discoveries, and lunar dust as main-protective local material. Also the craters itself as volcanic action or as meteoric impact, could be suitable places for any researches about lunar minerals. On the other hand, from physiological point of view, astronauts will use less energy and have less negative physiological impacts by the help of two sides slopes from the camp toward the crater's surface and toward the moon's surface.

B3.1-0072-18 RETURN TO THE MOON: FINDINGS FROM THE LUNAR SCIENCE FOR LANDED MISSIONS WORKSHOP

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The Lunar Science for Landed Missions workshop was held at NASA Ames Research Center January 10-12, 2018. The meeting was attended by both lunar scientists and representatives from commercial companies, and was jointly sponsored and co-chaired by SSERVI and LEAG. The goals of the workshop were to produce a set of priority targets for near-term landed missions on the Moon, primarily, but not exclusively, from commercial exploration firms interested in pursuing science missions to the lunar surface, and to foster discussion between scientists and commercial companies about a path forward to meet current lunar science goals. Scientists were invited to submit abstracts detailing high-priority landing sites on the surface of the Moon to which landed lunar missions would fulfill community science goals. These contributed talks presented landing site options across the surface of the Moon that would meet scientific goals in a wide variety of areas, including cratering processes, age determinations, volatiles, volcanism, magnetism, geophysics, and astrophysics. Invited talks and panels from commercial attendees focused on new technologies to enable landed lunar missions and potential payloads of lunar landers. In addition, invited talks from international colleagues addressed space programs in Japan, and the European Space Agency. The workshop findings are presented in a summary report of prioritized landing sites on the lunar surface prepared for the NASA Science Mission Directorate. This talk will report on the findings (high-priority landing sites, overarching science themes) from the the workshop.

The contributed science talks centered around 5 overarching themes:

Impacts: Establish a precise impact chronology, and better understand impact processes

Volatiles: Understand the source, form, and concentration of lunar volatiles

Volcanism: Determine the origin and evolution of lunar volcanism through space and time

Geophysics/Tectonism: Constrain the interior structure and evolution of the Moon

Space Weathering/Astrophysics: Examine regolith formation and space weathering processes, including astrophysical and cosmological analyses

Each proposed landing site within these themes works to meet science goals laid out by the 2007 National Research Council's (NRC) Scientific Context for the Exploration of the Moon (SCEM) report, and the Vision and Voyages for Planetary Science Decadal Survey. Each landing site also meets exploration goals established through Strategic Knowledge Gaps (SKGs) determined by NASA's Human Spaceflight Architecture Team and two LEAG Specific Action Teams.

An emerging theme from the workshop was the need for advancements in technology in order to meet primary science goals. The necessary technological advancements included automated hazard avoidance, cryogenic sampling, caching, and transport, landers and rovers that can survive extreme cold and darkness, and permanent lunar infrastructure in the form of a communications relay. A dedicated communications relay is perhaps the most enabling of the above technologies, as over half of the landing sites discussed at the workshop have the potential for communication difficulties due to locations on the lunar limb or farside.

B3.1-0073-18 NEW DEVELOPMENTS IN X-RAY DIFFRACTION AND X-RAY FLUORENCE FOR LUNAR APPLICATIONS

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Introduction: X-ray diffraction (XRD) is a general purpose technique used for definitive, quantitative mineralogical analysis. The MSL CheMin instrument, the first XRD instrument flown in space, established the quantitative mineralogy of the Mars soil [1], char-acterized the first habitable environment on another planet [2], and provided the first in-situ evidence of Martian silicic volcanism [3]. CheMin is now employed in the characterization of the depositional and diagenetic environments of lacustrine mudstones that comprise the lower strata of Mt. Sharp [4]. CheMin requires substantial sample preparation. Deployment of XRDs for smaller missions to the moon will require simpler sample preparation and decreased instrument size and complexity. Efforts in these direc-tions are underway.

XRD with Limited Sample Preparation: XTRA (Extraterrestrial Regolith Analyzer) is intended to analyze fines in as-delivered surface regolith, without sample preparation [6]. XTRA can be configured in transmission or reflection geometry using vibrated cells for as-delivered powders, allowing direct analysis of materials scooped at the surface.

XRD without Sample Preparation: Hybrid-XRD (HXRD) is a concept under development to analyze rocks or soils without sample preparation [7]. If the material is sufficiently fine-grained, a powder XRD pattern is obtained, similar to CheMin or XTRA. With coarsegrained crystals, the white bremsstrahlung radiation of the tube is diffracted into single crystal Laue patterns. Unlike typical Laue applications, HXRD analyzes the energy of each Laue spot, enabling the measurement of single crystal Bragg diffractions. Dedicated crystallographic software has been developed for identification of minerals responsible for the Laue patterns.

High resolution XRD: With CheMin and any of the previously described XRD concepts, instrument resolution suffers from the system miniaturization and is limited to about 0.3° 2. A planetary XRD based on Guinier geometry is under development to provide a compact high-resolution instrument. This design hinges on the use of a parafocusing geometry with a curved 2D detector to cover the angular range of interest. A substantial gain in resolution has been demonstrated with a basic proof-of-concept instrument. Both reflection and transmission geometries can be developed with the Guinier design and are being explored as part of a PICASSO funded project.

X-ray Fluorescence Imaging: MapX is a full-field XRF imager which employs a CCD detector operated in single photon counting mode. The number of electron hole pairs created by an incident photon is energy dependent, and by summing multiple frames it is possible to produce XRF spectra for each pixel of the CCD. The same technology is employed in the CheMin instrument on MSL, which provides qualitative bulk compositional information as well as spatially-resolved diffraction information for mineral identification. MapX combines this CCD with a micro-pore optic (MPO) which focuses X-rays 1:1 onto the CCD. The resulting instrument is capable of producing XRF maps with a resolution of 100 m. Data is currently being collected using two prototypes employing X-ray tube sources, MapX-II and MapX-III, which are at TRL3 and TRL4 respectively [8,9].

Development of High TRL Components: Rapid and cost-effective development of flight instruments requires the availability of mature technologies of the critical components. High TRL subsystems are being developed for future XRD and XRF instruments in collaboration with industry partners who can provide expertise in design and manufacturing of flight subsystems. Special full-frame and frame-transfer X-ray CCD detectors are being developed with e2V (UK); some detectors featuring internally cooled packages. Custom FPGA based electronics for low noise CCD operation with embedded data processing capabilities are under development with Baja Technology. Miniature microfocused X-ray tubes capable of operation

>10W are being developed by RTW of Germany with power supplies developed by Battel Engineering.

Deployment Opportunities: XRD and XRF instruments will be proposed for future lunar instrument opportunities. Instruments can be tailored to the specific mission constraints (robotic or human missions) and will be comprised of combinations of the features and flight hardware presented above.

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B3.1-0074-18 THE LUNAR LANDER NEUTRON & DOSIMETRY (LND) EXPERIMENT ON CHANG'E4

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Chang'E4, the next Chinese mission to the Moon, is planned to launch in December 2018 and to land on the far side of the Moon in the South Pole Aitken Basin. The mission consists of a lander, a rover, and a communication relay around the Earth-Moon L2 libration point. Here we describe the Lunar Lander Neutron Dosimetry experiment (LND) on the lander. It consists of a stack of 10 segmented Si solid-state detectors (SSDs) which forms a particle telescope to measure charged particles (electrons 150-500 keV, protons 12-30 MeV, and heavier nuclei 15-30 MeV/nuc). A special geometrical arrangement allows observations of fast neutrons (and g-rays) which are also important for dosimetry and cosmic-ray exposure of lunar soils. Thermal neutrons are measured using a very thin Gd conversion foil which is sandwiched between two SSDs. Thermal neutrons are sensitive to subsurface water and important to understand lunar surface mixing processes. Despite the aim of landing humans on the Moon in the not too distant future, radiation measurements in the vicinity of the Moon are remarkably scarce. Fairly recent measurements in lunar orbit were provided by the Radiation Dose Monitor (RADOM) on board Chandrayaan-1. The spacecraft reached its operational 100 km circular orbit on November 12, 2008. Measurements showed a dose rate of 0.23 mGy per day averaged over 3545 hours of measurement time (20/11/2008 to 18/5/2009). Newer measurements have been provided by the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) instrument on board the Lunar Reconnaissance Orbiter (LRO). CRaTER measured a radiation exposure of about 0.22

0.27 mGy per day in its 50 km orbit. In comparison with these meager orbital data, there is a real dearth of data on the lunar surface. The current knowledge about the radiation environment on the surface of the Moon is based exclusively on calculations using radiation transport models with input parameters from models for the galactic cosmic ray spectra and for solar particle events. This is highly questionable, especially since we know that these models are fraught with uncertainties. Thus LND will provide the first active dosimetry measurements on the surface of the Moon. In this presentation we will discuss the science, implementation, and status of LND on China's Chang'E4 mission.

B3.1-0075-18 CONSTRAINING THE RATIO OF MICROMETEOROIDS FROM SHORTAND LONG-PERIOD COMETS AT 1 AU FROM LADEE OBSERVATIONS OF THE LUNAR DUST CLOUD

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Because of the lack of atmosphere, small meteoroids impact the Moon surface at high speeds. The impacts release plumes of dust from the surface termed the secondary dust ejecta cloud. The Lunar Atmosphere and Dust Environment (LADEE) was a NASA satellite launched in 2013 with several scientific objectives, one of which was to measure and characterize this ejecta. LADEE showed several surprising temporal features of this cloud. We interpret recent observations of the secondary dust ejecta cloud around the Moon from the Lunar Dust Experiment (LDEX) on board the LADEE spacecraft with help from dynamical models of meteoroids. Results suggest that in order to match the spatial structure of observed ejecta profiles, the flux of meteoroids on the Moon must be primarily provided by short-period comets with an excess ratio of at least 1.3:1 compared to long-period comets. This ratio increases significantly if the dependence of the ejecta yield on impactor velocity is stronger than generally believed. The model accounts for the orbital geometry of LADEE and shows no indication of a large asymmetry in the meteoroid flux impacting from the Helion and Anti-Helion directions.

B3.1-0076-18 LUNAR ULTRAVIOLET COSMIC IMAGER (LUCI)- NEAR UV ASTRONOMICAL OBSERVATIONS FROM THE LUNAR SURFACE

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Observations from the Moon provide a unique opportunity to observe the sky from a stable platform far above the Earth atmosphere. This is especially relevant in the ultraviolet (UV) field. Hence we have explored the prospects for UV observations from the lunar surface, mainly the feasibility, scientific outcomes and possible configuration of UV telescopes. To realize this, we have been in collaboration with TeamIndus, (an entry to the Google Lunar X prize competition), to put a UV telescope (LUCI-Lunar Ultraviolet Cosmic Imager) on the Moon as a piggyback payload. LUCI is an all spherical near UV (passband:200 -300 nm) telescope with a field of view of 0.46° x 0.34°. LUCI will be mounted on the lunar lander as a transit telescope and will perform a survey of the available sky from the surface of the Moon. It has potential capability of delivering unique science - perform a survey of the available sky in the NUV domain from the surface of the Moon, with the aim to detect bright UV transients such as SNe, novae, TDE etc. The instrument has been assembled in the class 1000 clean room at the M.G.K Menon Laboratory for Space Sciences and is awaiting various environmental tests. Here we will describe the various science cases of LUCI and will also cover the design and development of the instrument. We will also briefly explain the assembly, integration, and calibration of LUCI.

B3.1-0077-18 MULTI-OBJECTIVE OPTIMIZATION FOR SPACECRAFT STATION KEEPING ON LIBRATION HALO ORBIT OF EARTH-MOON SYSTEM

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There are five equilibrium points (three collinear libration points and two triangle libration points), called libration or Lagrangian points, in the Circular Restricted Three Body Problem (CRTBP) model. The existence of periodic halo orbits around such libration points has been known for many years and has been focus of much astronomical observation mission, research in celestial mechanics and deep space exploration. The important applications of libration point orbits have been paid more attentions from all over the world.The halo orbit around L2 point (a collinear libration point at the far-side of the moon) in Earth-Moon system can provide an approach to deal with the far-side communication problems of the moon, due to the same face of the moon always faces the earth. But the halo orbits around the L2 point are unstable, the necessary orbit station keeping operations are required for spacecraft in order to maintain around L2 libration point for a long time. In the past, many of strategies dealing with halo orbits station keeping have been researched. The Target strategy and the Floquet strategy are the most efficient solution for halo orbits station keeping problem. The divergence of unstable flow is restrained to realize orbit station keeping in Floquet strategy. The guidance law is designed for guide spacecraft close to target orbit in Target strategy. Although the fuel consumption in Floquet strategy is less than Target strategy, Target strategy has advantage in engineering implementation due to its common structure of spacecraft control systems. This paper adopts the time-variant LQR optimal control theory deal with the problem of Spacecraft Station Keeping on libration Halo Orbit of Earth-Moon System based on the Target strategy. Under the contradict objectives, fuel consumption and orbit maintaining precision, a multiobjective optimization method to design time-varying controller in the Halo orbit stabilization missions is proposed. Firstly, a time-varying controller, based on the linearization CRTBP model, is constructed. Then, the weighting matrix elements of the controller are optimized with multi-objective algorithm. Finally, numerical simulations are presented. A study case is optimized and the Pareto fronts of the optimization are obtained. The results show the trajectories of spacecraft are closed to the nominal orbit under the environment errors. The Pareto fronts show the trade-off between the fuel consumption and orbit maintaining, and prove the feasibility of this method. The method in this paper can be applied to other halo orbits station keeping problems in circular restricted three body systems, and have high value of engineering application and prospects.

B3.1-0081-18 STUDY OF SKID SLIDING SYSTEM TO TRAVEL ON LUNAR AND PLANETARY SURFACE

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To improve the exploration efficiency of planetary landing missions, planetary surface exploration techniques including traveling on the surface of planets need to be studied. As a traveling technique, we propose a "skid sliding system", which uses skids and thruster forces to travel via skid sliding. In this study, we considered the application of this system to a small lander. The reason of this is that the skid sliding system can be configured to be light weight; it is advantageous for a small lander mission with severe weight constraints. To implement this system, we performed a numerical skid sliding simulation and a skid sliding experiment using a small lander model. To express skid sliding in the simulation, we developed a three-dimensional interaction force model for the forces between the skid and the soil via an experiment that measured the interaction force between a moving flat aluminum plate adjusted for attitude and soil type. This paper reports the skid sliding simulation using the interaction force model and the skid sliding experiment using the small lander model.

B3.1-0082-18 HOLMS, HETERODYNE OH LUNAR MINIATURIZED SPECTROMETER

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There are many indications in recent lunar studies that water ice and other volatiles are present near the lunar poles. Temperatures of the lunar cold traps are low enough to prevent substantial sublimation losses over billion-year time scales. Understanding the source and the processes that affect the delivery of lunar volatiles is key to understanding the formation of the moon, and early volatiles in the inner solar system. It also has a great importance for lunar mining and possibly utilizing volatiles in future missions. Lunar remote sensing by orbital spacecraft, and the Lunar Crater Observation and Sensing Spacecraft (LCROSS) impact experiment provided compelling evidence for the existence of cold-trapped volatiles, but their abundance, composition, and distribution remain uncertain. This is, in part, because the most commonly used technique for remote sensing spectroscopic measurements is grating spectrometers. These instruments are broadband, but they have small fields of view (FOV) and relatively low throughput and have to be paired with large aperture telescopes for high spectral resolving power (R) applications.

Here, we demonstrate a lunar volatile remote sensing technology, by employing a Spatial Heterodyne Spectrometer (SHS) in an orbiter around Earth. SHS is a relatively novel candidate for high throughput spectroscopy in compact, low-mass, a low-power architecture using no or small aperture (D<10cm) telescope for UV to IR wavelengths. SHS provides integrated spectra at high R (R>50,000), over a wide FOV (FOV 40 arcmin) in compact designs in which it offers the ability to search for OH volatiles at 308nm. SHS can be implemented on ISS or a dedicated SmallSat that can sit at a GEO altitude and stare at lunar exosphere for the long duration of time that cannot be done from the ground or on big missions. SHS measurements will improve constraints on lunar volatile composition and could help identify possible origins, including comet and asteroid impacts, solar wind ion implantation, and outgassing of primordial volatiles from the lunar interior.

B3.1-0083-18 A POLITICAL HISTORY OF THE HUMAN MISSION TO MARS GOAL IN THE U.S.

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Mars is the only other world we can reach that has the basic stuff of life - atmosphere and water. It beckons us both as a possible place with extinct or even extant life and also as the most likely place where humans could evolve as a multi-planet species. The literature of Earth is replete with stories containing the visions. Sending humans to Mars has been a goal of space exploration since before the space age. In the space age that goal has remained constant, but mostly implicit - never resulting in any flight development and only in the last Administration (Obama) was it a specific program objective. When first suggested by Wernher von Braun in 1948 he imagined it could be done in 1965 (17 years hence). 21 years later, in 1969, the same year as Apollo first Moon landing, von Braun published an updated and more detailed plan imagining launches beginning in 1981 (12 years hence). This led to the first political initiative for a human Mars mission goal for the American space program - a proposal to President Nixon. This paper reviews the political history of the humans to Mars mission goal in NASA. It does not review the technical history - the many mission studies conducted by and for NASA over the years. Many of these were wish fostering the thought, others were generated as part of program initiatives or budgetary proposals, and others were generated as intellectual exercises of what could be done if only. No attempt is made here to capture or review those technical studies; our focus is only on what has led to serious political consideration of the human Mars goal. Since that goal has in one way or another driven NASA in three of the last four Administrations we hope that it will offer guidance on how to proceed or not with its further consideration. Ironically, we will conclude that none of those three Administrations came close to a real political initiative and that the closest we ever come to a political decision for humans to Mars was in the Reagan Administration, even though they, themselves, didn't really consider it.

The table below summarizes the consideration of a human Mars mission goal in each of the space age Administrations.

President Proposal/Initiative Result Kennedy Apollo:Race Soviets to the Moon, No Mars Connection Success - Concluded Johnson Nixon Space Task Group's Mars Goal rejected Shuttle program Ford Carter No "high challenge" goal Reagan 1. Space Station - No Mars Connection 2. U.S.-U.S.S.R. Summit - Consideration of joint Mars mission in context of broad peace and disarmament negotiations. Gorbachev intent to propose 1. Development delayed to Clinton Administration post-Soviet engagement 2. Foundered on issue of SDI testing in space as a weapons issue Bush 41 SEI: Back to the Moon and on to Mars nothing Clinton 1. Rejected Mars Goal 2. Engage Russians in ISS Shuttle-Mir, Built the ISS, no Mars connection Bush 43 Vision for Space Exploration - Moon, Mars and Beyond Constellation program only with Moon goal Obama 1. Cancel Constellation 2. Human to Mars goal with Asteroid first step ARM Mission development, Journey to Mars program formulated Trump 1. Cancel ARM - stops Journey to Mars 2. Back to Back to the Moon

B4.1-0001-18 CURRENT MARS WEATHER AND CLIMATE.

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Since Viking, we know that the present-day Mars climate is a complex system in which the atmospheric circulation is coupled with an atmospheric dust cycle (dust devils and dust storms), CO2 cycle (seasonal and perennial polar caps and clouds), water cycle (clouds, frost and glaciers) and even an active photochemistry. Twenty more years of observations by a fleet of modern spacecrafts (notably Mars Global Surveyor, Mars Express, Mars Reconnaissance Orbiter and MAVEN) interpreted with the help of numerical models have helped identify the physical processes at work and shown how much they are connected. However, these studies have also revealed new enigmas: what creates the detached layers of dust in the atmosphere? Can water vapor be strongly super-saturated in the middle atmosphere? Why global dust storms occur some years and not others? How clouds and dust evolve throughout the diurnal cycle? Can the sublimation of CO2 ice carve the surface and create gullies? Many questions remain. Furthermore, the Martian climate system has probably experienced large variations related to the oscillations in the parameters of the Martian orbit a few millions or even thousands of years ago, and we are just starting to understand what could have happened then and how these variations have shaped the observed Mars geology.

In my presentation, I will briefly review our current understanding of the Mars Climate system and highlight the most puzzling enigmas.

Interestingly several new space missions will soon provide unprecedented observations and most likely revolutionize our understanding of the Martian environment. We can cite in particular the ESA Exomars Trace Gas Orbiter (starting its science mission in spring 2018) which combines nadir observations at various local time with high precision solar occultations to monitor the vertical profiles of multiples species and aerosols. The Emirates Mars Mission will later (in 2021) complement these investigations by monitoring Mars meteorology throughout the diurnal cycle thanks to an innovative orbit, and several other missions from various countries (China, Japan, India) may also contribute to this international investigation on the mysteries of the Martian world.

B4.1-0002-18 THE MARS CLIMATE SOUNDER - SIX MARTIAN YEARS OF GLOBAL ATMOSPHERIC OBSERVATIONS

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The Mars Climate Sounder (MCS) on the Mars Reconnaissance Orbiter (MRO) spacecraft, began continuous observations of the surface and atmosphere of Mars on 24th September 2006 and has been operating successfully ever since, completing six Mars years of daily, global coverage on 6th January 2018.

MCS is a compact, limb sounding radiometer with 5 mid-infrared channels, 3 far-infrared channels, and one broadband 0.3-3.0µm albedo channel. All 9 spectral channels use uncooled, linear, thermopile detector arrays, consisting of 21 elements, to sample the atmosphere from

-10 to 90 km with 5km vertical resolution when pointed at the martian limb. Elevation and azimuth actuators direct the instrument fields-of-view over the entire downward hemisphere from the nadir oriented MRO spacecraft, allowing MCS to view Mars using nadir, off-nadir, and limb viewing geometries in all azimuth directions.

Surface temperature and atmospheric profiles of pressure, temperature, dust and water ice opacity are retrieved operationally from radiance profiles measured by the MCS infrared channels. Every day, atmospheric fields are sampled globally with a resolution of 5km in altitude, 4° in latitude and 27° in longitude at local times of both 3 am and 3 pm from the sunsynchronous, polar orbit of MRO. Early in the mission, measurements focused on the forward in-track limb, but these are now interspersed with off-track and cross-track limb measurements to broaden the coverage of local time, particularly at high latitudes. Retrieved atmospheric profiles are delivered to the Planetary Data System (PDS) every three months, and are publically available at: http://atmos.nmsu.edu/data_and_services/atmospheres_data/MARS/ atmosphere_temp_prof.html.

Although MCS operations are mature, there are still many improvements planned for the data set. In particular CO2 ice profiles will be retrieved, and dust and water ice profiles will be extended to higher opacities using radiance profiles from the far-infrared channels. Further improvements in aerosol profiles and columns will be realized by combining off-nadir and limb measurements, which has already been done operationally for temperature. Ultimately, assimilating the dataset into Mars general circulation models, will extract the maximum amount of information on atmospheric dynamics and the transport of dust and volatiles from the measurements.

The MCS climatological atmospheric data set is distinguished by the superior vertical resolution, radiometric sensitivity, and radiometric stability provided by limb sounding radiometry with linear thermopile arrays, combined with the daily global coverage, both day and night, provided by the MRO spacecraft for 6 Mars years. This has resolved the global structure of the atmospheric tides for the first time, and has revealed unexpected complexity in the vertical distribution of dust and water ice and their seasonal and inter-annual variation.

The pointing flexibility of the MCS instrument has allowed it to make coordinated observations with other MRO instruments and Mars missions. In particular, MCS has supported orbiter aerobraking and the Entry Descent and Landing (EDL) activities and surface operations of landers and rovers with both climatological and real-time data. Plans for MRO spacecraft operations extend to 2028 to provide relay services for future landed missions. MCS will continue its support for these missions, and extend the climatological data set, increasing its value for future missions to Mars by humans. At the time of writing MCS is healthy and appears capable of continuing operations well into the future.

B4.1-0003-18 A MARS ATMOSPHERIC CLIMATOLOGY SPANNING A MARTIAN DECADE

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Over the last martian decade (almost 20 terrestrial years), orbiting spacecraft have acquired a global continuous set of temperature and aerosol observations of the lower atmosphere (surface to at least 40 km). The observations were acquired by MCS (on MRO), TES (on MGS) and THEMIS (on Odyssey). The measurements span Mars Years 24 though 33 (MY; MY 1 started in 1955) and are continuing into MY 34. The observations include sufficient overlap between the individual instruments to help validate the entire dataset. In addition to helping understand the atmosphere, the climate record will provide vital input for successfully designing and executing future human and robotic missions to Mars.

Here, we focus on the zonal mean daytime and nighttime temperatures at 50 Pa (25 km), which provide an excellent overview of the climate. The binned, zonal mean temperatures filter out the boundary layer and local weather phenomena, better revealing the background climate. Temperatures at 50 Pa are influenced by large scale dust activity that dominates the inter-annual variability. Likewise, they are influenced by the overall seasonal changes, including the change in distance to the sun as well as aerosols. To help understand the climate, we have used the 10 year record to create a median year for Mars.

The most obvious, and well known, feature in the climatology is the difference between the cool aphelion season and the warm perihelion season. In addition, the polar vortices are clearly defined at 50 Pa, revealing the extremely cold winter polar regions (where CO2 clouds form).

The aphelion season, northern spring and summer, is not only cloudy (water ice clouds), but is also quite repeatable from year to year. The coldest non-polar temperatures at 50 Pa are not at aphelion (nor the northern summer solstice), but are around Ls 40°. At this time, the atmosphere is rapidly transitioning from the equatorially symmetric two-cell Hadley circulation of the equinoctial season to the single, cross-equatorial, cell of the solstice season. The other three transitions of this kind are less obvious, but are also rapid (<15° of Ls) and visible in the dataset. During the aphelion season, inter-annual variability is generally limited to less than 5 K. While relatively uncommon, dust events affecting middle atmosphere temperatures occur during the season and result in larger differences (up to ~20 K of warming).

The perihelion season, southern spring and summer, shows much more inter-annual variability due to the occurrence of large-scale dust events. Many years have three regional-scale events in a generally repeatable pattern, but two years in the climatology show the impact of a global dust storm. Even in years with a repeatable pattern, there are noticeable differences, as well as subtle similarities. Despite the sometimes large variations in this season, by the beginning of the aphelion season, the climate returns to the median state.

With both MRO and Odyssey still returning data and TGO soon to start observing, we hope to continue the collection of this valuable atmospheric dataset into the next martian decade.

B4.1-0004-18 MAJOR DUST STORMS AND CHANGES IN ATMOSPHERIC CIRCULATION ON MARS

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Dust storms on Mars can sometimes grow into planetary scale and profoundly affect global atmospheric circulation. These major dust storms control the seasonality and inter-annual variability of the Martian dust cycle, and are of great concern for spacecraft missions. The atmospheric circulation at each development stage of a major dust storm appears to have its own special characteristics. The relationship between the development process of a major dust storm and the timing of change in the circulation is important for deciphering the mechanism involved. This relationship will be investigated for representative examples using dust storms observed in Mars Daily Global Maps (MDGM) and meteorological variables in Mars Analysis Correction Data Assimilation (MACDA) product. Special attention will be paid to large-scale eddies, such as, traveling waves, stationary waves, and thermal tides.

B4.1-0005-18 MODELING THE MARTIAN SEASONAL DUST CYCLE

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An outstanding problem for simulating the present Mars climate is representing the spatial and temporal variability of aerosols and the feedbacks that connect dust raising and transport with the evolving atmospheric circulation. A particular challenge has been the inability of Mars global circulation models (MGCMs) to realistically simulate interannual variability, most notably in the occurrence of major dust storms. The threshold for dust lifting by resolved surface stresses plays a central role in the current parameterizations of dust lifting used in these simulations. In the results to be presented, the GFDL MGCM is run with fairly typical representations of convective ("dust devils") and wind stress lifting. A new type of negative feedback has been introduced to the model climate system by providing a finite surface dust reservoir and allowing the stress threshold for dust lifting is vary as a function of the surface dust depth. The simulated surface dust typically evolves toward a relatively statisticallystable distribution that reflects the seasonally-integrated effects of stress dust lifting. Dust is preferentially depleted in regions with unusually high stress but surfaces are never stripped clean. Thus the stress lifting scheme continues to allow dust to be raised in these regions, but on a more episodic basis that is dependent on the replenishment by local and remote dust lifting activity. This work provides support for the concept, first proposed in a pair of papers by A. Pankine and A. Ingersoll, that surface/atmosphere dust interactions are able to organize to yield aperiodic global dust storm activity.

B4.1-0006-18 ADDRESSING INTERANNUAL VARIABILITY OF MARTIAN GLOBAL DUST STORMS WITH ORBIT-SPIN COUPLING AND ACTIVE DUST LIFTING IN STUDIES WITH A MARS GENERAL CIRCULATION MODEL

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The occurrence of global dust storms (GDS) in some Mars years and not in others is recognized as an outstanding unsolved problem of atmospheric physics. While GDS exhibit a clear seasonality as to when they occur (centered loosely around Mars' perihelion), no clear pattern exists among years in which GDS take place, and predicting their occurrence in any one Mars year remains a problem that is stubbornly unresolved. Attempts to address the underlying factors behind this interannual variability have generally focused on two complementary areas.

First, it has been suggested that the limited availability of dust in key regions on the martian surface may inhibit the growth and development of GDS, simply due to the absence of enough dust to loft into the atmosphere and trigger positive feedbacks which grow more regional dust activity into a global-scale event. Simulations that assume an infinite supply of surface dust show much more limited growth behavior (with respect to timing and source location) than do simulations that exhaust dust in key regions over time. These key regions are areas with peak surface stress lifting, from which dust is most readily lofted. As these regions are depleted of dust, secondary regions continue the process of injecting dust into the atmosphere. This increased distribution of lifting sites yields model results with greater interannual variability, and which coincide with observations of the origin of recent dust storms.

Second, it has been recently argued that year-to-year differences in the orbital angular momentum of Mars, and the coupling of this orbital angular momentum to Mars' rotational motion can yield small but cumulatively significant changes in the martian circulation that have heretofore been unrecognized. These changes come about from the effect of a time-varying 'coupling term acceleration' (CTA), based on the calculable Mars ephemerides, and which varies significantly in time and exhibits variable phasing with respect to Mars' annual insolation cycle. A strong correspondence between years in which the CTA act in such a way as to constructively enhance the overturning meridional circulation on Mars and years in which a GDS was observed has been identified.

Most recently, studies have been undertaken to combine these two processes in a Mars general circulation model (GCM), examining the feedback of enhanced dust lifting and the CTA on the growth and timing of GDS in prior Mars years. Together, they make up the first successful attempt at replicating the observed interannual variability of GDS on Mars, and provide an avenue for making viable predictions of future dust storms. Such predictions can impact launch considerations and surface operations of spacecraft at Mars. Here, we present the current status of this work and demonstrate results obtained for both prior and future Mars years.

B4.1-0007-18 TEN YEARS OF MESOSCALE AND MICROSCALE MODELING OF THE MARTIAN ATMOSPHERE AT LMD: FROM MARS EXPRESS TO INSIGHT

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Following the scientific activities of Mars Express, the LMD Martian Mesoscale Model was developed circa 2007 as an interface between an adapted version of the terrestrial WRF model and the physical parameterizations developed for the LMD Global Climate Model. Since its inception, the model has been applied to various topics of interest to understand the variability of the Martian atmosphere at spatial scales smaller than those resolved by GCMs. This includes: slope flows and their thermal impact, boundary-layer turbulence and dust devils (with Large-Eddy Simulations), gravity waves (notably their impact on the formation of CO2 clouds), polar meteorology and katabatic jumps, dust-induced convection in "rocket dust storms", ice-induced convection in "turbulent snowstorms". The simulations with the LMD Martian Mesoscale Model helped to interpret the results obtained from space missions in the last decade, contributing to an international community effort with Martian Mesoscale Models developed and used in other teams. The approach developed at LMD for Martian mesoscale modeling has also been recently transposed to Venus. The upcoming InSight mission to Mars opens new perspectives for mesoscale and microscale atmospheric science, where the use of small-scale simulations has proven useful to prepare the mission's observations and will be instrumental to interpret the unprecedented signals caught by the InSight instruments.

B4.1-0008-18 THE UPPER ATMOSPHERE OF MARS: FREEWAY OR BOTTLENECK FOR ATMOSPHERIC ESCAPE?

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Above the well-mixed lower and middle atmospheres of Mars, above the homopause at 120 km, lies Mars' upper atmosphere, partially ionized and extending tenuously to many tens of thousands of kilometers out into space. Its structure and dynamics are complex, driven both from below by lower atmospheric conditions (temperature, density, waves) and from above by solar extreme ultraviolet photons and energy input from the solar wind in the form of charged particle precipitation and plasma waves. It is also the conduit through which all escaping atoms and molecules must pass on their way out to space. Building on the success of previous missions, the MAVEN mission is the first to focus exclusively on exploring the structure, composition, variability and dynamics of the Mars upper atmosphere and near-space environment. Here we review what MAVEN has taught us about the upper atmosphere, the processes which operate therein, how they affect water and CO2 escape from Mars, and how they vary with season and solar activity. We will also look forward to upcoming synergistic measurements from the ESA Trace Gas Orbiter and the Emirates Mars Mission, both of which will explore the connections between Mars' lower and upper atmosphere and escape.

B4.1-0009-18 PICKUP ION INSIGHTS INTO THE NEUTRAL EXOSPHERE OF MARS

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Neutral escape of hydrogen and oxygen is the most important atmospheric escape mechanism currently at work at Mars. Pickup ions provide important insights into the exospheric density and escape rates of these neutrals. As they are escaping the planet, neutral hydrogen and oxygen atoms become ionized in the solar wind and are picked up by the solar wind electric and magnetic fields. Charged particle detectors onboard the Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft can measure these pickup ions, acting as a probe for their source neutrals. By following the production and transport of pickup ions in the solar wind, the source positions of the measured pickup ions can be found and neutral densities at those positions derived by comparing the modeled pickup ion fluxes with the measured ones. Neutral escape rates can also be constrained using these model-data comparisons, since neutral escape rates are directly proportional to exospheric neutral densities. We use this pickup ion modeldata comparison technique to probe the exosphere of Mars by fitting to data different exospheric density profiles based on a variety of exobase distribution functions. This allows us to gain insights into the sources and structure of the Martian exosphere, constrain the 3D distribution of neutrals in the exosphere, and investigate the neutral escape variability at Mars.

B4.1-0010-18 INDIAN MARS AND VENUS MISSIONS: SCIENCE AND EXPLORATION

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Mars and Venus have been the focus of explorations in recent decades by various space agencies. Several orbiters have provided a wealth information on the planet Mars and Venus, but have also posed some important questions for further exploration. Indian Chandrayaan-1 and Mars Orbiter Mission Mangalyaan-1 were explored to Moon and Mars in October, 2008 and September, 2013 for a focused study of Moon and Mars' environment respectively. ISRO is now planning to explore Mangalyaan-2 and Shukrayaan-1 in the orbits of Mars and Venus during 2022-2023. The science objectives of these missions are to investigate the atmosphere, ionosphere, surface geology, magnetic fields, and interplanetary dust in the environment of both planets. In this talk we will discuss in brief objectives and science of important Indian payloads viz. color Camera (MCC), Radio Occultation Experiment (ROX), Retarding Potential Analyzer (RPA), Langmuir Probe Electric Field Analyzer (LPEX), Magnetometer (MAG) and Mars Orbit Dust Experiment (MODEX).

B4.1-0011-18 ACTIVE MARTIAN SURFACE PROCESSES: A DYNAMIC WORLD

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The surface of Mars has been known to change since the era of telescopic observation [1]. The advent of long-duration orbital missions with high-resolution imagers has enabled detection of many smaller-scale changes. This has demonstrated that current processes are not merely repainting the albedo, but are actively shaping the surface through both Earth-like processes and some that are unique to Mars.

Several planet-wide processes are now recognized. Aeolian processes account for the large-scale albedo changes [2] and have been studied in situ by landers, particularly Curiosity [3]. Perhaps the key recent discovery has been planet-wide dune and ripple migration [4]. New impacts up to decameters in diameter have also been found to occur globally [5].

Seasonal frost effects occur at middle and high latitudes and produce a variety of spots and fans, redistributing surface fines [6]. These are driven by basal sublimation of CO2, a uniquely Martian process [7]. The effects of this are not merely superficial: observations now confirm formation of new araneiform landforms [8] and annual modifications of the dunes of the north polar erg [9]. The south polar residual cap also has pits that expand every summer, but the net mass balance is uncertain [10].

A host of different slope processes are now also known and provide some of the most important puzzles in understanding modern Mars. Thousands of slope streaks may form every Mars year [11]. Blockfalls and powder avalanches occur regularly on the north polar layered deposits [12]. Boulders shift on creep slopes [13] and lobate slump features occur in Valles Marineris [14]. Perhaps the most important slope processes are those where liquid water has been suspected. New deposits in gullies were at first thought to indicate liquid water [15]. However, a decade of observation has demonstrated that activity correlates with seasonal frost, which is primarily CO2 [16, 17]. The activity includes major channel incision and new lobate deposits, which raises the possibility that gullies could form with no liquid water involvement. Recurring Slope Lineae (RSL) have many characteristics expected of present-day liquid flows [18]. However, new evidence demonstrates that they terminate on slopes that closely match the dynamic angle of repose for dry sand [19], suggesting that RSL are granular flows.

An axiom of geology is that the present is the key to the past, and understanding Martian surface changes is essential to an understanding of the planet. The long-baseline monitoring by a succession of orbiting spacecraft has been essential to the detection and initial characterization of these changes. This

presentation will summarize current activity and discuss the many unknowns about the processes and their effects, particularly the role of volatiles in gullies and RSL.

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B4.1-0012-18 THE COLOUR AND STEREO SURFACE IMAGING SYSTEM (CASSIS) ON THE EXOMARS TGO - FIRST OBSERVATIONS

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The Colour and Stereo Surface Imaging System (CaSSIS) is the imaging system onboard the joint-European Space Agency/ Roscosmos ExoMars Trace Gas Orbiter. The instrument provides colour and stereo imaging of Mars at 4.6 m/px from the nominal orbit 400 km above the surface of Mars. CaSSIS has been tested during the first capture orbits in November 2016 but has been switched-off during the aerobraking phase of the mission. The instrument was shown to be performing well with stereo pairs, colour composites and images of Phobos produced from two short 40 minute bursts of data. At the time of writing, preparations are being made to enter the prime mission in April 2018 when up to 36 individual images can be acquired per 2 hour orbit during high data rate periods. We will present the first results from this mission phase.

B4.1-0013-18 WATER IN THE GALE CRATER, AS OBSERVED BY DAN INSTRUMENT ONBOARD THE CURIOSITY ROVER

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Recent results of DAN experiment are presented for estimations of water mass fraction in the soil of the Gale crater along the traverse of NASA Curiosity rover. They are based both on active and passive DAN measurements of the shallow subsurface gathered for the period from August 2012 till now. Local variations of water content are discussed in comparison with results of another instruments installed onboard of the Curiosity rover and the orbital missions.

B4.1-0014-18 INCREASING OUR UNDERSTANDING OF PERCHLORATE SALTS DURING THERMAL DECOMPOSITION AND THEIR IMPLICATIONS FOR LIFE DETECTION ON MARS

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The search for life on Mars targets the detection of organic matter from extinct or extant organisms. The majority of life detection missions have used thermal extraction as a method to transfer organic matter to the mass spectrometry detectors. So far, however, no mission has conclusively detected anything other than CO, CO2 and simple organochlorine molecules. It has been suggested that it is the presence of oxidising minerals, such as perchlorate salts, which obfuscates organic detection. Thermal decomposition of perchlorate releases oxygen which promotes combustion of any organic carbon present - thus the majority of organic molecules are lost as CO and CO2.

We have performed studies on magnesium perchlorate, one of the main perchlorate parent salts proposed to be present within the Martian soil, to better understand its response to thermal decomposition in order to find a work around for this 'perchlorate problem'.

In one series of experiments, magnesium perchlorate hydrate was dehydrated to various extents. This revealed that the hydration state of this salt affects the temperature of O2 release just as much as cation chemistry, which has previously been attributed to the differing O2 responses between MSL drill sites. Consequently, incorrect identification of perchlorate species may occur if hydration state is not taken into account and a mixture of metastable hydration states may be mistaken for a mixture of perchlorate salts. Our findings are important for Mars as the hydration state of salts in the regolith may change throughout the Martian year due to large variations in humidity and temperature.

In a follow-on study we investigated the gas-phase breakdown products of magnesium perchlorate and organic matter during thermal decomposition to identify a minimum organic matter: perchlorate ratio in the samples that allows excess organic carbon

to survive combustion for detection in the GC-MS. Our data show that there needs to be a minimum of 5 times more organic carbon than perchlorate in analysed samples for incomplete combustion; although for a statistically significant detection this rises to around 9 times. Therefore the expected organic carbon and perchlorate content for average Martian regolith would preclude the detection of organic matter by thermal decomposition techniques. Locations on Mars with an increased concentration of organic carbon and/or a decreased concentration of perchlorate will need to be targeted to increase the chances of successful life detection. Because habitability is enhanced by the presence of liquid water and because perchlorate is a water-soluble salt, locations on Mars with evidence of past or recent liquid water are obvious high priority targets. This could explain the detection of chlorinated hydrocarbons in the lacustrine Sheepbed Mudstone deposit.

B4.1-0015-18 INVESTIGATION OF SUBSURFACE STRUCTURES IN LUNAE PLANUM, MARS, WITH MARSIS SUPER-FRAME FLASH MEMORY DATA.

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Here we report the results of our ongoing study of Lunae Planum, a vast Martian plain centered at coordinates 294°E - 11°N, bounded by Echus Palus (west), Sacra Mensa and Kasei Valles

(north), Xanthe Terra (east), and the northernmost chasmata of Valles Marineris (south). Overall, Lunae Planum appears to be morphologically uninteresting when compared to other geological features in the region. The presence of wrinkle ridges, grabens and impact craters with fluidized ejecta however, indicates that Lunae Planum had a complex geological history, further evidence of which is likely buried under the surface. To obtain information about the nature of subsurface materials and the presence of subsurface structures, we have processed data from the Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS), which has been operating on board Mars Express (MEX) since 2005. Throughout the duration of its mission, the sounder acquired hundreds of orbits over the approximately 1,500,000 km^2 areal extent of Lunae Planum. We processed 36 orbits in standard mode, but found no obvious reflectors, which we interpreted to indicate that: (a) similar material, or materials with similar values of dielectric constant (ε), form Lunae Planum at all depths of penetration of the radar signal; and/or (b) porous lithologies compaction by overburden pressure affect the ε values [1]. From new super-frame (SF) data acquired during the period November 20-30, 2017, we observed time-delayed echoes in MEX-MARSIS orbits 17590, 17597, and 17604 radargrams. The absence of similar echoes in surface clutter simulations suggests the presence of a real subsurface reflector with a time delay of 11 µs along one of the SF tracts of orbit 17597. Assuming a putative value of $\varepsilon = 8$ (for basalt [2]), this would indicate a reflector at a depth of 580 m in this location. We continue to test this working hypothesis by: (a) conducting additional processing of the data;

examining the implications of the putative presence of reflectors at this depth in the area, within the known geological context. [1] Caprarelli et al. (2017) LPSC 48, 1720. [2] ElShafie

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B4.1-0016-18 THE AMAZONIAN CLIMATE OF MARS: A COLD AND DRY SUMMARY

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The climate of the last 3 billion years of Mars' history, the "Amazonian," has been characterized by cold and dry conditions. During this time, atmospheric and surface conditions have been largely controlled by periodicities in orbital and rotational parameters analogous to Earth's Milankovitch cycles. The obliquity of the planet in particular has undergone large variations that affect the distribution of insolation and therefore volatile stability. Much progress has been made to inventory the current distribution of volatiles on Mars, including recent discoveries of extensive water ice deposits at mid-latitudes from radar and image data. However, outstanding questions remain as to the relationship between the current inventory and the previous climatic conditions in which these volatiles were emplaced and subsequently modified. I will present on the current understandings, as well as the outstanding questions, regarding the climate of the Amazonian, especially as it pertains to the role of volatiles. Included in this presentation will be a synthesis of the studies presented at the Mars Workshop on Amazonian and Present Day Climate [1] to be held June 18-22, 2018, as well as the progress and outstanding questions identified at the Sixth International Conference on Mars Polar Science and Exploration [2].

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B4.1-0017-18 FINE RESOLUTION EPITHERMAL NEUTRON DETECTOR (FREND) ONBOARD EXOMARS 2016 TRACE GAS ORBITER. FIRST DATA AND FUTURE RESULTS.

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Neutron flux observed from the orbit is sensitive to hydrogen content in the planetary soil, up to 1m depth. Performing such measurements allows to build, with time, maps of hydrogen content in the surface of a celestial body. This technique was successfully used in the past, for example by HEND instrument onboard Mars Odyssey. Fine Resolution Epithermal Neutron Detector (FREND) is an instrument onboard the Trace Gas Orbiter (TGO) of the ExoMars mission and its main feature is the collimator that allows for neutron detectors' very narrow field of view up to 28 km radius spot. This will create new hydrogen deposition maps of a much higher spatial resolution than that of HEND, which produced maps with only 200 km radius pixel size. A finer resolution of hydrogen deposition maps would allow for selection of prospective landing sites and help understanding the geology of Mars better, cross-correlating neutron data with relief features. TGO arrived in the Martian orbit in October 2016 and finalized its aerobraking period in April 2018 that brought the mission to the final circular 400km altitue orbit. After short period of engineering commissioning, the Science Phase begins and we present here the first data acquired by the instrument, together with preliminary interpretations.

B4.1-0018-18 GROUND ICE RESOURCES OF THE PROTONILUS MENSAE

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The Mid-Latitude Protonilus Mensae region on Mars is host to a number of distinctive land- forms that can be interpreted as evidence of the presence of water ice buried and preserved under the regolith. If existing at depths accessible by excavation equipment, these deposits may represent a significant water resource for future human missions to the red planet. In this work we discuss the geomorphological properties of these features and interpret them in the context of their formation, preservation, and age. We also discuss technological approaches for the potential utilisation of these deposits as a resource to support human operations, and present a review of the environmental and terrain conditions in which mining and exploration activities may likely be conducted.

B4.1-0019-18 HOW PLAUSIBLE IS AN ORBIT-DRIVEN WATER ICE CLOUD GREENHOUSE ON MARS?

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Clouds in planetary atmospheres can either cool or warm the climate system. Clouds provide a negative forcing to the system by increasing the planetary albedo when they reside over relatively dark surfaces. Conversely, clouds provide a positive forcing to the system in the infrared, where they absorb radiation and emit a fraction of it back to the surface. The net effect on the climate system depends on the relative strength of these opposing effects, which depend on the cloud optical depths, altitudes, and particle sizes. In Earth's atmosphere, low clouds tend to cool the surface, while high clouds tend to warm the surface. A similar effect occurs in Mars' atmosphere-low clouds cool while high clouds warm. Water ice clouds in Mars' current atmosphere provide weak net annual warming of less than 1 Kelvin. However, recent climate modeling studies suggest that water ice clouds could have provided significant greenhouse warming during Mars' recent history. Even modestly increasing obliquity to 30° can produce water ice cloud greenhouse annual mean warming of 15 K. At 35° obliquity, the cloud-generated greenhouse warming can reach more than 25 K. If clouds warm Mars this significantly at moderate obliquity, the planet's climate could have been dominated by the effects of water ice clouds through much of its history. Given the potentially large effect of water ice clouds, it is important to critically evaluate how realistic these results are. The conditions necessary for a significant cloud greenhouse depend both on microphysical processes and on the characteristics of the general circulation and transport processes. We use a Mars global climate model, equipped with a state-of-the-art water ice cloud microphysics package, to isolate and investigate these processes to better understand the plausibility of a strong water ice cloud greenhouse in Mars' recent past.

B4.1-0020-18 MAPPING ANCIENT PERIGLACIAL LANDSCAPES ON MARS

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My project is about searching for evidence of the nature of the Martian climate during the ancient past. In this work, I investigated the nature of an enigmatic terrain observed at 25 S latitude on Mars. Qualitatively, the terrain resembles a periglacial landscape, which is land that built up in a cold climate, often adjacent to a glacier or an ice-sheet, and was subjected to intense cycles of freezing and thawing. However, at the latitude where this terrain is found, ground ice is not stable in the present day. Thus, we hypothesized that this terrain could represent the remnants of an ancient icy climate in this region. To test the hypothesis, I performed a quantitative morphometric comparison of the landscape with known periglacial surfaces on Mars. I worked on three different HiRISE images (from NASA Reconnaissance Orbiter) in the southern hemisphere of Mars. The first and second images were located in area where the ground ice is not stable in the present day. The third image was located in area where the ground ice is stable at depth. With the help of ArcGIS and ArcMap, I was able to map the distinctive terrain patterns that were observed at relatively low latitudes where ground ice does not exist. And then I measured the size, orientation and clustering of a distinctive set of quasi-circular features that resemble pingos on the earth or as an inverted crater. Pingos also called hydro laccolith are small, elongate to circular, ice-cored mounds that can reach up to 70 m (230 ft.) in height and up to 600 m (2,000 ft.) in diameter. And inverted carter means a once-normal appearing impact crater that was filled in with sediment. The fill became indurated, or hardened, until it was more resistant to subsequent erosion than the surrounding material. At last, I compared those patterns with the present-day periglacial landscapes at higher latitudes on Martian surface. At the end of my research I was able to conclude that features in image 1 and 2 are similar in diameter to known periglacial features in image 3, supporting the hypothesis that the enigmatic terrain had a periglacial origin.

B4.1-0021-18 ISOTOPIC CONSTRAINTS ON MARTIAN CLIMATE SUGGESTED BY SAMPLE ANALYSIS AT MARS (SAM) MEASUREMENTS

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Since arriving at Gale Crater in August 2012, the Sample Analysis at Mars (SAM) suite of Mars Science Laboratory's Curiosity rover has probed the isotopic composition of the martian atmosphere and of volatile compounds in surficial and near-surface deposits with its Quadrupole Mass Spectrometer (QMS) and Tunable Laser Spectrometer (TLS). The complementary capabilities of these two instruments provide an unprecedented ability to query multiple isotope systems in situ on Mars. Through a combination of direct-sampling and enrichment experiments, SAM has observed evidence for fractionation and ongoing loss to space in atmospheric isotope ratios of C, O, H, N, and Ar [1-5]. Significant fractionation of atmospheric Kr and Xe isotopes as measured by the QMS suggests a history of early hydrodynamic escape [6] overprinted by contributions from spallation and neutron capture [7]. These collective observations indicate substantial loss of Mars' initial atmosphere to space [8]. Isotopes of volatile elements preserved in minerals offer additional constraints on the history of atmospheric loss, the current atmospheric composition, and geochemical processes that have occurred within sedimentary deposits over time. The D/H ratio of hydroxyl groups in hydrated minerals, such as sulfates and phyllosilicates, released at high temperature through pyrolysis of drilled fines by SAM, may record the isotopic composition of water in more ancient times, providing constraints on the history of H loss to space [3]. In addition, ongoing SAM measurements of readily exchangeable water released from minerals at low temperature, which reflect the isotopic composition of the current atmosphere, suggest seasonal variability in D/H. Sulfur isotope ratios in reduced and oxidized mineral phases indicate a history of S fractionation by photochemistry in the martian atmosphere and hydrothermal processing in the subsurface [9]. Significant fractionation in Cl isotopes of HCl produced from processing of oxychlorine and chloride minerals during pyrolysis also suggests effects of atmospheric photochemistry or reduction of oxychlorine compounds at the surface [10]. Details regarding the history of atmospheric loss and the environment, on both global and local scales, at the time when lakes were present at Gale crater [11] are still poorly constrained. More in situ measurements are needed to expand our understanding of Mars' climate history.

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B4.1-0022-18 THE LONGEST RECORD OF WATER ON MARS: RECENT RESULTS FROM MRO NEAR THE MARS-2020 LANDING SITE CANDIDATE NORTHEAST SYRTIS

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The Mars-2020 rover mission is in the process of selecting a landing site for the first step in sample return. Recent new results from the Mars Reconnaissance Orbiter (MRO) provide new insights into the oldest and youngest materials accessible at one candidate landing site, highlighting the ability to interrogate, at the mesas of Northeast Syrtis, multiple igneous units spanning the Noachian and Hesperian, megabreccia and basement recording the effects of basinscale impacts, and multiple later episodes with water in groundwaters and surface waters – including lakes – in multiple phyllosilicate, carbonate, and sulfate deposits.

To review, prior work [1] showed the lowermost stratigraphic group to be a basement of phyllosilicate and low-calcium pyroxene rich units, disrupted by the Isidis basin impact, with diverse morphologies ranging from megabrecciated to layered to massive and with variable degrees of alteration. This was overlain unconformably by an olivine-enriched unit, variably altered to Mg-carbonate. In the southern part of the region, layered sulfates and lavas from Syrtis Major unconformably overlie the olivine-carbonate. The compositional stratigraphy has a characteristic geomorphology [2].

Recent new work on the basement unit [3,4] shows that Fe/Mg phyllosilicates are found in topographic highs within the landing ellipse with small patches of kaolinite while low-calcium pyroxene is restricted to topographic lows. The massive units with low-calcium pyroxene show no signs of aqueous alteration in CRISM data. Furthermore, distinct classes of megabreccia are identified including zones of layered, polymict, monomict, and single, dispersed megabreccia. The landing site has multiple distinct outcrops with megabreccia blocks, including both those dominated by Fe/Mg phyllosilicate and those dominated by low-calcium pyroxene in distinct 1- 100 m blocks. In the extended mission zone, one of the largest outcrops of layered megabreccia is found near the sulfates.

Recent new work [5] on the layered sulfates shows that they fill local topographic lows with sediments reaching 500 m thick. Shallow (<10deg) but non-zero dips and thinning of deposits embaying basement indicate the NE Syrtis sulfates were deposited subaqueously in deep sedimentary basins. Either these represent deposits from an ocean that filled Isidis or local confinement by an ice sheet, now removed. Subsequently, dewatering, creation of fractures, and mineralization created large veins of jarosite boxwork cross-cutting the sulfates. These were capped, eroded by fluvial valleys, and then the valleys were exploited by Syrtis Major lavas, filling in channels previously carved by waters. Aqueous activity continued even after these Hesperian lavas, carving channels on the surface of the lavas and depositing flat lying sediments and fan-deltas in local topographic lows indicative of a late generation of lakes in the late Hesperian or Amazonian.

Thus, recent data confirm the Northeast Syrtis mesas preserve the longest records of geological processes on Mars, including liquid water. Fe/Mg phyllosilicate-rich basement from the Early Noachian (or earlier) is preserved in megabreccia and the sulfate and fan-deltas in the extended mission sulfates near the Syrtis Major lavas record Amazonian surface waters in lake/ocean sediments, all available for in situ interrogation and sampling.

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B4.1-0023-18 SPECTRAL AND CHEMICAL ANALYSES OF PROBABLE MARTIAN CHEMICAL ANALOGUE MINERALS, COPIAPITE AND ROZENITE OF WAYANAD IN SOUTHERN INDIA: IMPLICATIONS FOR HYDRATION PROCESSES ON MARS

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The chemical and spectral characterisation studies of hydrated secondary sulphate minerals, copiapite [Fe2+Fe3+4(SO4)6(OH)2 20H2O] and rozenite [Fe2+SO4 4H2O] in Southern India, can be considered as probable chemical analogue minerals of Mars. Copiapite and rozenite in Wayanad region in Kerala in South India are associated with gossan developed over sulphide-rich Banded Iron Formations (BIFs). Copiapite in Wayanad occurs as pale-yellow bloom over sulphide-rich rocks while white-coloured rozenite occurs as powdery encrustations. The formation of these minerals as encrustations on primary sulphide minerals (pyrrhotite and pyrite) indicates direct transformation of primary sulphide minerals to secondary sulphates by the processes of weathering and oxidation. The sulphide-rich BIFs hosting hydrated iron sulphate minerals in Wayanad region were identified and reported by Geological Survey of India (Praveen et al., 2013, Geological Survey of India Reports, Vol. ME/SR/KRL/2012/070, pp. 61-64 & Praveen and Sajinkumar K. S., 2017). We carried out hyperspectral analyses in visible-NIR-SWIR band, Thermal infrared emission spectroscopy (TIR), laser Raman and Fourier transform mid-infrared spectroscopy (FTIR) measurements and interpreted the absorption and emission bands and vibration modes in the lattice.

Copiapite shows the characteristic triple absorption feature around 2400 nm which is due to combinations of different bending and stretching modes of SO42−, H2O and OH−. In rozenite, only two absorption bands are observed around 2400 nm which characterises and helps in distinguishing the absorption features from that of copiapite. Copiapite also exhibits strong doublet peak around 1000 cm−1 region in Laser Raman spectrum which is due to symmetric stretching mode of sulphate. For rozenite, strong characteristic stretching vibration of sulphate molecules is observed at 993 cm−1. The continuum-removed spectra were quantitatively matched with reference spectra (RELAB and USGS databases) and MRO-CRISM data using different matching algorithms like Pearsonian Correlation Coefficient (PCC) metric

and Spectral Feature Fitting (SFF). We will discuss the ocurrence of copiapite in outflow channels in Mawrth Vallis, Mars (W.H. Farrand et al./Icarus 241 (2014) 346-357) and the implications of terrestrial occurrences of hydrated secondary sulphate to Mars. The genetic model of copiapite and rozenite occurrence in Wayanad will be compared with Martian occurrences outlining the importance of aqueous processes.

The above-mentioned instruments are considered as next-generation instruments for exploration of Mars. Laser Raman spectrometer is also included in near-future Mars missions (SHERLOC, MARS 2020, Exo-Mars Pasteur suite, 2020) and the results can be helpful in instrument calibration using mineral/chemical and site analogue and can aid in minerals and organic compounds detection. Copiapite-occurring analogue sites in terrestrial conditions include the Río Tinto (Iberian Pyritic Belt) and El Jaroso ravine, Sierra Almagrera, Spain, hosting microbial colonies with Methanogenic activities which is also precursor to complex organic compounds on earth. The abundance of water in these sites can give important hints to the aqueous processes on Mars. These hydrated sulphates are thermodynamically stable on Mars and may preserve the biogeochemical properties and gives an insight to environmental condition prevailed in geological history and evolution of Mars with possibility of different genesis mechanisms.

B4.1-0024-18 CLAY MINERAL BASED PALEOENVIRONMENTAL RECONSTRUCTION OF ANCIENT GALE CRATER LAKES, MARS

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Mars Science Laboratory (MSL) has documented clay minerals in various drill samples as it traversed the floor of Gale crater and began its ascent of Mt. Sharp. The clay minerals provide important constraints on the syndepositional conditions within lakes that occupied the crater floor sim3.5 Ga. The most recent drill samples, named Marimba, Quela, and Sebina come from a succession of fluvio-lacustrine mudstones/siltstones/sandstones making up part of the Murray formation. Clay minerals constitute as much as 28 wt.% of these samples. A combination of CheMin X-ray diffraction, SAM evolved gas analysis, and APXS bulk chemical data indicate that clay minerals consist of a mixture of Al-rich dioctahedral and Mg-rich trioctahedral smectite. This contrasts with Fe-rich trioctahedral smectite (saponite) documented in lacustrine mudstones recovered from Yellowknife Bay (YKB), earlier in the mission.

YKB saponite is thought to have formed via isochemical aqueous alteration of detrital olivine close to the time of sediment deposition, under anoxic to poorly oxidizing conditions. Al-rich dioctahedral smectite and Mg-rich trioctahedral smectite are also thought to have formed close to the time of deposition. However, these clay mineral species indicate oxidizing conditions in which sediments were subject to an increased degree of element mobility and evaporative concentration. Observed changes in bulk mineralogy and sedimentary facies support the inferences from clay mineralogy. These observations include: 1) a transition from magnetite to hematite as the main Fe-oxide in sediments over the course of MSL's traverse, 2) increasing abundances of Ca-sulfates, 3) a reduction in the quantity of reactive mafic minerals, and, 4) mudcracked Murray formation mudstones - indicating episodic desiccation. These results broaden the spectrum of mineralogical facies documented by MSL. Together sedimentology and mineralogy indicate a long lasting, dynamic, fluvial-lacustrine system encompassing a range aqueous geochemical processes under varying redox conditions.

B4.1-0025-18 CLIMATE IMPLICATIONS OF AN ANCIENT LAKE BASIN IN GALE CRATER, MARS

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The sedimentary rock strata explored in Aeolis Palus and the lower slopes of Aeolis Mons using the Curiosity rover are interpreted to be a record of persistent fluvial, deltaic, and lacustrine environments. Fluvial and deltaic rocks of the Bradbury group are interpreted to interfinger with the recessive Murray formation exposed on lower Aeolis Mons (Mount Sharp). The environments are arranged into a progradational stacking pattern similar to lacustrine basins on Earth in which the accumulation of water and sediment exceeds loss from evaporation. The more than 250 vertical meters of Murray formation investigated using Curiosity consist mainly of finely laminated (0.5 to 2 mm) mudstones, with intercalated cross-stratified facies and sandstones higher in the succession. These rocks are interpreted as lacustrine with minor fluvial, lake margin, and possible aeolian intervals. Comparison with depositional rates in Earth's lacustrine settings suggests that lakes were present in Gale crater for millions of years.

Facies diagnostic of seasonal or perennial ice cover, or of ice within the sediment, have not been identified. Calculated chemical index of alteration (CIA) values are consistent with cold and drier conditions in the rocks of Aeolis Palus, with warmer and more humid conditions in the younger rocks of lower Aeolis Mons. Evidence of early and late diagenesis, e.g., concretions, mineral veins, crystal molds, and fracture-adjacent alteration haloes, implies that multiple generations of groundwater interacted with the sediments after deposition. The fractures and veins indicate continued interaction with subsurface fluids long after the sediments were lithified, providing an extended duration for potentially habitable conditions.

Crater counts indicate that Gale crater formed at about 3.8-3.6 Ga near the Noachian-Hesperian boundary and that deposition, burial, lithification, and exhumation of the lower section of the central mound occurred by 3.3-3.1 Ga. Together, these observations constrain the climate of early Hesperian equatorial Mars to conditions that permitted liquid water to be thermodynamically stable at the surface and in the subsurface at Gale crater, and that were sufficiently humid to reduce evaporative losses and to drive fluvial erosion, transport, and re-charging of the lakes with a hydrological cycle.

Isotopic measurements of atmospheric gases and of water evolved from Hesperian-age clay minerals support models of atmospheric loss in the early history of Mars. These measurements indicate that the planet's exchangeable water inventory had not yet decreased to its present value when the clay minerals formed.

B4.1-0026-18 WARMING EARLY MARS BY IMPACT DEGASSING OF REDUCED GREENHOUSE GASES

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We suggest a new role for impacts on early Mars: the delivery of reduced greenhouse gases that can raise surface temperatures above freezing for geologically significant periods of time. Rainfall during these temporary warm epochs can erode the surface, alter basaltic rocks, and cut fluvial features thus providing at least a partial solution to the vexing faint young sun paradox. The mechanism operates as follows. Some of the kinetic energy of an impactor is converted to thermal energy when impacting the surface. This heats the materials it contains and the surrounding atmosphere. The fast thermochemical reactions that take place in the plume eventually cease as it rapidly cools and reactions are quenched. Gas equilibrium calculations suggest that for many impactor types (e.g., carbonaceous chondrites, comets, etc.) CO2, CO, and H2 are the dominant gases at typical quenching temperatures (1000-1500K), but CH4 can also be produced. If the impact takes place in a thick enough pre-existing CO2 atmosphere, collisions between the CO2, H2, and CH4 molecules introduce new infrared absorption bands that reduce the outgoing longwave radiation and strengthen the greenhouse effect. Surface temperatures then rise facilitating a hydrological cycle involving rainfall and runoff. The effect is temporary, however, since H2 escapes and CH4 is photo-chemically destroyed. Eventually (105 years) conditions return to "normal" until the next impact disturbs the system. The cumulative effect of multiple impacts depends on the impactor flux, size distribution, type, and delivery history, as well escape rates and photochemical sinks. A simple model we developed that includes these processes suggests that just the H2 alone produced from impact events is sufficient to elevate Mars surface temperatures above freezing for cumulative times between 105-107 years during the Noachian epoch depending on impactor type. Any CH4 added would lengthen these times. It is not clear if this mechanism can explain all of the water-related features on Noachian surfaces, but these results suggest it must have played some role since impacts did occur. Thus, a new line of research into the mystery of early Mars opens up.

B4.1-0027-18 EXPLORING GEOMORPHIC PROCESSES AND MARTIAN GALE CRATER TOPOGRAPHY USING CTX AND HIRISE EXPRESS IMAGE DATASET

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Spatially referenced topographic dataset Context Camera images acquired from Mars reconnaissance orbiter were used to explore geomorphic processes and topography of Gale Crater. A base map was prepared by mosaicking all images. This base map was utilized for preparing geomorphologic map of the crater. Surface map of the topography of the Crater was prepared using Mars Orbiter Laser Altimeter (MOLA) data. HiRISE images were used to enhance the identified geomorphic features. Results revealed the presence of both fluvial and aeolian processes and their respective associated landforms in the Crater. Depositional landforms such as alluvial fan, inverted channel and mound and erosional landform namely canyons produced by fluvial action were distinctly identified and mapped. Yardangs produced by erosional and ripple and dunes formed by the depositional work of wind were also identified in the Crater. The fluvial channels, inverted channels and fan shaped deposits further clued of ongoing aqueous activity. Sinuous ridges are most common features present on the floor of crater. Rock sand and silt in the crater were found to have been transported and deposited by flowing water on its floor. Presence of different sedimentary structures and valley revealed ancient sedimentary deposits due to water action. Erosional and depositional signs found in observation make the study a good comparison among other intra-crater fans and sedimentary land forms. Topographic data set Context Camera (CTX) and High Resolution Imaging Science Experiment (HiRISE) images can best be utilized for geomorphic and topographic mapping of the Mars planet.

Keywords: Fluvial; aeolian; processes; landforms; gale; mars

B4.1-0028-18 THE AGE OF MODELING THE MARTIAN HABITABILITY IN 4D (IN SPACE AND TIME)

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Abstract: A rocky planet, from deep interior to atmosphere has the potential to generate essential nutrients and redox gradients critical for the emergence and the evolution of life. I will present first results on two very different large-scale planetary processes that generate nutrients and redox gradients on Mars-within the deep interior and in shallow brinesacross time (from planet formation to modern day) and space (local resolution, global coverage).

We use time-dependent geodynamic models, capable of computing the 3D temperature profile - self-consistently accounting for serpentinization and radiolysis reactions as a function of subsurface temperature, pressure, and chemistry - throughout the last 4.5 billion years (based on [1]-[4]). Additionally, we couple a global climate model (the Mars Weather Research and Forecasting, MarsWRF). MarsWRF is a global model based on the terrestrial mesoscale WRF model (see [5]-[7]) and is a Mars-specific implementation of the PlanetWRF GCM [8], accounting for a changing climate with variable planet obliquity through time.

Geodynamic and climate models combined allow us to compute for Mars the 4D distribution (one dimension in time and 3D distribution in space) of 1) hydrogen-rich reducing subsurface environments, driven by serpentinization and radiolysis of water, and 2) oxygen-rich regions as a product of atmosphere-brine (e.g., perchlorate brines) interactions governed by climate and surface chemistry. We will show time-dependent spatial maps of such zones, suggesting a large potential for aerobic respiration on Mars today and in its recent geologic past (previous 20 Ma) varying with obliquity changes throughout time, as well as the potential for locally large modern-day hydrogen fluxes. These two examples provide insight into the emerging capabilities of modeling the Martian habitability in three spatial dimensions with increasing resolution and across time, from planet formation to today.

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B4.1-0029-18 SEIS/INSIGHT: TOWARD THE SEISMIC DISCOVERING OF MARS

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The NASA InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) mission will land on Mars on November, 26th after a launch in May, 2018. The payload is a complete international geophys-ical observatory, with a seismometer (SEIS, France), a heat flux experiment (HP3, Germany), a geodesy experiment (RISE, US), a magnetometer and the APSS (US) suite of atmospheric sensors measuring wind (TWINS, Spain), atmospheric temperature, pressure and magnetic fields. SEIS is the primary instrument of the mission and consists of a 3-axis very-broad-band (VBB, France) instrument and a 3-axis short period (SP, UK) instrument, mounted on a Leveling system (LVL, Germany), connected to acquisition and control electronics (Ebox, Switzerland) by a Tether (US), and protected by a Wind and Thermal Shield (WTS, US). The SP noise floor is 3 10-9 m/s2/Hz1/2 between 0.1 and 6 Hz and significantly better than SP requirements (10-8 m/s2/Hz1/2 between 0.1 and 10Hz). The VBBs are en-closed in a vacuum thermal enclosure (EC) under JPL responsibility, which not only provides a high thermal pro-tection for the VBBs but also reduces their Brownian noise, enabling the VBBs to reach a very low noise floor of 3 10-10 m/s2/Hz1/2 between 0.1 and 1 Hz, which is also significantly better than VBBs requirements (10-9 m/s2/Hz1/2 between 0.01 and 1Hz). We describe first the SEIS experiment and present its science goals and performance demonstrated during the Flight Model characterization done during the 2017 Flight Model delivery activities, both in the clean rooms of CNES and LMA for the Flight Units and in the Black Forest Observatory seismic vault for the qualification unit. As SEIS is expected to provide the first seismic records of Mars, implementation of the science goals has been very challenging due to the lack of information on the deep seismic interior structure of Mars, as well as its level of seismic activity and surface seismic noise. Nevertheless and in parallel with the hardware technical developments made by the SEIS hardware team, the SEIS science team has developed sophisticated noise models, blind tests with synthetic data and field tests, including during activities of the HP3 mole system, which will be presented. We then summarize and review the most recent analysis made by the SEIS team for predicting the seismic per-formance of the SEIS experiment in the Martian environment, including pressure and magnetic decorrelations using APSS sensors. We present the most recent update estimates of seismic signals generated by quakes, impacts and the Martian dynamic atmosphere, as well as structure inversion and seismic catalogue perspectives. We conclude by describing the Public Outreach and Educational program of SEIS.

B4.1-0030-18 EXOMARS TRACE GAS ORBITER - MARS ATMOSPHERE AND GRAVITY EXPERIMENT SUPPORT

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The ExoMars Trace Gas Orbiter (TGO) reached Mars orbit on October 19, 2016, and after aerobraking, it will begin its final science and operational data relay phase in April 2018 in a 400 km near-circular orbit. Tracking data from these mission phases are collected and analysed for TGO's Mars Atmosphere and Gravity Experiment investigation (MAGE).

MAGE will make use of ground infrastructure as well as spacecraft subsystems. During the orbital phase of the mission, X-band will be used for uplink for commanding, and downlink for telemetry return and tracking. Deep-space ground stations from ESA, NASA and Russia's Roscosmos will track TGO. Doppler shift in the radio communications signal can be used to determine the gravitational field of Mars. From the time variability of the gravity field one can derive and track seasonal changes in the location of carbon dioxide deposited on the surface. TGO's Doppler tracking data is also used for estimates of the neutral density of Mars thermosphere during the aerobraking passes.

ESA's Science Operations Centre (SOC) is responsible for science planning and operation for TGO, as well as low-level processing and archiving in the ESAC Planetary Science Archive (PSA) of the resulting data. We have created the Mars Atmosphere and Gravity Experiment

Working Group (MAGE WG) that acts as a liaison between the guest investigator and ESA. MAGE WG coordinates the process that ensures a proper data provision mechanism to the guest investigator, starting with the data requirements to conduct the MAGE investigation. The Data Processing pipeline receives raw telemetry from the Mission Operations Centre in ESOC and generates PDS4 products for inclusion in the PSA. Products for the archive are grouped into containers known as collections and these in turn are grouped into bundles of collections, following the PDS4 standard. For TGO there are bundles for each instrument plus a separate bundle for generic mission data, with a typical instrument bundle containing separate collections for different processing levels plus calibration, documentation, ancillary and other distinct data types.

In this paper we will give an overview of the TGO's MAGE investigation and ESA's support to provide the required products to the selected guest investigator and archiving for the working group.

ExoMars is a joint programme between the European Space Agency and ROSCOSMOS.

B4.1-0032-18 WATER ICE CLOUD PROFILES DURING THE APHELION SEASON ON MARS RETRIEVED FROM MARS CLIMATE SOUNDER FAR-INFRARED RADIANCE MEASUREMENTS

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Limb sounding of thermal emission in the infrared wavelength range is a powerful technique for measuring aerosols in the martian atmosphere. It provides superior vertical resolution and, due to the long optical path, typically has a higher sensitivity compared with nadir viewing measurements. However, the limb path can become opaque in high aerosol conditions, preventing a limb sounding measurement from penetrating the atmosphere. This is a particular problem in the aphelion season on Mars, where water ice clouds reach opacities that make limb measurements at mid-infrared wavelengths challenging. This problem is greatly improved with measurements in the far-infrared wavelength region, where water ice opacities are much reduced.

The Mars Climate Sounder (MCS), a passive infrared radiometer onboard Mars Reconnaissance Orbiter (MRO), has been operating in Mars orbit since September 2006. With its 5 midinfrared, 3 far infrared, and one broadband visible/near-infrared channels it views the martian atmosphere in limb, nadir, and off-nadir geometries. Each spectral channel uses a linear detector array consisting of 21 elements, which provides -10 to 90 km altitude coverage with 5 km vertical sampling when pointed at the Mars limb. From the measured radiance profiles, atmospheric profiles of temperature, dust and water ice opacity are operationally retrieved using the midinfrared channels.

Here we present the first retrievals of water ice profiles from MCS limb measurements in the farinfrared. The retrievals combine detectors of the far-infrared channel centered at a frequency of 254 cm-1 in high water ice opacity conditions with detectors of the the mid-infrared channel centered at 843 cm-1 in low opacity conditions. The conversion between far-infrared and midinfrared opacities is based on extinction efficiency ratios obtained empirically from the MCS limb measurements [Kleinböhl et al., Sixth International Workshop on the Mars Atmosphere, 2017]. Limb retrievals of water ice in the far-infrared channel are typically possible at opacities a factor 2-3 higher than in the mid-infrared channel.

Initial results from these first retrievals indicate that the vertical structure of the water ice clouds in the equatorial cloud belt significantly changes between daytime and nighttime. During daytime water ice profiles exhibit a layered structure with peak opacities around 30 km altitude. During nighttime peak opacities tend to be lower but the ice is distributed over a larger vertical range. These first results suggest that the new capability of retrieving water ice profiles in the far-infrared will provide new insights into the structure of the equatorial cloud belt and its temporal evolution on diurnal to seasonal time scales.

B4.1-0033-18 A LOOK BACK AT MARS

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A review of the 1969 Mariner Mars images from the Narrow and Wide Angle cameras aboard Mariners 6 and 7 will be presented.

B4.1-0034-18 STUDY OF THERMOSPHERE/ EXOSPHERE OF MARS USING MOM OBSERVATIONS AND VALIDATION WITH MODELS

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The atmospheric composition data of Mars has been utilized from Mars Exospheric Neutral Composition Analyser (MENCA) experiment on board the Mars Orbiter Mission (MOM) during the period September 2014 through September 2016. The time series data has been processed to derive the corrected, calibrated and normalized parameters of various gaseous constituents along with the total atmospheric pressure of Mars. The time tagged data is further organised with reference to the satellite sub-point coordinates and its altitude from the surface using SPICE kernels of MOM with proper codes developed by us. The overall data is categorised for different orbits of MOM in order to select preferable data points, particularly near to the periareion of MOM. The total pressure values were analysed to study the characteristics of its variability with altitude, seasons and influence of solar activity. The results obtained were compared with a simple model developed for this purpose. Further analysis is carried out to compute the partial pressures of CO_2, Ar, (N_2+CO), H, N and O to derive their spatial and temporal variations. In addition, high resolution results are also obtained for selected data from MOM orbits for comparison with similar observations made by other missions of Mars. The results presented provide various points to validate the model developed by us and existing models elsewhere.

B4.1-0035-18 MARTIAN ACTIVE GULLY STUDIES AND WHAT THEY IMPLY ABOUT PRESENT AND RECENT SURFACE PROCESSES

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Young martian gullies, first observed in 2000 by Malin et al., usually consist of an alcove, channel, and apron and are found on both sandy and rocky slopes, primarily through the mid-latitudes (e.g., Auld and Dixon, 2016; Harrison et al., 2015). Due to their morphological resemblance to terrestrial water-formed ravines (or large gullies), many of the early studies proposed water-driven mechanisms for their formation. Furthermore, due to their superposition over young geologic features, pristine features, and lack of superimposed craters, some of these features were interpreted as potential geomorphic evidence of recent surface liquid water flow and thus categorized as a potential ('uncertain') Special Region (as described by the Special Regions Science Analysis Groups (Beaty et al., 2006; Rummel et al., 2014) and adopted by COSPAR (Kminek et al., 2010)): regions within which conditions for replication of terrestrial organisms might be found, especially with regards to temperature and water availability. Proposed water-driven mechanisms for gully formation were questioned, however, when active martian gullies were observed within the southern mid-latitudes, on both dune and non-dune (e.g., crater walls) slopes (Diniega et al., 2010; Dundas et al., 2010; Malin et al., 2006). Based on the winter-timing and locations of activity, those studies showed that present-day gully activity was likely tied to a seasonal frost-driven process. Since those first investigations, the activity within the southern mid-latitudes has been quantified over several Mars years and timing has been constrained further to late winter/early springtime (possibly related to springtime sublimation-driven or initiated processes) (Dundas et al., 2012; 2015; in press: Geo Soc London). Furthermore, studies of north polar dune "gullies" (i.e., alcove-apron features, often lacking a channel - hence the quotation marks) show activity also constrained to the frosted periods of the martian year (although possibly not the same frosted period) (Diniega et al., 2017; Hansen et al., 2011; 2015). This has motivated efforts to identify possible CO_2-frost driven mechanisms and to constrain the exact form and quantity of frost needed to initiate activity. However, it is not yet clear if all gullies form through the same driving environmental conditions and/or mass-wasting processes. In particular, equatorial gullies, while smaller than those in the mid-latitudes, also exist in regions where CO_2 frost is not expected and some have shown activity (Dundas et al., 2015; McEwen, in press: From Habitability to Life on Mars). In this presentation, we will give an overview of martian active gully studies from 2010 through the present. Within these results, we will discuss present-day rates of gully activity that have been extrapolated by Dundas et al. (2015; in press: GSL) to constrain what older features may reflect about past environmental conditions and processes. We will identify the current, most pressing gully-related questions (and when possible, relate these to ongoing investigations) and compare our current understanding of gullies to the definition of potential Special Regions as outlined in the latest SR-SAG and COSPAR reports.

B4.1-0036-18 SLOPE STREAKS SEGMENTATION USING WAVE ATOMS AND MORPHOLOGICAL OPERATORS

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Slope streaks are a form of down-slope mass-movements that typically occur on the surface of Mars. The study of slope streaks has become a hot topic in recent years, motivated especially by scientists and astronomers who seek to understand this phenomenon and its hypothetical relationship with transient water activity on Mars. Since detecting slope streaks plays an important role in most computer vision systems and cartographic products, in this work we propose a new approach to detect and segment slope streaks in Mars images. We combine a recent harmonic analysis tool called wave atoms with classical morphology operators as an effective and concise framework. The wave atoms-driven model is a variant of 2D wavelet packet that improves the sparse representation of specific stripe-like features in the image when compared to more popular expansions such as wavelets, Gabor atoms and curvelets. In fact, the wave atoms package has two main advantages when compared against others texture analysis tools: first, the ability to systematically capture a certain pattern at pre-selected scales, and second, it ensures high anisotropy when representing image features such as stripes and oscillatory textures. We show that the designed framework produces high scores in terms of quantitative quality metrics when assessed on various data sets of Mars surface.

B4.1-0037-18 SURFACE GEOLOGY AND PHYSICAL PROPERTIES INVESTIGATIONS OF THE INSIGHT LANDING SITE

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Although the prime focus of the InSight lander is determining the interior structure of Mars, it will also carry out geology and physical properties investigations that will test surface materials and subsurface structure predicted by interpretations of remote sensing data used to select the landing site in western Elysium Planitia near 4.5°N, 135.9°E [1]. Mapping of platy and smooth lava flows indicates the plains surface on which the InSight ellipse is located is composed of Early Hesperian volcanics about 2 km thick [2]. A surficial layer of fragmented regolith 3-17 m thick is indicated by the presence of rocks in the ejecta of fresh craters 30-200 m in diameter (but not smaller craters), and exposures of relatively fine-grained regolith that grades with depth into coarse blocky breccia over strong, jointed bedrock in nearby Hephaestus Fossae in southern

Utopia Planitia [3]. The surface is dominated by smooth terrain with a homogeneous thermal inertia of 200 J m–2 K–1 s–1/2 consistent with a surface composed of dominantly cohesionless, fine sand (0.17 mm) or sandy soils with low cohesion (<few kPa). Rock abundance is very low (<6%) except near sparsely distributed rocky ejecta craters where it can be as high as 35%. The albedo and dust cover index of the landing site are similar to dusty and low-rock abundance portions of the Gusev cratered plains, and both sites have been dominantly shaped by impact and eolian processes [1,4].

The geology and physical properties investigations will also provide critical information for both placing the instruments

(seismometer and heat flow probe with mole) on the surface after landing and for understanding the nature of the shallow subsurface and its effect on transmitted seismic waves [2]. Two color cameras on the lander will obtain multiple, wideangle stereo images of the surface and its interaction with the spacecraft and instruments.

Images will identify the geologic materials and features present, quantify their areal coverage, help determine the basic geologic evolution of the area, and provide ground truth for orbital remote sensing data. Continuous measurements of wind speed and direction offer a unique opportunity to correlate dust devils and high winds with eolian changes imaged at the surface and to determine the threshold friction wind stress for grain motion on Mars. A radiometer will determine the hourly temperature of the surface in two spots, which will allow derivation of the thermal inertia of the surface materials present and their particle size and/or cohesion. During the first two weeks after landing, these investigations will support the selection of instrument placement locations that are relatively smooth, flat, free of small rocks and load bearing. Location of the lander in high-resolution orbital images and direct-to-Earth spacecraft tracking will yield the best located position on Mars in both inertial and cartographic space. Soil mechanics parameters and elastic properties of near surface materials will be determined from experiments with the arm and scoop of the lander (indentations, scraping/trenching, and piling), passive monitoring of seismic waves, mole penetration and thermal conductivity measurements from the surface to 3-5 m depth, and the measurement of seismic waves during mole hammering [2].

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B4.1-0038-18 ANALYSIS OF GEOMORPHOLOGY OF ARSIA-MONS USING MCC, VIKING, HIRISE AND MOLA DATASET

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In this investigation we use MCC, Viking, HiRISE and MOLA elevation data to understand the geomorphology of Arsia Mons. Arsia Mon is located in the Tharsis rise. The features identified as 1) scrap, which is considered to be the displacement of the land surface due to the movement along faults during tectonic events; 2) lobate facies which are convex lobes and resembles like rock-glacier on earth; 3) Knobby Facies, this sedimentary deposition often interpreted as a sublimation till which is resulted from downwasting of ash-rich glacier ice; 4) shield of Arsia Mons; 5) Caldera Floor, which represents the surface of the bowl-like depression inside the magma chamber ; and 6) Caldera Wall, it represents the surrounding walls Arsia Mons volcano.

B4.1-0039-18 TEMPORAL ANALYSIS OF MARTIAN SLOPE STREAKS

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Slope streaks are typically dark, narrow and fan-shaped features that extend down slope on Mars surface. They are one of the most active and dynamic process observed on the Martian ground nowadays. Dry and wet processes have been suggested for causing their formation but their origin is still unclear. Moreover, the streaks tend to fade with time, providing clues about dust settling and material properties. Thus, the objective of this work was to quantify and to compare the temporal variation of slope streaks albedo. Therefore, was analysed 63 streaks obtained from 25 overlapping images (10 MOC e 15 CTX) distributed on equatorial regions of Mars (Arabia, Amazonis and Tharsis). The overlapping images were acquired between the years 2000 and 2013. The fading process quantification was determined by the albedo contrast ratio of the inside and neighborhood pixels of the each individual streak. The streaks were segmented automatically by a morphological algorithm in order to obtain the media digital number (DN) of the interior and exterior of each streak. Once defined the media DN, it was converted into albedo value, taking as reference the calibration documentation of the MOC and CTX cameras. This procedure was made for each streak on 25 images. In a global evaluation throughout 13 terrestrial years, all the 63 slope streaks have faded. However, during some short periods we observed a slight reversal to darkening, and then brightening over again on the three regions. We also observed that the speed of fading is higher on the streaks with lower contrast ratio. The full inside pixel analysis of the streaks along with albedo transformation provided by our method ensure a whole set of reliable data.

B4.1-0040-18 EQUATORIAL SUBSURFACE ICE DETECTION IN THE PLAINS OF SOUTHWEST OF OLYMPUS MONS, MARS

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The detection of subsurface ice in mid-latitudes using SHAllow RADar (SHARAD) sounder onboard the Mars Reconnaissance Orbiter (MRO) and the formation of North Polar Layered Deposits (NPLD) and South Polar Layered Deposits (SPLD) revealed the journey of planet from various axial tilts. Mars Paleoclimate have always been the curiosity for the researchers. In the same mission, Compact Reconnaissance Imaging Spectrometers for Mars (CRISM) also played a vital role for many successful missions onward MRO to choose their prolific study area. The terrain boundary of south of the Olympus Mons shows geologically Amazonian and Hesperian transition. Many studies suggested pyroclastic flow deposition process formed Medusae Fossae Formation (MFF) units, steep sided Yardangs and ridges seen in images of Mars Color Camera (MCC) onboard Mars Orbiter Mission (MOM). The region observed with High Resolution Imaging Science Experiment (HiRISE) images having centimeter to meter scale roughness and low near subsurface permittivity decreases the strength of radar echo, even some parts are totally fade-up and these are the stealth areas. In this study, we detected subsurface reflector of low permittivity (nearby water-ice) bearing materials along the rise of south terrain (10.12° N, 220.10° S) towards roughest surface of MFF southwest of Olympus Mons. The Recurring Slope Linea Identified by HiRISE in this area hypothetically brings a scenario that they may be feeding by shallow aquifer of melting ice lies under the stealth area of porous rocks.

B4.1-0041-18 IDENTIFICATION OF CHLOROBENZENE IN THE VIKING GAS CHROMATOGRAPHMASS SPECTROMETER DATA SETS: REANALYSIS OF VIKING MISSION DATA CONSISTENT WITH AROMATIC ORGANIC COMPOUNDS ON MARS

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The twin 1976 Viking landers (VL-1 and VL-2) performed the first in situ search for organic compounds on the martian surface. Each lander carried a pyrolysis-gas chromatograph mass spectrometer (pyr-GCMS), which were used to search for organic molecules in regolith samples excavated with a robotic arm [1]. Chloromethane was detected by VL-1 at levels of 15 parts per billion (ppb) and dichloromethane was detected by VL-2 at levels of 2-40 ppb [2]. Both chlorinated hydrocarbons were attributed to either terrestrial contamination resulting from the pre-flight use of chlorinated cleaning-solvents, or from the reaction of absorbed traces of methanol and HCl [2]. After martian perchlorate was discovered by the Wet Chemistry Laboratory on the 2008 Phoenix lander [3], Navarro-Gonzalez et al. [4] suggested that parts per million (ppm) levels of indigenous martian organics may have provided the carbon source for the reaction with perchlorate in the Viking GCMS ovens that resulted in the formation of the detected level of chlorinated organics. Motivated by the recent detection of chlorobenzene by the Sample Analysis at Mars (SAM) instrument suite on the Curiosity rover, and the identification of its carbon source as indigenous to Mars [5], we reexamined the original, microfilm preserved, Viking pyr-GCMS data sets. Here we show evidence for the presence of chlorobenzene in VL-2 data at levels corresponding to 0.08-1.0 ppb (relative to sample mass), in runs when the sample was heated respectively to 350°C and 500°C. We considered possible sources of carbon that may have produced the chlorobenzene signal, by reaction with perchlorate during pyrolysis, including potential indigenous martian organics and previously unreported instrument contamination. We conclude that the chlorobenzene signal measured by VL-2 originated from martian chlorine sources, and its carbon source is consistent with a martian origin, though a carbon source contribution from the instrument background cannot yet be ruled out. Through this work we have demonstrated that the Viking pyr-GCMS experiment may have detected organic materials indigenous to Mars' surface for the first time, almost forty years before the Curiosity rover's SAM experiment detected indigenous martian organics.

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B4.1-0042-18 MINERALOGY AND MORPHOLOGY OF EOS CHAOS REGION IN EASTERN VALLES MARINERIS, MARS: IMPLICATIONS FOR DIVERSE GEOLOGICAL PROCESSES

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Structural and compositional variations within various segments of Valles Marineris, Mars can provide significant information on diverse geological processes operated within this largest valley system. Eos chaos is Martian morphological feature with diverse lithological units and structural features located towards east of Valles Marineris and with the central latitude and longitude 16.82o and 313.48o respectively. Light toned layered deposits and mineralogical evidences for aqueous processes has been reported from nearby areas of Eos chaos including Capri chasma and Eos chasma. Hyperspectral data derived out of Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) onboard NASA's Mars Reconnaissance Orbiter (MRO), Images of Mars Colour Camera (MCC) onboard ISRO's Mars Orbiter Mission (MOM 1), Context Camera (CTX), and High Resolution Imaging Science Experiment (HiRISE) instrument on board MRO have been utilized. Using MTRDR CRISM data hydrated sulphate minerals have been identified from the western part of Eos chaos region within the Valles Marineris. Light toned sedimentary rocks having strong spectral signatures of kieserite ($MgSO_4.H_2O$) provide evidences for past aqueous processes operated in this area. Hydrous sulphate minerals like szomolnokite ($FeSO_4.H_2O$) and romerite ($Fe^{2+}Fe^{3+}{}_2(SO_4)_4.14(H_2O)$) have also been detected from this area. Low-grade metamorphic mineral zoisite ($Ca_2Al_3(SiO_4)_3(OH)$) has been identified from south sloping eroded surface of the western Eos chaos based on a characteristic spectral absorption feature at 1.5μm. Zoisite hints for a hydrothermal condition favorable for the formation of low grade metamorphic mineral associations. Presence of metamorphosed plagioclase glass maskelyinte implies an impact origin. An impact generated hydrothermal or low-grade metamorphism on Eos chaos has been proposed for the formation of zoisite. Various morphological features such as eroded face of chaotic mount with distinct layering, mesas formed by fluvial erosion, light toned boulders having spectral signature of hydrated minerals, gullies and channels partially filled by eolian sediments of western Eos chaos also implies past aqueous processes. Landslip with lobate structure directing north has been identified from eastern segment of Eos chaos. This flow of terrain towards north indicates saturated nature of land. Terraced appearance of the terrain sheds light on a series of faults occurred here. A model for the faulting has been prepared after analyzing profile derived from the Digital Elevation Model (DEM) created using stereo CTX images of the study area.

B4.1-0043-18 VACUUM SOLUTION APPROACH FOR THE SEIS INSTRUMENT ON THE INSIGHT MISSION TO MARS

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The SEIS seismometer on the NASA InSight mission to Mars is of paramount importance for the surface-based geophysical investigation of Mars. The instrument contains three VeryBroad-Band (VBB) sensors [1], which enable the determination of the origin and magnitude of earthquakes, and aid the understanding of the planet structure. Due to the low mass, which couples to the seismic waves, the instrument has an inherently high sensitivity to the ambient pressure, which causes viscous damping and increased noise through heat transfer. Vacuum of <0.01 mbar is required for optimum performance and 0.1 mbar is considered the end-of-life pressure limit. In 2015, the instrument encountered anomalies that prevented achieving such vacuum levels. An air leak was first discovered and, subsequently, the non-evaporative getters were found to have insufficient capacity to cope with the instrument outgassing rates. Due to the insufficient time to resolve these issues, the InSight launch was postponed for 2018 [2]. The Evacuated Container (EC), the housing of the SEIS instrument, was redesigned to address the vacuum anomalies. The vulnerability to physical leak was alleviated on component level. Mitigating the outgassing rate requirement necessitated the development of novel zeolite-loaded aerogel (ZLA) getters [3]. Such materials were devised, tested and implemented in place of the original non-evaporative getters. The getter adsorption requirements were derived from residual gas analysis (RGA) spectra, taken during the SEIS bakeout events in 2015, as well as from a VBB outgassing test conducted in 2016. At the 117 C bakeout temperature, the spectrum was dominated by volatile organic materials, originating from an incompletely outgassed adhesive with a 105 °C glass transition temperature, whereas water was the overwhelmingly dominant component of the constituents of the RGA spectra at room temperature. Therefore, water became the primary adsorbent target for the new getters. The other measured components, H_2, CO and CO_2, can also be explained by byproducts of water breakup at the hot tungsten filaments. However, CO_2 can also be a cross-linking byproduct of adhesives, and titanium and stainless steel alloys contribute H_2, albeit at extremely small rates, reduced through annealing. These adsorption needs were addressed as a precautionary measure. CO_2 adsorption capability was also implemented in lieu of a redundancy mechanism for the mitigation of a potential Mars atmospheric leak during the mission. Water and CO_2 adsorption capabilities were provided by custom-developed ZLA getters, made by incorporating Na^+ and Ca^+ ion-exchanged faujasite zeolite micron-sized particles into an aerogel matrix, which facilitated molecular transport of the adsorbent to the zeolite. The ZLA getters were prepared from a liquid precursor, solidified into six metal getter canisters, engineered into the space allowed for the six original SAES getters. The canisters were open to the EC volume through a 1 µum filter to eliminate particulate contamination form the getters.

Validation and verification tests with assembled canisters were done to assess the level of water desorption from the getters at the bakeout temperatures, as well as to evaluate the getter adsorption capacity. Accelerated test conditions utilized water vapor as a proxy for outgassing at significantly higher rates. Due to the inability to complete the testing of Pd^+ exchanged zeolite on time for InSight to be added to the ZLA mixture for H_2 adsorption, the latter was addressed by SAES Ti/Pd getter films, deposited on modified thermal shields, welded to the shells of the Evacuated Container. The capacity of the Ti/Pd getters was tested at the manufacturer. Details of the verification and validation program for ensuring a viable vacuum solution for InSight are presented. The SEIS crown, containing the three sensors and the six getter canisters was first baked to reduce the outgassing from fresh adhesives. After welding the shells, whose fabrication included a 320 °C anneal step to minimize H_2

outgassing, the hermeticity of the complete SEIS instrument has been tested and verified to the state-of-the-art level ($<1x10^{-10}$ mbar.L/s He) in the full temperature range from 105 °C to +60 °C. The final instrument bakeout was done at 100 °C for 10 days. A satisfactory initial pressure of $3x10^{-5}$ mbar, measured by the pressure rise method, was achieved at room temperature, and the instrument was separated from the ground pumping system by pinching off the connecting copper tube (queusot). After the pinch-off, there is no possibility for a direct pressure measurement inside the instrument for levels below 0.002 mbar; a heat-transfer method was developed by CNES to measure higher pressures. The most recent in situ pressure measurements have not yet detected a pressure increase. A worst-case SEIS pressure forecast, constructed on the basis of getters test data, exceeds the mission requirements. Given the SEIS thermal conditions during the mission, the expected vacuum operational VBB environment is, expectedly, $<10^{-5}$ mbar for a duration far exceeding that of the primary mission. Furthermore, the ZLA getters have the capacity to deal with a significant atmospheric leak on Mars should such a necessity arise.

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B4.1-0044-18 IMPACT-SEISMIC INVESTIGATIONS PLANNED FOR THE INSIGHT MISSION

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The InSight NASA Discovery mission (Banerdt et al. 2017) will study the interior of Mars using seismic signals. These will emanate from both interior tectonic sources as well as from meteoroid impacts. We are planning many impact-related investigations that will further the scientific goals of the mission. For one, measuring the rate of crater formation at the surface will achieve the mission goal of determining the impact flux at Mars. Additionally, impacts will inform the major goal of investigating the interior structure of Mars, as each impact located on the surface will provide known seismic ray paths through the interior. Impact-related scientific analyses also include the seismic source and waveform modeling of impact generated seismic signals; detection, localization, and characterization of impact sources; detection of meteors; modeling of meteor infrasound and acoustic source and shock signals; and comparative analyses between Mars, Earth and the Moon. Unlike the Moon, Mars has an atmosphere; thus we must consider the seismic effects of airbursts and fragmentation.

Differentiating impact signals in seismic data from those of marsquakes will be challenging. We plan to utilize a suite of discriminating features, including: positive first motions, relative energies of P and S waves, ratios of body to surface wave magnitudes, cutoff frequencies, and the presence or absence of surface reflection phases from depth. Once InSight detects an impact in seismic data and a rough location is derived, images will be requested from spacecraft orbiting Mars to search for the new impact feature. Identification of fresh crater(s) will provide a definitive source location, something that will most likely not be possible for tectonic seismic sources. This will be of high scientific importance, allowing for determination of the ray paths and calibrating interior structure models and seismic attenuation. Any successful impact detections will also constrain the seismic source parameters (moment; frequency cutoff; and seismic efficiency, the ratio of impact energy to radiated seismic energy). The latter value in particular is not well constrained, with values in the literature ranging from 106 to 102 (Pomeroy 1963; McGarr 1969; Latham et al. 1970a; 1970b; Patton and Walter 1993; Walker 2003; Shishkin 2007; Richardson Kedar 2013; Güldemeister Wünnemann 2017).

Predictions of detectable impacts are uncertain to several orders of magnitude because of unknown aspects of the seismic propagation properties of Mars, the current impact rate, and the background noise level. In general, the larger the impact, the farther away it will be possible to detect it. Small impacts will only be detectable within a very limited range of the InSight landing site; only rare impacts producing craters > 30-40 m in diameter will be detected at large distances. Given the uncertainties mentioned above, (Teanby 2015) estimated that between 0.1-30 impacts per Earth year will be detectable at moderate distances < 1,000 km, while (Lognonné Johnson 2015) estimated 10 total impacts/year. (Daubar et al. 2015) determined a similar estimate of 4-8 total impacts detected/year. Large events that could be detected globally only occur once every 1 to 10 years (Teanby Wookey 2011). With a few to tens of impact events detected, the impact-related scientific goals of InSight should be achievable within the timeframe of the prime mission (one Mars year).

B4.1-0045-18 THE COLOR CAMERAS ON THE INSIGHT MARS LANDER

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The InSight spacecraft is scheduled for launch in May 2018 with a Mars landing six months later in November 2018 [1]. The key objective of the InSight mission is the investigation of the interior structure and processes of Mars using a seismometer [2] and heat flow probe [3]. A robotic arm [4] will lift these instruments off of the top deck of the lander and place them onto the ground at specific locations chosen by the InSight science and engineering teams. To assist in this deployment task, the lander is equipped with two cameras: an Instrument Deployment Camera (IDC) mounted on the robotic arm and an Instrument Context Camera (ICC) mounted on the lander body underneath the top deck.

The primary objectives of the IDC and ICC are to: 1) support terrain assessment for the selection of the SEIS and HP3 instrument deployment locations, 2) facilitate and document the deployment activities, and 3) monitor the location and state of the instruments postdeployment. In addition, images from the cameras will be used to investigate the geology and physical properties of the landing site [5]. These objectives are met by the acquisition of images of the lander deck and the deployment workspace, nominally located to the south of the lander.

Both InSight cameras are flight spare Mars Science Laboratory (MSL) engineering cameras

[6] which flew build-to-print copies of the Mars Exploration Rover (MER) cameras [7]. The InSight project has converted the MSL cameras from greyscale to RGB color by replacing the MSL detector with a Bayer color filter array (CFA) version of the same detector. The camera electronics and optical assemblies are otherwise unchanged from MSL. The cameras utilize frame transfer charge-coupled devices (CCDs) with a photosensitive area of 1024 by 1024 pixels digitized at 12 bits. Both cameras use identical detectors and readout electronics, differing only in the type of lens mounted to the camera head. The IDC field of view (FOV) is 45 x 45 degrees, and the angular resolution at the center of the FOV is 0.82 mrad/pixel. Because it is attached to the robotic arm near the elbow, the IDC field of regard can cover areas above and below the lander deck, including views of the lander footpads, equipment on top of the lander deck, the sky, and terrain not obscured by the lander. Stereo IDC images are acquired by moving the arm-mounted camera between images. The ICC, mounted to the lander, has a FOV of 124 x 124 degrees and an angular resolution at the center of the FOV of 2.1 mrad/pixel.

All onboard IDC/ICC image processing is done by the lander flight software running on the lander computer. After an image is read out from the camera, a shutter image is acquired and subtracted from the image of interest; this removes frame transfer readout smear and any dark current acquired during frame readout. The raw Bayer image is demosaicked into RGB triplets, color balanced onboard using preloaded color correction coefficients, and companded to 8 bits using a 12-to-8 bit square root lookup table (LUT). The resultant images are JPEG-compressed

[8] by the lander computer and packetized for downlink. Typical JPEG quality values used for deployment activities are 85, 90, and 95, which correspond approximately to compressed bit rates of 1, 2, and 3 bits/pixel, respectively, although the exact relationship between compression quality and bit rate is scene-dependent.

Once on the ground, images are processed by the JPL Multimission Image Processing Laboratory (MIPL) using heritage image processing software from the MER and MSL missions [9]. The resulting three-dimensional (3D) terrain maps will be scrutinized by the science and engineering teams, and after careful topographical evaluation the operations team will command the robotic arm to place the instruments at the selected locations. The ICC will provide a wide-angle view of the activities during the deployment and will also serve as a partial backup to the IDC.

A full color panorama is also planned, as well as surface change detection and atmospheric imaging investigations. All InSight camera images acquired during the mission will be archived to the NASA Planetary Data System (PDS).

For a more detailed description of the InSight cameras, see [10].

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B4.1-0046-18 UNVEILING THE INTERIOR OF VENUS: USING TECTONIC DEFORMATIONS ALONG CANALI TO CONSTRAIN LITHOSPHERIC STRUCTURE & MANTLE CONVECTION

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Venus is Earth's "sister planet;" they both have nearly identical sizes and densities. However, analysis of its surface and atmosphere reveals that it took a very diverse evolutionary path from Earth. Studying the interior of Venus can help us understand when the evolutionary paths of Earth and Venus diverged and what caused this divergence. With the massive interest in the search for life beyond Earth, understanding the evolution of Venus could also significantly contribute towards answering the timely and provocative question of what makes a planet habitable. Deformational features of various varieties and styles are ubiquitous on the surface of Venus, and many of these display characteristic scales (widths or spacings) of deformation that fall into distinct size classes. We are studying the mantle convection and lithospheric structure of Venus by analyzing tectonic deformations along canali. Canali-type channels are long lava channels with almost constant widths found in the Venusian plains. Stratigraphic evidence points towards the canali being old features on the plains that formed with the last phases of extensive plains volcanism possibly induced by the hypothesized global resurfacing event 300 Myr ago. When these channels formed, they must have had downhill gradients, but post-depositional tectonic deformations in the Venusian lithosphere have caused them to be interspersed with nearly periodic topographic relief. The dominant length scales associated with these nearly periodic deformation features can inform us on the lithospheric structure and mantle convection of Venus. We have mapped all major (longer than 300 km) canali on Venus and generated their topographic profiles. Since the canali are sinuous and may not always flow perpendicular to the deformation features, the characteristic length scales of tectonic deformations we obtain by studying the canali undulation profiles may have a path dependent error in them. We are applying statistical modeling methods to eliminate this sinuosity-induced error in an attempt to accurately determine the deformation length scales. Once we eliminate the errors in the deformation length scales, we will build on crustal-thickness models of Zuber and Parmentier (1990) and plume models of Kiefer and Hager (1992), to link the observed length scales to the lithospheric structure and mantle convection of Venus.

B4.2-0001-18 THE INSIGHT MISSION TO THE INTERIOR OF MARS

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Introduction: InSight was selected by NASA to illuminate the fundamental processes of terrestrial planet formation and evolution by performing the first comprehensive surface-based geophysical investigation of Mars. It will provide key information on the composition and structure of an Earth-like planet that has gone through most of the evolutionary stages of the Earth up to, but not including, plate tectonics. The traces of this history are still contained in the basic structural parameters of the planet: the size, state and composition of the core, the composition and layering of the mantle, the thickness and layering of the crust, and the thermal flux from the interior.

Science Goals: The scientific goals of InSight are to understand the formation and evolution of terrestrial planets through investigation of the interior structure and processes of Mars and to determine its present level of tectonic activity and impact flux. These goals will be realized through a specific set of basic scientific objectives: 1) Determine the thickness and structure of the crust; 2) Determine the mantle's composition and structure; 3) Determine the size, composition, and physical state of the core; 4) Determine the thermal state of the interior;

5) Measure the rate and distribution of internal seismic activity; and 6) Measure the rate of meteorite impacts on the surface.

Instrumentation and Flight System: InSight will delineate these parameters for Mars with a focused set of investigations centered on seismology and supported by precision tracking and heat flow measurements. It carries two primary scientific instruments: SEIS, a six-component

(3 Short Period and 3 Very-Broad-Band sensors) seismometer with careful thermal control, shielding from martian wind and temperature variations, and a sensitivity comparable to the best terrestrial instruments across a frequency range of 1 mHz to 50 Hz; and HP3 (Heat Flow and Physical Properties Package), an instrumented self-hammering mole system that will penetrate as deep as 5 m below the surface, trailing a string of temperature sensors to measure the planetary heat flux through thermal gradient and conductivity measurements. A third investigation, RISE (Rotation and Interior Structure Experiment), uses the spacecraft X-band communication system to provide precision tracking measurements of variations in the rotational axis of Mars.

A key aspect of the mission is the use of a robotic arm and a set of cameras to deploy the seismometer and heat flow package to the ground, enabling these instruments of perform their precise geophysical measurements. In addition, InSight carries a set of environmental sensors to monitor the magnetic field ambient air temperature, pressure and wind in order to separate environmental noise from seismic signals.

The InSight flight system, built by Lockheed-Martin, is based on a near-copy of the proven Phoenix lander. It has been updated with modern avionics and includes power system upgrades (larger solar arrays and cold-temperature batteries) to support the baseline 2-year equatorial mission.

Mission Timeline: Originally scheduled for launch in 2016, InSight was forced to slip by one Mars launch opportunity (26 months) by a flaw that was uncovered late in testing in the seismometer's vacuum enclosure. The enclosure was redesigned and exhaustively tested, and by the time of this presentation InSight will have been launched twoard Mars in May 2018 from Vandenberg AFB. After a 6½ month cruise in a Type-1 trajectory, it will land in western Elysium Planitia on November 26, 2018. During a roughly 2-month deployment phase the seismometer, its wind and thermal shield, and the heat flow probe will be placed on the ground. Subsequently the mole will penetrate to its final depth and the lander will settle into a largely passive observation phase lasting at least one Mars year. Data will be relayed to Earth through orbiters (InSight can use any of MRO, Odyssey, MAVEN, Mars Express, or TGO). A lowrate X-band DTE channel is available for commanding and low-rate data return in case of emergency.

Summary and Conclusions: The InSight mission fills a longstanding gap in the scientific exploration of the solar system by performing an in-situ investigation of the interior of an Earth-like planet other than our own. It will provide unique and critical information about the fundamental processes of terrestrial planet formation and evolution.

B4.2-0002-18 EMIRATES MARS MISSION (EMM) 2020 OVERVIEW

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United Arab Emirates (UAE) has entered the space exploration race with the announcement of Emirates Mars Mission (EMM), the first Emirati mission to another planet, in 2014. Through this mission, UAE is to send an unmanned probe, called Hope probe, to be launched in summer 2020 and reach Mars by 2021 to coincide with UAE's 50th anniversary. The mission should be unique, and should aim for novel and significant discoveries that contributed to the ongoing work of the global space science community.

EMM has passed its Mission Concept Review (MCR), System Requirements Review (SRR), System Design Review (SDR), and Preliminary Design Review (PDR) phases. The mission is led by the Mohammed Bin Rashid Space Centre (MBRSC), in partnership with the University of Colorado Laboratory for Atmospheric and Space Physics (LASP), University of California Berkeley Space Sciences Lab (SSL), and Arizona State University (ASU) School of Earth and Space Exploration. The mission is designed to answer the following three science questions:

How does the Martian lower atmosphere respond globally, diurnally, and seasonally to solar forcing?

How do conditions throughout the Martian atmosphere affect rates of atmospheric escape?

How does the Martian exosphere behave temporally and spatially?

Each question is aligned with three mission objectives and four investigations that study the Martian atmospheric circulation and connections through measurements done using three instruments that image Mars in the visible, thermal infrared and ultraviolet wavelengths. Data will be collected around Mars for a period of an entire Martian year to provide scientists with valuable understanding of the changes to the Martian atmosphere today. The presentation will focus on the overviews of the mission and science objectives, instruments and spacecraft, as well as the ground and launch segments.

B4.2-0003-18 STATUS REPORT ON THE NASA MARS 2020 MISSION

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NASA's Mars 2020 mission has the twin goals of in-situ exploration of an ancient astrobiologically relevant site, and preparation and caching of samples for possible return to Earth by future missions. Mars 2020 will also test new technologies of potential value for future investigation of Mars.

The rover draws heavily on the design of the Mars Science Laboratory, with new instruments and capabilities for the mission's specific objectives. The science payload includes a high resolution stereo zoom camera (Mastcam-Z), an instrument for remote characterization of rock chemistry and mineralogy (Supercam), a high resolution microscopic imager (Watson), instruments for elemental, organic chemistry, and mineralogical mapping at the 100 m scale (PIXL, SHERLOC), a ground penetrating radar (RIMFAX), and an instrument to characterize environmental conditions (MEDA). An additional instrument (MOXIE) will demonstrate the conversion of atmospheric CO2 to O2 as a potential resource for future Mars exploration.

As the first mission in a possible Mars Sample Return (MSR) campaign, Mars 2020 has the capability to select, prepare, and cache about 35 rock core samples of about 15g each. To achieve very stringent organic, inorganic, and biologic contamination limits, the samples will be drilled using very clean hardware into ultraclean sample tubes. These tubes will be hermetically sealed immediately after collection. Eventually the rover will deposit these tubes at one or possibly more depots, accessible for individual retrieval at some time in the future. The sample tubes are designed to tolerate tens of years of environmental exposure on Mars and in orbit during the possible return journey.

The fundamental concept of this mission is that the in-situ investigations provide the geologic data that is necessary to understand the landing site and simultaneously to select and document samples worthy of return to Earth. In support of this ambitious undertaking the Mars 2020 project has improved rover autonomy and provided tools for faster decision making.

Three potential landing sites remain under consideration for Mars 2020. Jezero Crater is a crater lake site with a well-developed delta, Northeast Syrtis has evidence for shallow subsurface aqueous alteration, and a feature in the Columbia Hills may be a fossil hot spring. The final workshop leading to landing site selection will occur in early Fall, 2018.

The Mars 2020 mission is now transitioning into the integration stage. It is scheduled to be launched in July or August 2020, and arrive at Mars in February 2021. Its prime mission will be at least one Mars year.

B4.2-0004-18 SEARCHING FOR TRACES OF LIFE WITH EXOMARS

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The first ExoMars mission was launched on 14 March 2016 and arrived at the red planet on 19 October 2016. It included two elements: 1) the Trace Gas Orbiter (TGO) to study atmospheric trace gases and subsurface water with the goal to acquire information on possible on-going biological or hydrothermal rock alteration processes; and 2) Schiaparelli, a European Entry, Descent, and Landing (EDL) demonstrator to prove technologies for landing and perform measurements during descent and on the martian surface. TGO is performing well and will soon complete a one-year aerobraking phase to reach its science orbit-from where it will also provide data communication services for surface missions, nominally until end 2022. Unfortunately, the lander was lost during the last minute of the EDL sequence.

The second ExoMars mission is scheduled to launch on 25 July 2020. It will deliver an instrumented landed platform and a 310-kg mass rover to the martian surface. After the Rover will have egressed, the platform will carry out environment measurements at the landing site.

The rover will explore the local geology and search for signs of past and present life. A drill will allow the rover to collect and analyse samples from outcrops and at depth. The subsurface sampling capability will provide the best chance yet to access and analyse well-preserved sedimentary deposits, possibly containing molecular biosignatures.

The rover's Pasteur payload includes: panoramic instruments (wide-angle and high-resolution cameras, an infrared spectrometer, a ground-penetrating radar, and a neutron detector); a subsurface drill capable of reaching a depth of 2 m to acquire specimens; contact instruments for studying rocks and collected samples (a close-up imager and an infrared spectrometer in the drill head); a Sample Preparation and Distribution System (SPDS); and the analytical laboratory, the latter including a visual and infrared imaging spectrometer, a Raman spectrometer, and a Laser-Desorption, Thermal-Volatilisation, Derivatisation, Gas Chromatograph Mass Spectrometer (LD + Der-TV GCMS). The very powerful combination of mobility with the ability to access subsurface locations is unique to this mission.

This presentation will discuss both missions, but concentrate more on the ExoMars rover, its strategy to search for biosignatures, and the possible importance of its discoveries for Mars Sample Return.

B4.2-0005-18 THE MARS ORGANIC MOLECULE ANALYSER (MOMA) EXPERIMENT ONBOARD THE EXOMARS ROVER

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The Mars Organic Molecule Analyzer (MOMA) is one among the 9 science instruments onboard the Exomars 2020 rover. This is a unique chemical laboratory fully devoted to the search of organic molecules in the soil samples collected by the rover drill. The clay-rich rock accessible in Oxia Planum, the current preferred landing site zone, will provide the opportunity to sample ancient material, which are known to trap and stabilize organic molecules for very long durations on Earth. Moreover, the capability for the drill to collect samples down to 2 m deep will allow collection of samples that are protected from the harsh radiation and chemical conditions at the surface, thus increasing the potential to detect ancient organic materials. To achieve its goal, MOMA is composed of four main subsystems: - a pulsed UV laser (=266 nm, 1 ns duration) for performing Laser Desorption/Ionization (LDI) of molecules from the solid samples collected by the rover. This sampling method is known as a soft ionization process producing large, intact ions from the sample - a set of ovens able to conduct sample pyrolysis up to 850°C, or chemical treatments (i.e. derivatization) of the sample to enhance the analysis of key organic species indicating biotic or prebiotic chemistry, such as amino acids. - a gas chromatograph (GC) devoted to separate the many volatile species that may be released by heating or chemical treatment of the solid samples in the ovens. To produce the separation, the GC is composed of 4 analytical channels, each one targeted for separating a specific class of organic compounds. One of them will perform enantiomeric separation in order to assess the enantiomeric excess of key organic molecules, a feature that is important for identifying the existence of prebiotic chemistry. - an ion trap mass spectrometer (MS) that will characterize the ions produced from LDI, or from ionization by electronic impact (EI) of the molecules eluting from the GC. The design of this new mass spectrometer allows for both LDMS and GCMS analyses and its performances can be tailored to the analytical mode. Basically, the MS is able to characterize the ions in the m/z 50-500 range in the GCMS mode, and the m/z 100-1000 range in the LDMS mode, thereby focusing on the expected mass ranges produced by each ionization technique. In this contribution, we present an overview of the MOMA and of its performances derived from various experiments carried out on subsystem modules, and on the engineering test unit of the instrument. We will thus show the capability for this instrument to detect organic materials in relation to biotic and prebiotic processes on Mars.

B4.2-0006-18 CALIPHOTO: AN OPTICAL METHOD TO HELP IDENTIFICATION OF ROCKS DURING THE EXOMARS 2020 MISSION

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The objective of the ExoMars 2020 mission (ESA-Roscosmos) is to search for past or extant traces of life on the red planet. The originality of the mission is its drill, which will permit production of drill-cores (3 cm long for 1 cm diameter) from up to 2 meters in depth. The drill-cores will be observed before crushing by the CLUPI and by the HRC cameras. During the drilling phase, the CLUPI camera will also observe the pile of rock powder forming at the surface. On Earth, there is no need to observe rocks in powder form or as centimetric drillcores. Thus, to date, there has been no investigation to determine what geological information can be deduced from the observation of these kind of samples. The aim of the present study is thus to describe powders and drill-cores made from analogue samples in order to maximize the scientific data that can be deduced from these ExoMars 2020-specific observations.

The majority of rocks on the surface of Mars are volcanic [1,2] or derivatives of volcanics. Thus, for this study, relevant samples were selected from the Massif Central, in France, in order to cover a large range of volcanic rock types, as designated in the compositional TAS diagram (Total Alkali Silica). The samples were then crushed to less than 60 µm and displayed next to each other showing a large variety of colour. Although the preliminary observation shows differences in colour between the different samples, two main issues still remained to be tackled.

First, we observed that the main difference between the different powders was the brightness, the different powders having various tones of greys. Unfortunately, it also appears that decreasing grain size induces an increase in brightness. The powders must thus be compared after sieving to obtain a uniform grain size distribution. Nevertheless, this step remains relevant since experiments have shown that drill powders (fines) are characterised by a more or less similar grain size (<60 µm).

Secondly, the most important issue was the fact that the colour of a powder is totally dependent on the ambient luminosity. In order to solve the last issue, a new method called CaliPhoto® was developed that consists of adding a reference target to the field of view of the camera, close to the sample. An image processing algorithm is then used to calibrate the images and permit comparison of the different samples. Well characterized rocks were then crushed, sieved and photographed using a commercial camera equipped with a detector similar to that used by the ExoMars Close Up Imager, CLUPI, i.e. a digital Foveon® sensor, in order to create a database of the colours of rock powders.

Several tests were carried out. For rocks included in the database created so far, the method permits identification with good accuracy. More interestingly, for those rocks not included in the database, it was still possible to make a good match based on rocks of similar composition in the database. Moreover, rocks having similar elemental composition but very different bulk colours, such as rhyolite (light) and obsidian (dark), have a similar powder colour, permitting thus a good identification. At present, the method is being used to help the interpretation of the ExoMars 2020 drill-cores. The protocol is also adapted in order to free the method from additional targets to be fixed onto the rover. Finally, the CaliPhoto® method could be very useful on Mars to help identification of rocks during drilling without adding any new instrumentation.

Acknowledgements: We acknowledge the Maison du parc national des volcans d'Auvergne for permission to sample. We thank the CNES and the SATT Grand Centre for funding.

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B4.2-0007-18 MARTIAN MOONS EXPLORATION (MMX): JAPANESE PHOBOS SAMPLE RETURN MISSION

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Martian Moon eXploration (MMX) is the 3rd Japanese sample return mission followed by Hayabusa and Hayabusa-2. The MMX spacecraft is scheduled to be launched in 2024, orbit both Phobos and Deimos (multi-flyby), and retrieve and return >10 g of Phobos regolith back to Earth in 2029. The origins of Phobos and Deimos are still a matter of significant debate: capture of asteroids versus in-situ formation by a giant impact on Mars. In either case, MMX will definitely provide clues about their origins and offer an opportunity to directly explore the satellite building blocks or juvenile crust/mantle components of Mars. MMX will also aim to understand physical processes in the circumplanetary environment of Mars. The new knowledge of Phobos/Deimos and Mars will be further leveraged to constrain the initial condition of the Mars-moon system and to gain vital insights regarding the sources and delivery process of water (and organics) into the inner rocky planets.

We select six nominal science payloads for the remote sensing observations: 1) telescope (TL) and wide-angle multi-band (WAM) cameras, 2) near-infrared spectrometer (MacrOmega), 3) gamma-ray and neutron spectrometer (MEGANE), 4) light detection and ranging (LIDAR), 5) circum-Martian dust monitor (CMDM), and 6) mass spectrum analyzer (MSA). The spacecraft also carries a sampler system equipped with a robotic manipulator and corers, which enables the acquisition of Phobos regolith >2 cm beneath the surface.

The spacecraft consists of propulsion, exploration, and return modules (total launch mass =

3,500 kg). The chemical propulsion system is utilized for Mars orbit injection and escape maneuver. The outward interplanetary flights take 1 year by the most efficient Hohmann-like transfer. The spacecraft stays at circum-Mars orbits 3 years for exploration followed by the 1 year homeward interplanetary flight to Earth. The Phobos exploration includes multiple landing/sampling operations; each takes 2.5 hours. The spacecraft employs ballistic descent to reach the space right above a landing site before the final free-fall descent without a thruster jet to prevent whirling wind from blowing regolith particles.

B4.2-0008-18 FORWARD PLANNING FOR MARS SCIENTIFIC EXPLORATION

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The last two decades of NASA's exploration of Mars has combined science-focused inquiry with cutting edge technology to provide detailed and comprehensive datasets whose analyses have revolutionized our scientific understanding of past and current Martian environments. Data from past and ongoing Mars missions will continue to make significant discoveries in the areas of life, origins, and workings, and raise new high-priority questions, many of which will inform and drive aspects of Mars Sample Return (MSR) missions. In turn, the findings from MSR will require the contextual information provided by these missions, and will motivate additional discovery-driven science investigations.

NASA has supported an outstanding community of Mars scientists and engineers with expert knowledge of the martian environment and the technological means by which to explore it. They represent a national asset, spanning the full-range of career levels, with irreplaceable experience working in the Martian system via orbital and landed science operations. This community is a critical cog in the cycle of advancing our understanding of the Mars system: research and analysis clarifies and expands key scientific questions that feed directly into the design and development of technologies and missions that provide data for subsequent analyses. For NASA to continue the study of Mars during and beyond sample return, retention and expansion of the present engineering and science expertise in the community will be critical. However, the range and number of addressable Mars science investigations are expected to decline within the "lean MSR" architecture, and thus preservation of this knowledge and experience is at risk.

New discoveries in Mars system science, Mars sample science, and future human exploration remain to be made, but only if appropriate funding is available to support analyses of the substantial amounts of under-analyzed data returned by Mars missions. The receipt of samples from Mars in the 2030 timeframe will require a large community of sample scientists and analysts. But full interpretation of these samples requires placing them into broader planetary geologic context, such that a community with a mixture of geologists, geophysicists, geochemists, and atmospheric scientists also will be needed from now through the end of the existing extended missions and into the Mars2020 era (2021-2030). A representative portion of this experienced workforce will be needed to efficiently and effectively identify and respond to discoveries from Mars missions and MSR, including the development of investigations after

MSR.

In summary, two main challenges face the Mars community: (1) How to maintain momentum in interpreting the large amounts of data to address key goals of the Mars exploration program, including maximizing the science content of each phase of the MSR mission arc; and (2) How to retain the critical expertise and knowledge of a vibrant Mars science and engineering community both during and after MSR, and leading up to human exploration of Mars, in part through the targeted implementation of mission concepts at all levels. These issues could be addressed by deliberately and systematically increasing the resources provided to data analysis and technology maturation programs and ensuring their ongoing effectiveness during and after this period.

B4.2-0009-18 THE NEXT 30 YEARS OF MARS EXPLORATION: A PERSPECTIVE FROM THE NASA VISION 2050 WORKSHOP

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In February 2017, NASA convened a meeting to identify potential science goals and enabling technologies that can be implemented by the end of the 2040s that would support the next phase of Solar System exploration. Here I summarize the findings on Mars. This abstract focuses on the vision contributed by 19 leading earlyand mid-career scientists who will professionally have their entire careers in the period from now until 2050 [1]. Additional materials are derived from the Mars Exploration Program summary of goals [2] and a post-conference synthesis of these and all the Mars abstracts [3].

Organizing principle for Mars Exploration: The engine driving the Mars Exploration Program is and will remain fundamental science questions that can only be answered on Mars. Two questions "Is/was there life?" and "What sustains a habitable planet through time?" are crucial as we seek to understand the prevalence of inhabited terrestrial planets like our Earth. New discoveries of the last decade show that obliquity cycles periodically enhance Mars' habitability today and groundwaters were persistent through its history. Moreover, Mars is the only body in our solar system that provides the geologic record from its first billion years to access answers to questions about the response of a terrestrial planet (like Earth) to atmospheric change, loss of a magnetic field and heavy impact bombardment.

Synergies with human and commercial space: In 2018, we are at a point of natural HEOMD, SMD, and "new space" commercial synergy in questions and needed technologies. With well-thought out, continued coordination, this can be a tremendous boon to Mars science and exploration. Although many HEOMD and science-driven measurements overlap, some science questions are fundamentally different from those solely in service of exploration. For example, rather than only "what?" and "how much?", scientific questions about a rock unit with hydrated minerals on Mars are also "when?", "how?", and "why?". Measurements for understanding the timing and processes behind early planetary evolution fall largely within the province of science alone. As such, a science-driven robotic and sampling program at Mars can and should continue, independent of but complementary to HEOMD activities, incorporating the enhancements that human capabilities can provide as they become available.

Mission types and architectures: Robotic sample return should be performed at least once, as rapidly and cost-effectively as possible, by leveraging support from international, commercial partners, and HEOMD. This can happen in the 2020s. However, Mars is like Earth in terms of the diversity of environmental conditions in space and time. Interrogation of multiple locations are needed to determine the processes driving Mars environmental change, its timing, and to search for life. The current juncture in science must recognize Mars is diverse, requiring tens of science mission opportunities in 2020-2050, overall enabled by a return to the cost-saving paradigm of multiple small craft rather than solely single large missions.

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B4.2-0010-18 THE POTENTIAL SCIENTIFIC VALUE OF RETURNED MARTIAN SAMPLES: THE 2018 IMOST STUDY

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Introduction: The analysis of well-collected, properly documented Mars samples in Earth laboratories is of ex-tremely high interest to the international Mars exploration communities. As part of its goal to promote international cooperation in the exploration of Mars, the International Mars Exploration Working Group (IMEWG) recent com-missioned a major study (referred to as iMOST) to update the recommended scientific and engineering objectives for the potential 1st Mars sample return mission, the kinds of samples needed to achieve those objectives, and the measurements that would need to be performed on those samples. The iMOST analysis began in November 2017, and draft results are expected to be presented for initial public discussion in late April 2018 at the 2nd International Mars Sample Return Conference in Berlin, Germany.

Why Now?: There are two primary reasons why an updated analysis of the scientific potential of Mars sample return is appropriate:

1. The last major analysis of the specific scientific objectives of Mars sample return, and how they translate to sample types and sample quantities, was the Mars Exploration Program Analysis Group (MEPAG)'s End-to-End International Science Analysis Group (E2E-iSAG) work carried out in 2010-11 (and published in early 2012). Since then, there have been advances on several different fronts that may change the scientific priorities for Mars sample return: • The number of Mars meteorites in our collections on Earth grew to over 100 (this number was 55 in 2011), and includes one brecciated sample differing in age from all the other martian meteorites, and thus presumably rep-resenting a different region of Mars. Therefore, we ask the question "What has changed from prior investiga-tions into martian meteorites and how can those data inform MSR strategies?" • The Curiosity rover landed on Mars (Aug. 2012) after E2E-iSAG had completed

its work, and has since operat-ed successfully for more than five years. It has analyzed a number of solid samples (both rocks and regolith) as well as the martian atmosphere. In addition, scientific output from the wealth of data returned by orbiter missions since 2011 (e.g. NASA's Mars Reconnaissance Orbiter, Mars Odyssey, and ESA's Mars Express) funda-mentally shaped and improved our understanding of the martian surface. We need to evaluate whether any of these discoveries change the priority of Mars returned sample science. • Research on terrestrial analogs, especially in the general field of astrobiology, has blossomed. We have im-proved our understanding of how life adapted to extreme environments survives in those conditions through geologic time. • Our ability to handle and analyze very small samples has improved substantially. A highly visible example is the work conducted on the Hayabusa samples (JAXA). There have been many instrumentation developments around the world. Did these developments meaningfully change what could be learned from returned martian samples of constrained size? 2. To plan the potential investigations of samples after they arrive on Earth, we need to systematically ana-lyze and prioritize the measurements that could or should be performed on the samples. Successor teams can use this information to derive an instrument list and determine the logical sequence of analyses. Sample receiving and curation facilities should incorporate this vital input into planning strategies and key operational decisions.

Results: This presentation will summarize the results of the iMOST project.

B4.2-0011-18 MARS SAMPLE RETURN ARCHITECTURE DEVELOPMENT

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The most recent planetary science decadal survey places high scientific priority on the eventual return of samples from Mars, for investigation in terrestrial laboratories, enabling a breadth and depth of scientific analysis far beyond what can be achieved with in situ investigations, and allowing possible breakthrough discoveries regarding the geological, climatological, and astrobiological history of the planet. The Mars 2020 mission will take an important first step towards this goal, acquiring and caching a scientifically selected set of samples for potential return to Earth.

NASA and ESA are currently exploring options for follow-on missions that could complete the return of these samples to Earth. A Sample Retrieval Lander mission would deliver a landed platform to the same landing site as Mars 2020, carrying a Sample Fetch Rover (SFR) and a Mars Ascent Vehicle (MAV). The SFR would retrieve the Mars 2020 samples and transfer them to an Orbiting Sample (OS) canister, which would be placed in the MAV for launch into low Mars orbit. There, a second mission, the Earth Return Orbiter, would rendezvous with the OS, with a payload to capture, orient, and robustly contain the OS, transferring it to an Earth Entry Vehicle (EEV). After a return flight from Mars to Earth, the Earth Return Orbiter would release the EEV on a trajectory for landing at a selected Earth site.

This pair of mission concepts presents a rich architectural design trade space, with key interfaces between missions, demanding a rigorous, campaign-level systems engineering approach. We provide an overview of the current baseline MSR architecture, highlighting these cross-project interfaces, key design trades, and enabling technology developments.

(The information provided about possible Mars sample return architectures is for planning and discussion purposes only. NASA has made no official decision to implement Mars sample return.)

B4.2-0012-18 OVERVIEW AND RESULTS FROM CSA'S 2016 MARS SAMPLE RETURN ANALOGUE DEPLOYMENT

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An overview and discussion of results is presented for the Canadian Space Agency (CSA) 2016 Mars Sample Return Analogue Deployment (MSRAD) which took place in Utah from November 2016.

CSA's objectives for this deployment were to (1) Develop and strengthen partnerships and position Canada for future contributions through collaboration with iMARS agencies (2) Advance MSR science operations and sample targeting through a Cache Mission simulation 'CanMars' (3)Advance selected rover autonomy and arm positioning technologies through a Fetch rover technology demonstration scenario (4) Inform the general public and inspire young Canadians to pursue careers in STEM (5) Provide valuable learning opportunities to students through partnership in University of Western Ontario's NSERC CREATE project to train students for roles in future planetary missions.

The 'CanMars' cache rover simulation was conducted in partnership with University of Western Ontario with the remote science operations team based at the university.

The 'CanMars' Science Plan was developed in partnership with University of Western Ontario, NASA and UKSA, following an invitation to iMARS agencies to participate in the deployment. Its objectives were: 1. To test the accuracy of selecting samples remotely using the partial context available to mission scientists using rover-based field operations, compared to the full context available to a traditional human field party. 2. To test the efficiency of remote science operations with periodic pre-planned strategic observations compared to including strategic and tactical considerations in the tactical plan 3. To assess the utility of realistic autonomous science capabilities to the remote science team, to understand how such autonomy improves the effectiveness and rate of progress of the science mission, and to learn which strategies of exploration emerge from the availability of these capabilities, including in a downlink-constrained environment 4. To make a preliminary determination of the factors that affect the quality of sample selection decision-making in light of returned sample analysis Science plan objectives 1 2 were based on agency considerations and recommendations from previous analogue work.

The Science Plan was implemented by assigning the same success criteria to the remote science team and an independent Field Validation Team (1) identify the highest total organic carbon sample at the site as a proxy for an astrobiologically significant sample (2) advance understanding of the history of water at the site through development of a depositional model. The extensive data set and results generated as a result of successful implementation of the analogue mission are documented in a special issue of Planetary and Space Science which is currently in review.

The Fetch Rover scenario and tests successfully demonstrated autonomous navigation to 'cache depots' of Mars 2020-like sample tubes lying on the ground, acquisition of 6 such sample tubes using a novel tool developed by the CSA robotics group, and transfer to a Mars Ascent Vehicle (MAV) mock up.

CSA's Mars Exploration Science Rover ground prototype was used for both elements of the deployment, built by MDA, Brampton, who are also contracted to build ESA's ExoMars locomotion system. Rover operations were conducted from CSA's HQ at St Hubert, Quebec. In addition, UKSA and DLR conducted independent rover tests at the site making use of CSA's infrastructure and with a view to potential future co-ordinated campaigns.

The results will be discussed with a focus on science operations and their relevance to future missions.

B4.2-0013-18 PREPARING TO RECEIVE SAMPLES FROM MARS: RECOMMENDATIONS FROM THE INTERNATIONAL MARS ARCHITECTURE FOR THE RETURN OF SAMPLES (IMARS) PHASE II WORKING GROUP

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Background: While much of the effort in planning for a Mars Sample Return (MSR) campaign has been dedicated towards the flight mission elements, the programmatic challenges associated with MSR cannot be overlooked. Certainly, returning the samples in the first place would represent a significant technical achievement. However, it is apparent that managing those samples once they are returned will require extensive international coordination. To address some of these issues, the International Mars Exploration Working Group (IMEWG) chartered the International Mars Architecture for the Return of Samples (iMARS) working group in 2014. Building from the iMARS Phase I findings [1], the Phase II group comprised two panels of experts: (i) Engineering: to provide a status report on the technical planning for MSR architecture, and; (ii) Science / Earth Operations: to develop a proposed sample management plan. This abstract focuses on the findings and of the Science / Earth operations sub-team.

iMARS Report Structure and Topics: Following earlier recommendations [1], the iMARS Phase II team was tasked specifically to proposing the governance for sample science management plan. In doing so, three themes were central to the group's deliberations: (i) Sample Management Structure: determining an organizational structure outlining roles responsibilities for key stakeholders; (ii) Science Implementation Plan: outlining preliminary sample examination flow, sample allocation processes, and data policies, and; (iii) Curation Plan: including sample tracking and routing procedures, sample sterilization considerations, and long-term archiving perspectives.

A total of 21 recommendations were put forth by the working group, a selection of which are summarized below.

Programmatic Recommendations: MSR will be heavily dependent on international collaboration. It is thus inevitable that well-defined and agreed upon standards and regulations must be developed to ensure a successful campaign implementation. As such, the working group recommended that:

An international MSR Science Institute be established as soon as the commitment for conducting an MSR campaign is made

Detailed working groups will be required to establish guidelines and recommendations of standards to be implemented at the Sample Return Facility (SRF)

The minimum safety requirements for safely returning the samples must be clearly defined

The projected timeline for SRF design, construction, and operation could exceed a decade; SRF planning should commence immediately

Sample Management Recommendations: The interplay of science inquiry and safety requirements drove many of the working group's deliberations. Ensuring that world class science will be done as safely as necessary, the following recommendations were put forth:

A internationally-sanctioned Planetary Protection Protocol should be produced as soon as is feasible

The organization of science teams, sample allocation, and test protocol development should be specific to each sample suite returned by the mission

Scientific access to samples should be driven by scientific excellence, independent of the financial contributions of the bidder's home country

Extensive additional research is required on the methods and doses required to adequately sterilize the samples to ensure safe distribution outside of the SRF

PROGRESSING TOWARDS MSR In summary, the iMARS working group has produced a credible structure and process ensuring that the best possible science is performed on these invaluable samples, the Earth is protected from contamination, and public engagement and transparency drives decision-making. As the flight segments of MSR become an increasing reality, the community must ensure it is ready to receive the samples when they are safely returned. References: [1] iMARS Working Group (2008) https://mepag.jpl.nasa.gov/reports/iMARSF inalReport.pdf

B4.2-0014-18 EURO-CARES: GETTING EUROPE READY FOR SAMPLE RETURN MISSIONS - AN EMPHASIS ON RESTRICTED MISSIONS.

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EURO-CARES (European Curation of Astromaterials Returned from Exploration of Space) was a three year (2015-2017) multinational project funded under the European Commission's Horizon 2020 research programme. The objective of EURO-CARES was to create a roadmap for the implementation of a European Extra-terrestrial Sample Curation Facility (ESCF) suitable for the curation of samples from all possible return missions, to the Moon, asteroids, Mars, and other bodies of the Solar System. Here we summarize the main recommendations from the final project report for design and infrastructure requirements to allow the curation of samples from restricted bodies such as Mars.

Over the course of the project, the team has visited various facilities and companies, to gather best practices, bring innovative ideas, and build a strong network with the international sample curation community. Visits were made to the astromaterials curation facilities of NASA and JAXA, and to related facilities from the nuclear, cleanroom and BSL-4 sectors. Two successful collaborations with architects (Space architecture department of the Technical University of Vienna (Austria), then Merrick and Co. in Kanata (Canada) [1]) resulted in the development of more refined requirements and tentative designs for a Mars Sample Return (MSR) facility.

All possible activities that would take place in a MSR facility were first identified. All activities related to receiving, assessing, and opening the Earth Return Capsule are performed in a Sample Receiving Facility. Further activities, such as curation, Sample Early Characterization, and storage would be performed in a Sample Curation Facility (SCF). The SCF would also include a suite of instruments necessary for analyses defined in a Biohazard Assessment Protocol and for Life Detection. In addition, an Analogue and Mock-Up Facility (to be constructed first) would be used to assemble an analogue material collection, to test instruments and building materials/techniques, and to train staff members.

A MSR facility needs to integrate both cleanliness and containment principles, to keep the samples pristine, and to fulfill the Planetary Protection requirement of having a probability of release $P<10^{-6}$ for an unsterilized particle larger than 0.1 μm [2]. Primary enclosures for restricted samples were considered: depending on the activities, it was recommended that cabinets similar to the ones used in BSL-4 laboratories, or Double-Wall Isolators should be used [3]. Laminar flow cleanrooms were recommended for limiting cross-contamination while allowing flexibility in the future.

Because of the European nature of the project, the facility should be located in Europe. Other parameters, such as limited natural hazards, countries with histories of BSL-4 laboratories and space exploration expertise, would also need to be taken into consideration. Owing to so many uncertainties and decisions to be taken (such as the possible widespread use of robotics), it is impossible to evaluate a precise financial cost for such a facility, however, we estimate that a fully fitted MSR facility would cost at least 200 M€. Location, use of robots, cleanroom regime, instrumentation capacities, etc. are amongst the parameters that can drive the costs for the initial construction, and during the life of the facility.

It is estimated that a minimum of 7 to 10 years would be necessary to define the requirements, design, build, and commission the facility, while training the necessary staff. It is highly probable that such a facility will have various funding partners (space agencies, institutions, countries, etc.); a complex financial arrangement takes time to come to completion.

A MSR facility is a complex project, not only for the engineering aspects but also for financial and political reasons. In view of the timeline of sample return missions from Mars, it is imperative to move forward with this project as soon as possible. The design we developed encompasses the principles of Flexibility, Modularity, and Adaptability.

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B4.2-0015-18 THE EUROPEAN SPACE AGENCY EXPLORATION SAMPLE ANALOGUE COLLECTION (ESA2C) AND CURATION FACILITY - PRESENT AND FUTURE

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Introduction: Since 2014, the Natural History Museum (NHM) has been the prime contractor to the European Space Agency (ESA) for defining and initiating the development of an Exploration Sample Analogue Collection and Curation Facility in support of the Human Robotic Exploration mission preparation programme. The ESA Exploration Sample Analogue Collection (ESA2C) will support the ongoing or future technology development activities that are required for human and robotic exploration of Mars, Phobos, Deimos, C-Type Asteroids and the Moon. The long-term goal of this work is to produce a useful and useable resource for engineers and scientists developing technologies for ESA missions and for appropriately qualified international users as well. Sample Analogue Collection: The complex mission architectures and diverse target bodies of interest means that a variety of different analogue materials are required to test all systems that come into contact with, the target body, whether these be part of the spacecraft system, such as landing and/or roving systems (e.g. wheels), sample collection systems (e.g. drills or scoops) or scientific payload. The analogue materials must replicate as far as possible the expected 'geological' environment of the target body in terms of both physical/mechanical properties and chemical/mineralogical properties. Samples selected include a variety of aggregates from the olivine-rich basalts from the Upper Lava Formation of the Paleogene Antrim Lava Group of Northern Ireland and clay samples from Cyprus, Spain and Senegal. During 2016 and 2017 we carried out a detailed characterisation of the analogue samples' physical and chemical properties [1,2]: Chemical properties: Whole-rock chemistry major, minor and trace element analyses by ICP-AES and ICP-MS. Mineralogy - analytical SEM, EPMA and XRD (whole-rock). Physical and mechanical properties: Particle Size Distribution (PSD) (aggregate and granular samples) - sieving. Grain Size and Morphology - SEM, X-ray micro-CT and visual inspection. Density and porosity (all samples) - mass-volume measurement and helium pycnometry, X-ray micro-CT. Shear strength (aggregate, granular and powder samples) - shear box apparatus. Compressive and tensile strength (rock samples) - UCS testing and Brazilian indirect tensile method. As part of ongoing work, further samples have been acquired for the ESA2C - anorthosite from a Norwegian quarry, basaltic sand and basaltic/ hyaloclastite collected from the Askja Region in Iceland and volcaniclastic/sedimentary/clay masonry unit (CMU) analogues that will be used for system level testing of the ExoMars crushing station. ESA Sample Analogue Curation Facility: This unique venture will build on ESA's Human Robotic Exploration mission preparation programme by establishing methodologies and protocols/procedures for curating the ESA2C, as well as defining and validating the distribution mechanisms and information exchange protocols for the analogue materials. The overarching role of the Sample Analogue Curation Facility (SACF) is to:- Curate ESA2C samples and those identified and acquired for the Collection and associated data pertaining to those samples; make samples available for study and provide access to relevant data pertaining to those samples; carry out fundamental physical and chemical properties testing in the SACF (or testing via appropriately qualified external laboratories). All analogues in the ESA2C will undergo fundamental properties characterisation using procured (or outsourced) equipment in the SACF laboratory, which include the following: Mineralogical and Chemical Properties: X-ray diffraction (XRD) - bulk mineralogy; SEM - mineral chemistry by point analysis of dominant phases; X-ray fluo-rescence (XRF) - minor and trace element identification and quantification; fourier-transform infrared (FTIR) and raman - chemical/molecular bonding and fingerprinting. Physical and mechanical properties: soil PSD - sieving and laser particle analysis (latter outsourced); soil grain size and morphology - SEM and visual inspection; soil bulk density and rock dry density - mass-volume measurements; rock and soil particle density (for porosity) - gas pyc-nometry; soil shear strength (outsourced) - direct shearbox; rock UCS (outsourced) - uniaxial/ unconfined compression. Future Opportunities: The facility will formally open on the Harwell campus (UK) in 2018. Some level of operation is however already ensured by NHM and at present specimens from the ESA2C are being used by engineers and scientists in the United Kingdom, Hungary and the US to support planetary research, related technology developments and testing activities for a variety of missions and mission architectures. The global distribution of planetary analogue material which has been well characterised, i.e. has known fundamental physical/ mechanical and chemical/mineralogical properties, provides a vital resource for scientists and engineers to carry out comparative and collaborative investigations into the vast sector of space exploration. The ESA Sample Analogue Curation Facility hopes to spearhead and centralise access to these resources for many years to come. References: [1] Manick K. et al. (2017) LPSC XLVIII,

Abstract 1220. [2] Manick K. et al. (2017) LPSC XLVIII, Abstract 1222.
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B4.2-0016-18 MOBILE/MODULAR BSL-4 CONTAINMENT FACILITIES INTEGRATED INTO A CURATION RECEIVING LABORATORY FOR RESTRICTED EARTH RETURN MISSIONS

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NASA robotic sample return missions designated Category V Restricted Earth Return by the NASA Planetary Protection (PP) Office require sample containment and biohazard testing upon return to Earth. Since the 1960s, sample containment from an unknown extraterrestrial biohazard have been related to the highest containment standards and protocols known to modern science. Today, this is Biosafety Level (BSL) 4 containment. In the U.S., the Biosafety in Microbiological and Biomedical Laboratories publication authored by the U.S. Department of Health and Human Services (HHS): Public Health Service, Centers for Disease Control and Prevention, and the National Institutes of Health houses the primary recommendations, standards, and design requirements for all BSL labs. Past mission concept studies for constructing a NASA Curation Receiving Laboratory with an integrated BSL-4 quarantine and biohazard testing facility have been estimated in the hundreds of millions of dollars (USD). As an alternative option, we have conducted a trade study for constructing a mobile and/or modular sample containment laboratory that would meet all BSL-4 and planetary protection standards and protocols at a fraction of the cost. Mobile and modular BSL-2 and 3 facilities have been successfully constructed and deployed world-wide for government testing of pathogens and pharmaceutical production. Our study showed that a modular BSL-4 construction could result in 90% cost reduction when compared to traditional BSL-4 construction methods without compromising the preservation of the samples or Earth. For the design/construction requirements of a mobile/modular BSL-4 containment, we used the established HHS document standards and protocols for manipulation of agents in Class III Biosafety Cabinets (BSC; i.e., negative pressure gloveboxes) that are currently followed in operational BSL-4 facilities in the U.S.

A mobile BSL-4 negative pressure ISO class 5 cleanroom containment facility could secure a sample return capsule at the landing site. After biocide decontamination procedures, the facility could be transported anywhere in the world by land, sea, or air. The mobile facility could attach to an existing BSL-4 laboratory that could be used to conduct biohazard analyses on a sample subset while the mobile lab could provide primary clean containment of the science samples awaiting biosafety results. A second usage scenario could attach the lab to a dedicated NASA receiving and curation facility that could conduct the primary containment and biohazard testing. Additionally, a third scenario could have the mobile facility remain at the landing site as primary containment and a small sample is transported to an existing BSL-4 facility for biohazard testing. After completion of biohazard testing, decisions could be made to sterilize the sample or transport all or portions to a brick and mortar quarantine storage facility.

A modular BSL-4 negative pressure ISO class 5 cleanroom sample receiving facility could be assembled into any shell building or high bay using the same construction methods as the mobile laboratory. The modular construction could use standard 40 ft (12.2 m) containers, assembled together to create a large lab space with Class III BSC glovebox chains. Manufacturing in a dedicated cleanroom can maintain better control of the engineering, fabrication, assembly, and integration of a facility. Testing and certification could also be conducted at the manufacturing cleanroom facility and then transported and assembled on-site. While a modular BSL-4 facility has never been built, several modular Animal BSL-3 facilities have been successfully constructed worldwide. With added system redundancies, these facilities could be reclassified as BSL-4 laboratories.

Currently, NASA PP Office classifies Category V Restricted Earth Return for robotic sample return missions from Mars, Europa, and Enceladus with the caveat that future proposed mission locations could be added or restrictions lifted on a case by case basis as scientific knowledge and understanding of biohazards progresses. This presentation focuses on the design of a mobile/modular BSL-4 Curation Receiving Facility that can meet all current PP and HHS standards and protocols, including redundant systems and critical biological containment/pressurization requirements for future restricted Earth return missions.

B4.2-0017-18 FUTURE HIGH-RESOLUTION ORBITAL RECONNAISSANCE WITH MRO/HIRISE

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The High Resolution Imaging Science Experiment (HiRISE) on the Mars Reconnaisance Orbiter (MRO) has been orbiting Mars since 2006 (McEwen et al., 2007, JGR 112, E05S02). More than 1,000 peer-reviewed publications utilize HiRISE data. HiRISE obtains the highest-resolution orbital images of Mars, ranging from 25-35 cm/pixel scale. To acquire such images with a high signal:noise ratio (SNR), HiRISE uses time delay integration (TDI), imaging each patch of ground up to 128 times and summing the signal. Producing sharp images over such a small instantaneous field of view (1 microradian/pixel) and with 128 TDI lines requires very stable pointing from the spacecraft. HiRISE has 14 CCD detectors: 10 in a broad-band (RED) channel that cover the 5-6 km wide image swath, plus 2 with a blue-green (BG) filter and 2 with a near-infrared (NIR) filter, producing 3-color imaging in a narrow central swath of each image. There have been a number of anomalies that affect image quality. 1. The electronics supporting RED9 was lost in 2011, narrowing the swath width. Fortunately there have been no further failures to date, but this remains a distinct possibility in the future. 2. Soon after launch we discovered bit flips in some image channels. This problem has affected more and more image channels (each CCD has 2 readout channels). Fortunately we can mitigate this problem by warming the focal plane electronics (FPE) prior to Mars imaging, but this results in shorter images. Early images had up to 120,000 lines at full resolution (no pixel binning), the maximum now is near 50,000 lines (or 150,000 lines with 2x2 binning). 3. The percentage of images with noticeable blur (0.3-1.5 pixels) increased from near 0% in early 2017 to about 70% of full-resolution images in the fall of 2017 (at aphelion), then decreased to <20% in February 2018. The cause of this blurring seems most likely to be high-frequency pointing jitter. If the problem continues to be significant, we may decide that it is no longer useful to acquire bin-1 (full resolution) images in some seasons.

MRO has been in a sun-synchromous (nearly polar) orbit at close to 3 PM Local Mean Solar Time (LMST), which is usually close to ideal for imaging. However, to attempt to keep MRO functioning for another decade, a number of changes are being made to prolong battery life, including a plan to move to a later LMST (near 4:30 PM). The change to 4:30 PM LMST will provide three disadvantages and one advantage to HiRISE. First, it complicates change detection because we cannot repeat older images with similar lighting conditions. Second, it limits the latitude range of useful imaging within each season, reducing the seasonal range for polar monitoring. Third, stereo pairs must be completed more rapidly to avoid large changes in shadow lengths and positions. An advantage is that relatively flat equatorial regions are better imaged later in the day, to accentuate subtle topographic shading.

In the future, expect more binned images for two main reasons: (1) the later LMST provides lower brightness levels, reducing SNR, mitigated by pixel binning; and (2) we do not gain much or any resolution advantage from blurred bin-1 images, which may be a cold-season problem. However, we can cover four times as much of Mars with bin-2 images compared to full-resolution, and 0.6 cm/pixel remains better than any other orbital imaging of Mars. Many science objectives will benefit from the greater coverage. Landing site reconnaissance and small-scale change detection will be degraded but still useful.

HiRISE-class imaging is highly recommended in a study of the next NASA Mars orbiter (https://mepag.jpl.nasa.gov/reports.cfm) and is essential for landing sites. Advances in detector and electronics technologies since 2002 would lead to significantly improved images.

B4.2-0018-18 UNLOCKING THE CLIMATE RECORD STORED WITHIN MARS' POLAR LAYERED DEPOSITS

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The PLD contain an accumulation and erosion record of ice, dust, and other impurities, that acts as a climate archive waiting to be read by future exploration. Over the previous decade, Mars Polar Science has advanced significantly to the point where hypotheses testable with new missions have been generated about the climate record stored in the polar layered deposits (PLD). In 2017 we co-led a two-part workshop at the Keck Institute for Space Studies focused on missions to unlock the climate record stored in the north PLD. The first part of the workshop determined high-level science questions and priorities to address, and the second part developed mission concepts to answer these science questions. This talk will discuss those science questions and three mission concepts: a Discovery-class lander and orbiter, and small surface investigations called Mars Drop.

B4.2-0019-18 CAN WE OBSERVE ELECTROMAGNETIC RADIATION FROM ELECTRIC DISCHARGES IN THE MARTIAN DUST STORMS?

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Based on simulations and laboratory experiments, and according to an analogy with terrestrial volcanic and dust discharges, electric discharges are expected to develop in Martian dust storms. Numerical results indicate that it is possible to reach an electrical breakdown in a low-pressure carbon dioxide Martian atmosphere under specific particle density, particle composition and sufficiently high wind velocity. Laboratory experiments confirm the existence of visible electrical discharges in a cloud of Martian regolith simulant in a low-pressure carbon dioxide atmosphere. An ultra-low frequency magnetic radiation generated by terrestrial dust devils was also observed. Lightning discharges are frequently observed in many types of volcanic eruptions. Although these results may indicate the existence of atmospheric lightning discharges on Mars, there is no optical evidence of existence of Martian lightning discharges up to now. Impulsive radio signals originating in electric discharges from the Martian dust storms have also never been detected from space. Using the ExoMars 2020 plasma wave analyzer which is supposed to measure directly on the Martian surface we would like to help to solve the puzzle of Martian lightning.

B4.2-0020-18 MARS ANALOGUE SAMPLES LAB & FIELD SPECTRAL ANALYSIS

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We have analysed a set of Mars Analogue samples from field campaigns and from a petrological collection. We have acquired samples from Utah Mars Desert Research station, Eifel volcano region, Iceland, Hawaii, La Reunion and Tenerife. Several spectroscopy analyses in the UV/VIS spectrum were performed using the remotely controlled USB4000 spectrometer in the laboratory and during field campaigns. The EuroMoonMars campaigns were rehearsed at ESTEC for feasibility. We also used other diagnostic techniques. Spectroscopy of rocks, water, organics in the lab: The focus of these analyses (Vos et al 2017) was the detectability of certain elements known to influence the UV/VIS spectrum such as transitional metals, but also the influence on the spectrum of minerals, water, organics and volatiles. The influence of water was measured in accordance with known water absorption bands at 739 and 836 nm, and mineral or rock analyses signatures. We also investigated spectral biomarkers. Background on ExoGeoLab lander: The field spectroscopy was also performed during a campaign in the Eifel volcanic area in Germany at an outcrop near the Laacher See. The outcrop consisted of volcanic deposits from the Laacher See eruption from approximatly 13,000 years ago. During the campaign four analogue EVAs were performed and we collected geological samples brought to the lander for remote spectrometry analyses. We thank participants and collaborators for ILEWG EuroMoonMars 2016, 2017 and 2018 campaigns.

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B4.2-0021-18 CONSIDERATIONS RELATED TO PLANNING FOR THE EXPLORATION OF THE MARTIAN SUBSURFACE

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Abstract:

The Martian subsurface is of enormous interest for astrobiology, geochemistry, climatology, and In Situ Resource Utilization (ISRU) objectives, which cannot be addressed with surface missions alone. Specifically, subsurface data are needed to help complete the search for extinct of extant life started by the Viking landers more than forty years ago and to prepare for human exploration.

If Mars ever had life, whether it emerged on or below the surface, then as the atmosphere thinned and global temperatures dropped [1], life may have followed the groundwater table to progressively greater depths where stable liquid water could persist. At such depths, life could have been sustained by hydrothermal activity and rock-water reactions. Hence, the subsurface likely represents the longest-lived habitable environment on Mars. Moreover, while the preservation of ancient molecular biosignatures on Mars is debated, the consensus is that detection at depths greater than a few meters is favored because of the shielding from harmful radiation [e.g., 2, 3] and the possibility to preserve water/ice resources. On the other hand, if Mars hosts extant life, then the most likely place to find evidence of it may well be at depths of a few hundred meters to many kilometers, where groundwater could persist despite today's low geothermal gradients [e.g., 4, 5].

Beyond searching for signs of extinct or extant life, we also face today the need to determine the presence and accessibility of resources, the ISRU potential, and any hazards to human health within the Martian subsurface, as part of the process of planning future human missions to the Red Planet.

The need to explore the Martian subsurface for astrobiology/ science and resource purposes, with the support of national space agencies, academia, and the commercial sector, has motivated a Keck Institute of Space Studies workshop titled "MarsX: Mars Subsurface Exploration for

Life and Resources", held Feb. 12-16, 2018 in Pasadena, CA, with participants from NASA, JPL, ESA, SpaceX, Schlumberger, Honeybee Robotics, and various universities and research institutes. The goal of the workshop team was to identify, toward the search for life and resources, (a) scientific measurements, instruments, and technologies, as well as (b) mission concepts and strategies that would enable chemical characterization, mapping, and groundtruthing of subsurface volatiles, focusing on H2O, and the overburden over multiple spatial scales, from meters to multiple kilometers.

Here, we will report the outcome of this workshop, focusing on key subsurface measurements regions of interest, the feasibility of needed exploration technologies (drilling, sounding, analytic tools, and other methods), and goal-oriented mission ideas to chart a roadmap for Mars subsurface access as it applies to the search for life and resources.

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B4.2-0022-18 MARS CAVE EXPLORATION CONCEPT FOR SCIENCE AND HUMAN EXPLORATION

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Introduction: Planetary cave exploration is a topic of growing interest in the planetary science community as well as for human exploration. More than 200 lunar and 2000 Martian caverelated features have been identified. Vents and fissures associated with water ice plumes on Saturnian, Jovian, and Neptunian moons also represent possible cave systems. Lunar and Martian caves are most commonly associated with lava tubes, although some have been proposed to be present in karstic sulfate terrain (Mars) and cryovolcanic features (outer planet moons). Caves offer stable physio-chemical environments, may trap volatiles, enhance secondary mineral precipitation and microbial growth, are expected to preserve biosignatures, and provide record of past climate. Investigation of petrological sequences on skylight and cave walls can provide critical constraints on lava temperature and cooling history, leading to insights into Martian magmatic processes and differentiation. Caves also represent potential environment for future human exploration: they are believed to offer stable, UV-shielding environment and potential to act as volatile traps. Science Definition: Building on previous work, we identified that a future mission to Martian caves should provide reconnaissance both for scientific and human exploration. Key science objectives for this pathfinder mission would be: (1) map the cave geometry (cave diameter/ceiling height from entrance to >100 m depth), (2) determine traversability challenges for future missions (boulder distribution, unconsolidated material),

(3) document the cave environment (spatial and temporal variations in temperature and humidity and radiation), and (4) map the compositional and lithological diversity of the cave materials, in particular to characterize mineralogy and search for volatiles, and organics. These science goals led to identification of possible instruments and resource requirements. The payload leverages recent or emerging miniaturized instruments developed for CubeSat-class deep space missions. The mild radiation and thermal environment expected in caves justifies the use of CubeSat-class instruments while the multiple assets provide redundancy. Subsurface Explorer Concept: Resource analysis so far suggests that the science of interest for a reconnaissance mission could be carried out with small (10s kg) platforms. Yet, intrinsic to their sizes, these platforms have limited resources, science capability, and lifetime. The situation is exacerbated in the case of the present concept where the only power source comes from batteries (radioisotope heating units were not deemed valuable in terms of anticipated cost and complexity). Novel operational concepts are required to compensate for limited power, which are expected to include higher levels of autonomy and frequent communication among spacecraft for autonomous coordination. Managing the complex design space, and performing associated trade studies to find well-balanced solutions, requires appropriate computational methods and tools to support mission designers and systems engineers in their decision-making processes. These will be addressed in more detail in the poster. We have focused on utilizing a variety of assets and strategies to mitigate challenges related to communication and instrument operations while optimizing data acquisition and science data retrieval via an organized network. We studied heterogeneous architectures where responsibilities (science, telecom) are distributed among assets. Our study includes trade-offs between potential power sources, homogeneity and heterogeneity of the assets, as well as distribution of science instruments to optimize cost and achieved benefit.

B4.2-0023-18 SCIENCE CAN BE A POWERFUL GUIDESTAR FOR HUMAN SPACEFLIGHT

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The Planetary Society, in its report Humans Orbiting Mars: A Critical Step Toward the Red Planet (http://hom.planetary.org), recommended incorporating the goals of the scientific community starting from the earliest planning stages of NASA's future Mars exploration architecture. Here, we expand upon that recommendation and reinforce the fact that whether the evolving plan takes us directly to Mars, or first to the Moon and then eventually on to Mars, there will still be critical roles for science in the advocacy, planning, conduct, and ultimate success of that plan.

NASA frequently uses scientific discovery as a justification for national investment in human spaceflight, even though science has generally been given a relatively low priority in both mission planning and operations (e.g., in the planning of Apollo and the ISS). Concomitantly, much of the scientific community rarely discusses the potential utility (or even necessity) for astronauts in addressing the most pressing space science questions. There is a large community of lunar and Martian scientists, in particular, that could serve as a cornerstone of support within any coalition for the human exploration of the Moon and Mars, but this support is not a given, and at times is not even specifically sought out.

As NASA plans to potentially return astronauts to the Moon and engages in long-term planning for humans to Mars, we believe that science should be more openly used as one of the guiding forces in defining the goals of these endeavors, and that the scientific community should be more explicitly integrated in mission planning from the very earliest stages. Via the recent Planetary Decadal Survey and ongoing studies by groups like MEPAG and LEAG, the scientific community has already defined its top priority scientific goals for the Moon and Mars, and these goals can serve as helpful constraints when working to coalesce a broad coalition to support a focused program of human spaceflight. Indeed, the most recent Decadal did begin to explore the important ways that human exploration can contribute meaningfully to scientific advances. Such analyses will hopefully be expanded and amplified in the next Decadal.

Science should not be treated as an afterthought in human exploration missions, nor should science budgets compete with (and lose to) those for human exploration. Rather, NASA and the science community should focus the science objectives of human missions on areas best served by humans, rather than areas where robotic assets have proven capable and adequate. NASA can make significant steps toward this goal by providing focused research funding for the scientific community to study these opportunities, and by establishing cross-directorate planning committees between HEOMD and SMD that provide funding for scientific participation.

B4.2-0024-18 SCIENCE/RECON NEEDS TO ENABLE HUMAN EXPLORATION ON THE SURFACE OF MARS

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As we prepare for the future of human exploration at Mars, it is becoming increasingly clear that there are a number of reconnaissance objectives that need to be addressed in the coming decades. This talk will summarize the key Mars system reconnaissance data needed to inform NASA's ongoing human Mars exploration planning activities, especially as they evolve from architecture studies, to landing site selection and mission planning, and ultimately to technology development and maturation for future flight.

Such data needs to include next generation orbital reconnaissance to better understand water feedstock options and to provide high-resolution imaging of potential landing sites, as well as surface reconnaissance to validate observations made from orbit. This is especially important for water feedstock options such as hydrated minerals and subsurface ice. Leveraging these feedstocks for in-situ use by human crews relies on the confirmation of their existence (establishment of proven reserves), ease of access, and safety for use.

Next generation weather monitoring and prediction capability, involving both orbital and landed observing platforms, is also required to support major mission dynamic events such as landing and ascent, as well as for ensuring safe surface operations. Furthermore, data will be needed to establish next generation planetary protection policy and to establish the basis for its compliance.

Finally, there is growing evidence that returned Martian samples are needed not only for Decadal Survey science priorities, but also to improve our understanding of the mechanical properties of the regolith/dust (i.e. its abrasiveness, oxidizing potential particle size

etc.) and potential human health hazards (toxicity, respiratory, extant life, etc.). This information is needed for the design and development of the surface habitat/laboratory systems, human-class rovers, Mars surface suits, and the Mars Ascent Vehicle. The criticality of these samples may necessitate redundant paths for sample return, the first of which will likely be with a robotic mission, rather than with human mission. Such an approach would allow for the earlier return and analysis of samples needed to inform the engineering development of Mars surface systems (e.g. suit design, hatch seals, etc.), while also providing a roundtrip demonstration of the mission before attempts are made with humans.

B4.2-0025-18 ACHIEVING, AFFORDING, AND SUSTAINING HUMAN MARS EXPLORATION: SCENARIOS FROM THE FIFTH COMMUNITY WORKSHOP

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Initiated in late 2013 and sponsored by Explore Mars, Inc. and the American Astronautical Society, five workshops have been held to date to assess how to achieve, afford, and sustain human exploration of Mars. The workshops featured broad participation by representatives of the professional communities deeply involved in human exploration: NASA, academia, industry, and research institutions, as well as non-US colleagues. Formal reports and back-up material from the five workshops may be found at https://www.exploremars.org/affording-mars. In this special COSPAR session, we will present the results from our most recent workshop, the fifth, which was held in Washington, D.C., 5 - 7 December, 2017.

The overarching goal of our fifth workshop (aka, AM V) was to architect credible - that is, technologically achievable and plausibly affordable - scenarios for human exploration of Mars that achieved three distinctly different “end states” and to identify common architectural threads throughout the three scenarios. The three end states were chosen on the basis of published work to represent three commonly discussed options for human missions and are discussed in the accompanying presentations: (1) an Apollo-like series of short-stay landings, (2) a “beachhead”- type scenario, roughly analogous to current exploration of Antarctica, and (3) sustained and, eventually, growing human occupation.

Approximately 60 “mission architects” participated in the workshop over the course of three days, which followed extensive preand post-workshop activities. After a series of plenary discussions, the participants self-organized around the three unique mission scenarios. Each team was charged with identifying major elements of each scenario, developing a time line, identifying major milestones and decision points, developing justification for each decision, and producing a cost estimate. An essential element of the workshop was that each scenario was reviewed and critiqued in plenary by all participants. This invaluable activity allowed the creators of each scenario to iterate toward improved design before the workshop ended, iteration which continued for a subsequent month. Moreover, this community engagement allowed the three teams to take advantage on-site of expertise very rarely brought together in one place. Finally, the three unique architectures were analyzed to identify decision points that were common to

all scenarios as well as architectural decisions that were unique to the three end points. Both provide valuable insight, with the common architectural decisions providing the initial basis for a broad amalgam of human Mars mission scenarios.

In addition to building the three Mars scenarios, additional topics were assessed, including political sustainability of human exploration, potential roles of human lunar missions as stepping stones to Mars, and technology priorities common among all three scenarios. This latter topic allows the final report to be used as a guide for technology investments that would have the broadest impact regardless of final choice of scenario for eventual human Mars exploration.

B4.2-0026-18 SORTIE-CLASS HUMAN MISSIONS TO MARS

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A community architecture was developed in a two-day workshop with participation by subject matter experts in the NASA and industry human spaceflight field. The concept is for initial Mars human exploration with a series of near-term missions to Mars orbit and sorties to the Martian surface with crews of four. The approach would utilize proven technologies and vehicles that are currently under development by NASA, U.S. commercial aerospace, and international partners.

An initial flight rate of a crewed Mars mission every four years could be achieved with no more than two Space Launch System (SLS) launches per year. The concept would take advantage of commercial cargo deliveries to high Earth orbit and/or cislunar space and also commercial deliveries to Mars.

The initial architecture would have a Mars transit stack assembled at the Deep Space Gateway (or in high elliptical Earth orbit) consisting of a Deep Space Habitat (DSH), Mars Orbit Insertion stage, Trans-Earth Injection stage, Earth Departure Stage (EDS), and an Orion vehicle with a crew of four. For surface access, a single lander with a fully-fueled Mars Ascent Vehicle (MAV) would be separately delivered by two SLS launches and aerocaptured into High Mars Orbit (HMO) to await the crew.

After transferring the crew from Earth to HMO, the stack would rendezvous with the lander for crew transfer. The lander would de-orbit and perform entry, descent, and landing, and the crew would conduct a two-week mission on the surface, similar in scope to an extended Apollo 17 type mission with an unpressurized rover and science equipment. At the conclusion of the surface mission, the MAV would launch the crew to Mars orbit and use a pre-positioned boost stage to transfer to the transit stack. The crew would spend the remainder of their stay in HMO, teleoperating assets on the surface, including the rover. Upon Earth return, the crew would perform direct entry with Orion.

This example program architecture has some attractive advantages. It could represent a nearterm, low-risk approach for human exploration of Mars in the 2030s. Cost estimates were performed that suggest this example of a program could be executed with an annual budget and a total budget similar to that of the International Space Station. Although the architecture was intended to be minimal in scope for the initial missions, it would

have the capability to evolve and expand to support extensive long-stay human exploration of Mars, the incorporation of more advanced technologies and in-situ resource utilization, and the eventual buildup of a semi-permanent international base on Mars.

B4.2-0027-18 ACHIEVING MARS V BREAKOUT SESSION #2 GROUP REPORT

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AMV Breakout Session 2 COSPAR Abstract

Explore Mars, Inc.'s annual Achieving Mars Workshop, asked teams to develop draft mission architectures for Mars exploration scenarios. Breakout session 2 was assigned to consider human Mars missions with the goal of creating temporary research field stations on the surface of the planet. Team 2 leveraged the experience, insight, and expertise of its team members to define an architecture to enable the development of field stations on Mars capable of informing future human exploration objectives.

In framing our architecture and outcomes the team relied heavily on the policy guidance outlined in the bi-partisan NASA Authorization Act of 2010 as refined by the NASA Authorization Act of 2017 which mandates the Long Term Goals and Key Objectives of the NASA human spaceflight and exploration efforts. The three pillars of human exploration as recorded in the Authorization Act are: (1) To expand permanent human presence beyond LEO and to do so, where practical, in a manner involving international, academic, and industry partners;

(2) Crewed missions and progress toward achieving the goal in (1) to enable the potential for subsequent human exploration and the extension of human presence throughout the solar system; and (3) To enable a capability to extend human presence, including potential human habitation on another celestial body and a thriving space economy in the 21st Century.

Our architecture was also informed by the Strategic Principles for Sustainable Exploration established by NASA's Human Exploration and Operations Mission Directorate (HEOMD) - Fiscal Realism; Scientific Exploration; Technology Pull and Push; Gradual Build Up of Capability; Economic Opportunity; Architecture Openness and Resilience; Global Collaboration and Leadership; and Continuity of Human Spaceflight.

With the above principles in mind, our team outlined the following goals for our field station architecture. 1) Learn how to live and work sustainably on the surface of Mars, 2) Develop and test the technologies required for future human habitation on the surface of Mars, 3) Define the desirable characteristics of an exploration zone in preparation for future human activities,

4) evaluate the viability of biology (human, agricultural, or extant microbes) in the Martian environment, and 5) perform meaningful science to understand the Martian environment and the effects of long term habitation in space and at Mars on human health.

This work builds on the research carried out as part of the Evolvable Mars Campaign (EMC). NASA's EMC effort was directed toward a very similar endpoint, but performed under different constraints and optimized for slightly different goals. The AM V team re-examined this architecture in an attempt to incorporate more commercial/international participation and examine whether and how to integrate technology demonstration and operations development in cis-lunar space. We believe this architecture offers a sustainable path forward for humanity's future on the red planet.

B4.2-0028-18 PERMANENT HUMAN HABITATION SCENARIO

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As part of the Explore Mars, Inc. annual Achieving Mars workshops, one of the three teams in 2017 developing Mars exploration scenarios was assigned to approach the scenario from a permanent human habitation perspective. Team 3 combined the personal experiences and voluntary views of its team members to define a campaign of missions to enable permanent human habitation of Mars. To frame the discussions leading to a "community" derived mission scenario, the team strongly considered the policy guidance in the bi-partisan NASA Authorization Act of 2010 as refined by the NASA Authorization Act of 2017 which mandates the Long Term Goals and Key Objectives of the NASA human spaceflight and exploration efforts. Rolled up from a much larger set of guidance in the Long Term Goals and Key Objectives within the NASA Authorization Acts, the goal of the team is to select architectural features and mission elements that will: 1) Enable a capability for human habitation on Mars and a thriving space economy in the 21st Century; 2) Maximize the role that human exploration of space plays in advancing overall knowledge of the universe; and 3) Explore the viability of and lay the foundation for sustainable economic activities in space. The team also leveraged the Strategic Principles for Sustainable Exploration established by NASA's Human Exploration and Operations Mission Directorate (HEOMD). In short, those principles are Fiscal Realism; Scientific Exploration; Technology Pull and Push; Gradual Build Up of Capability; Economic Opportunity; Architecture Openness and Resilience; Global Collaboration and Leadership; and Continuity of Human Spaceflight. Key assumptions for a permanent human habitation scenario, which enable sustainability, include scaling the timeline to the available NASA budget and the involvement of international and commercial partner stakeholders and remaining flexible as the scenario builds up and starts to grow. Orbital missions and short stays may be key tools for managing technology development timelines, and subsequently budget outlays. A fundamental source of enterprise sustainability required for permanent human habitation is a critical mass and broad portfolio of international and commercial partner stakeholders. While it is hard to predict the exact contributions from each partner, their contributions increase sustainability by providing broad, diverse support for the mission campaign. The architecture needs to be designed to encourage partner stakeholders to contribute through open standards, flexibility, and a clear stable mission sequence. The campaign to reach an end state of permanent human habitation is broken into three phases that provide for intermediate evaluation and decision points on crew safety/mission success and affordability before proceeding to the next phase.

For each phase, the team identified key activities, plausible system upgrades, reusing assets, availability of resources, plausible technology and capability performance upgrades, required major technologies, major risks, the role of the ISS, cis-lunar space and lunar surface, and capabilities with the potential for partner contribution. The details presented herein repre- sent our initial attempt to define a campaign of missions towards achieving permanent human habitation of Mars. We believe that scenario three will not materially increase costs or risks over other options if appropriately sequenced and managed, and it will allow us to achieve the unimaginable - permanent human presence on another planet.

B4.2-0029-18 MARS HUMAN LANDING SITES STUDY (HLS2)

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This talk will provide an overview of NASA's effort to select the location for the first human base on Mars. It builds on the lessons learned from the first ever Mars Human Landing Sites Study (HLS2) Workshop held in October 2015. Since the workshop the HLS2 community has continued to expand its knowledge of potential human landing sites. Assets at Mars are being used to obtain images and data on potential landing sites proposed at the first HLS2 workshop. A number of studies have either been completed or are underway, such as an examination of what it takes to produce water from different types of water feedstocks on Mars. Researchers are also producing enhanced maps of Martian water feedstocks by combining existing datasets in new and innovative ways. The results of this study are expected to be delivered in mid to late 2018. This talk will look at lessons learned and unanswered questions.

B4.2-0030-18 STATUS OF NASA HUMAN-SCALE MARS ENTRY, DESCENT AND LANDING (EDL)

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Ensuring the capabilities are in place for humankind's future landing on the Mars surface requires careful planning. The atmospheric entry, descent and landing on Mars has been identified as the "longest of the long poles," in terms of engineering challenges, and will require a paradigm shift from the way EDL has been performed at Mars, thus far. The 20 metric ton payloads that are required in NASA's current human Mars architecture must be placed in precise locations relative to each other to form a safe and functional operations site. Early identification of the EDL technologies that are most effective at meeting these requirements is key to minimizing development schedule and cost. When large-scale testing is not affordable, analysis at a fidelity high enough to identify concept discriminators must be employed.

For the past three years, NASA has supported a small team to analyze the Mars EDL in-depth, in the context of its published human Mars architecture approach. The team is made of individuals from multiple NASA centers, and coordinates closely with the Mars Study Capabilities team. The study objective is two-fold-to establish a simulation capability that can be used to evaluate the end-to-end system from concept to flight, and to provide system performance data that can influence the architecture as well as be used in technology funding decisions. This presentation will describe the latest results of the study, which have helped narrow the hypersonic decelerator trade space to two concepts, from four in previous years. Current efforts and future plans to enhance the descent and landing segment of the simulation will also be presented.

B4.2-0031-18 SPACEX MARS DEVELOPMENT OVERVIEW

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SpaceX was founded in 2002 to revolutionize space technology, with the ultimate goal of making life multi-planetary through enabling the establishment of human civilization on Mars. Fundamental to achieving this goal is to vastly decrease cost and improve the reliability of access to and transport through space.

The commercial development of the Falcon 9 and Falcon Heavy launch vehicles and our successes in introducing launch vehicle and spacecraft reusability offer increased launch capability at reduced cost. With the largest payload capability of any operational launcher since the Saturn V, the Falcon Heavy provides significant trans-Mars injection mass delivery at a very affordable price point which can be quite valuable in the context of near-term robotic and human-precursor Mars missions.

We have also initiated development of the Big Falcon Rocket (BFR) launch and in-space transportation system, which will become available in the 2020's and provide Mars transportation capabilities well in excess of those currently available or being developed elsewhere, while continuing to decrease transportation costs by being fully and rapidly reusable. With a fully reusable launch system, Earth orbit propellant transfer, and a fully-propulsive Mars landing, BFR is capable of delivering over 100 metric tons of useful mass to the surface of Mars in an affordable fashion. In the context of human missions, through use of in-situ propellant production the system is capable of returning over 50 tons of useful mass from Mars to Earth. The system also offers additional capabilities for a wide variety of mission types, including in Earth orbit and to the surface of the Moon, which can be leveraged to help build operational experience and spread costs in parallel with Mars missions.

More information regarding the overall BFR system architecture and mission plans is available at http://spacex.com/mars.

B4.2-0032-18 DESIGN FOR EARTH-MARS CYCLER TRAJECTORIES BASED ON AERO ASSISTED ORBITAL TRANSFER

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Rogue planet

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Earth-Mars cycler trajectories is a promising scenario for sustaining Mars exploration. In this approach, a cycling vehicle is arranged in the Earth-Mars cycler trajectories, the cycling vehicle can be continuously transferred between the Earth and Mars. Using this flight scheme, we can keep the life-support systems or other structures that only for space missions in the circular orbit for a long time. This makes it possible that it is no longer necessary to consume fuel at the missions of getting that equipment into/out to orbit. In this paper, we have introduced the aero assisted orbital transfer base on the traditional Earth-Mars cycler trajectories. the aerodynamic force is used as an auxiliary way to make the modification method of cycler trajectories more flexible. For the traditional Earth-Mars cycler trajectories, the perturbations between the planets will gradually diverge the cycler trajectories, additional fuel consumption is needed to maintain the long-term operation of the cycler trajectories. Preliminary calculation and analysis illustrate that when the aero assisted is introduced, the maneuverability of cycling vehicle is effective increased, so, the situation of cycler trajectories divergence can be effectively avoided. With the gradual maturity of hypersonic flight technology, Earth-Mars Cycler Trajectories based on aero assisted orbital transfer will play an important role in the mission of Mars exploration in future.

B4.2-0033-18 ORBITAL SYNTHETIC APERTURE RADAR FOR SUBSURFACE ICE DETECTION ON MARS: SCIENTIFIC RATIONALE AND CANADIAN TECHNICAL CONCEPT

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SUBSURFACE ICE DEPOSITS ON MARS

Recent Mars exploration efforts have been largely focused on understanding the planet's history of water in all of its forms. From an environmental perspective, determining the presence and distribution of subsurface ice deposits can help reconstruct Mars's geological and climatic evolution [1]. Looking forward, it is inevitable that a human exploration architecture on the Martian surface will be heavily reliant on access to water resources [2].

Vast quantities of subsurface ice at midto high-latitudes have been relatively well-documented for some time [e.g. 3, 4]; in fact, some 1/3 of the Martian subsurface is believed to be underlain by ground ice [5]. Given, however, that future human landing sites are most likely to be equatorward of 50 degrees [2], identifying the presence, quantity, and locations of putative resource deposits at lower latitudes will be critical.

GROUND ICE DETECTION METHODS

Techniques for detecting near-surface ice are varied. At the global scale, surface hydrogen abundance has been used as a proxy for the presence of water ice [3]. At local scales, in rare cases ground ice bodies have been made visible at the surface through very recent impacts [6] or exposures of eroding slope faces [5]. Also, the Mars Phoenix lander directly identified a shallow water ice table at its landing site [4].

At intermediate scales, orbital ground penetrating radar has served as a useful tool. Data from both the MARSIS and SHARAD instruments have been used to infer ground ice in a variety of locales [e.g. 7, 8]. However, neither of these instruments are capable of detecting ice within 10m of the surface [9], and thus cannot be relied upon for identifying resource deposits that could be reasonably accessible to humans.

THE CASE FOR SYNTHETIC APERTURE RADAR

A variety of previous studies have suggested that a Synthetic Aperture Radar (SAR) instrument may be capable of locating ice resources at depths of 1-10 m [10-12]. Such findings were echoed in the MEPAG Next Orbiter Science Analysis Group (NEX-SAG) report, which stated that a polarimetric SAR payload could meet the high priority science objective of mapping and quantifying shallow ground ice deposits [13].

CANADIAN MARS SAR CONCEPT

Canada is considered a world-leader in Earth observing SAR technologies, based primarily on it successful Radarsat and Radarsat 2 programs. In 2017 the Canadian Space Agency issued a contract to MDA Corporation, in conjunction with a science team led by the University of Western Ontario, to develop a concept for a Mars SAR for a potential future orbital mission.

While the work remains ongoing, preliminary observation and instrument requirements have been developed. A series of important trades between penetration depth, resolution, antenna size, power consumption, and data rate are ongoing. At present, both P-band (500MHz) and L-Band (1GHz) center frequencies are being studied, as is a dual frequency solution. In SAR imaging mode, both fully polarimetric (quad-pol) and compact-pol options were considered. The primary benefit of the compact-pol is it potential to use the circular polarization ratio (CPR) as a proxy for ice presence [12] without the associated increase in data rate generated by the full polarization mode. In sounder mode, the current preferred configuration is a nadirlooking mode with a vertical resolution of 1m and along track sampling of < 50m.

FORWARD WORK

The requirements listed above are presently in draft form, and the concept is still evolving. Future efforts will be devoted to further expanding the investigation's scientific objectives (i.e. beyond ice detection), tightly defining observation requirements that satisfy the objectives, and refining the technical concept to ensure an efficient instrument design. Input from the community is welcomed.

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B4.2-0034-18 MOXIE, ISRU, AND THE CO2 ECONOMY

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Manifested for flight on NASA's 2020 Mars Rover, the Mars Oxygen In Situ Resource Utilization Experiment (MOXIE) is a 1% scale model of an oxygen processing plant that is intended to support a human expedition sometime in the 2030s. Like the "Oxygenator" in Andy Weir's "The Martian," MOXIE ingests the thin CO2 that comprises 96% of the Martian air, and produces O2 and CO as products. Such a process would produce 30 metric tons of liquid oxygen (LOx) for ascent vehicle propellant in the 16 months preceding launch of a human crew to Mars, representing 78% of the propellant mass needed for a CH4/O2 propulsion system. To bring this amount of oxygen from Earth would otherwise require 4 to 5 heavy lift launches [1]. At Caltech's Jet Propulsion Laboratory the MOXIE Project is now assembling and testing flight hardware. In the MOXIE enclosure, a scroll pump developed by Air Squared, Inc. collects and compresses the CO2 for conversion to O2 by MOXIE's solid oxide electrolysis (SOXE) stack, which is built by Ceramatec, Inc. [2]. The stack is constructed from scandia-stabilized zirconia electrolyte-supported cells with thin screen-printed electrodes, coated with a catalytic cathode on one side and an anode on the other. When CO2 flows over the catalyzed cathode surface at 800°C under an applied electric potential, it is electrolyzed to produce CO and oxygen ions. The ions are electrochemically drawn through the solid oxide electrolyte to the anode, where they combine to produce gaseous O2. On Mars, MOXIE will generate a minimum of 6 g/hr high purity oxygen from the Martian atmosphere in at least 15 separate runs, sampling different environmental conditions on Mars, in the 2.5 years following landing of the Mars 2020 rover in February, 2021 [3]. Oxygen production is expected to be limited both by the compressor capacity and by the external conditions that determine the density and quantity of air that can be drawn in. While MOXIE stands on its own as a means to perform the specific function of fueling an ascent vehicle, it is also an exemplar of the direction in situ resource utilization (ISRU) is likely to take in the exploration of a new world. On Earth, the single most important resource is sunlight, the ultimate source of all the energy to support life. Arguably, our atmosphere is the second most significant, followed by water. While the air serves many mechanical functions, from windmills to the expansion medium in hot air balloons, its most important role is as a source of oxygen, an oxidant for chemical reactions that include our own metabolical respiration. Instead of oxygen, Mars offers us carbon dioxide as an oxidant. MOXIE takes a decidedly Earth-centric view of this resource, using it as a source of the more familiar O2 and either discarding the CO as an unwanted byproduct or using it as a feedstock to produce methane fuel in combination with a to-be-determined source of hydrogen. In a Mars-centric viewpoint, we might instead consider burning the CO and O2 byproducts directly, closing the cycle by producing CO2. We might also consider bypassing oxygen production entirely and directly using CO2 as an oxidant with lithium or other reactive metals.

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B4.2-0035-18 RADIATION SHIELDING FOR MANNED MISSION TO MARS: CHALLENGES AND PROBABLE DESIGN

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NASA has postponed the manned mission to Mars by 2030 and even unlikely to be certain by then also. One of the major constraints for manned mission to mars is the radiation shielding. A round trip to mars will make astronauts susceptible to 100 REM of radiation which is of course a biologically dangerous radiation level for a human body. So, to sort out this constraint an effective radiation shielding is required. This technology may be inspired from earth's radiation shielding. Earth is protected from cosmic radiation and solar flares by the virtue of its atmosphere and magnetic radiation. Moreover one other point which is required to be considered is that radiation shielding is required not only in the free space but also on the martian surface as Mars is having very thin atmosphere. So a two level protection is to be developed for a prototype radiation shielding for future manned mission. First level protection is in the free space by making a prototype design inspired from earths shielding and second level protection is on the martian surface by settling the base in the local magnetic field which could provide some radiation shielding. This paper deals with these key issues in solving a major technological constraint for manned mission to Mars i.e Radiation Shielding.

B4.2-0036-18 THE POTENTIAL IMPACT OF MARS' ATMOSPHERIC DUST ON FUTURE HUMAN EXPLORATION OF THE RED PLANET

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With the increasing focus by NASA and other space agencies on a crewed mission to Mars in the 2039 time-frame, many Mars-specific environmental factors are now starting to be considered by NASA and other engineering teams. Learning from NASA's Apollo Missions to the Moon, where lunar dust turned out to be a significant challenge to mission and crew safety, attention is now turning to the dust in Mars' atmosphere and regolith. To start the process of identifying possible dust-caused challenges to the human presence on Mars, and thus aid early engineering and mission design efforts, the NASA Engineering and Safety Center (NESC) Robotic Spacecraft Technical Discipline Team organized and conducted a Workshop on the "Dust in Mars' Atmosphere and Its Impact on the Human Exploration of Mars", held at the Lunar and Planetary Institute (LPI), Houston, TX, June 13-15, 2017. The workshop addressed the following general areas:

What is known about Mars' dust in terms of its physical and chemical properties, its local and global abundance and composition, and its variability.

What is the impact of Mars atmospheric dust on human health.

What is the impact of Mars atmospheric dust on surface mechanical systems (e.g., spacesuits, habitats, mobility systems, etc.).

We present the top priority issues identified in the workshop.

B4.2-0037-18 SURVEYING MARTIAN SURFACE USING BALLOONS: AN OPEN-ARCHITECTURE MISSION CONCEPT

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Surface mobility is one of the primary limiting factors in planetary exploration. Current roverbased technology precludes the possibility of surveying large areas of Martian surface. Recent advances in materials and miniature instrumentation increase the attractiveness of using suggest that balloons to explore much larger areas of the, once thought not suitable for application on Martian surface, may provide a viable alternative to rovers in a Mars mission.

We present a feasibility study conceptual design to enable the exploration on a concept to survey of the Martian surface utilizing Martian balloons. Solar-heated balloons can autonomously select an operating altitude in order to find wind moving in a direction of interest to the mission. Using a weighted guide rope, the balloon can "land", enabling closer inspection, and even the dispatch of small rovers to gather samples. Samples can thus be returned from a wide area of Mars to a single area, facilitating eventual Mars sample return to the Earth.

A physics based simulation model was developed to simulate Martian balloon flight. Utilizing parameters from the Mars Climate database, simulations were carried out for various payloads and climate conditions. We find that a balloon with a volume of 105m3 (balloon mass 30kg) can be designed to carry a 10kg payload for longrange flight on Mars. This capability is sufficient to allow one to develop a balloonbased Mars surface survey and sample-collection mission. A mission concept for in-situ Martian surface characterization using balloons and a new miniature Gamma-Ray/Neutron Spectrometer will also be discussed.

B4.2-0038-18 OPPORTUNISTIC BISTATIC RADAR WITH TELECOMMUNICATIONS SYSTEMS ON PLANETARY HELICOPTERS: MARS RECURRING SLOPE LINEA AND BEYOND

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Bistatic radar is a technique that utilizes the telecommunication system to obtain science data about a target body. The New Horizons mission used this technique to probe the atmosphere of Pluto via transmissions from the Deep Space Network, the Cassini-Huygens mission used this technique to characterize the surface of Titan, and the Rosetta mission (with the CONSERT instrument) used this technique between the Philae lander and the Rosetta orbiter. In opportunistic bistatic radar, the technique is applied by taking advantage of required transmissions that are not otherwise planned for science purposes.

In the case of a helicopter flying in the atmosphere of another planet, a straightforward data transfer scenario is that the helicopter would relay its data through another surface asset, such as a rover. The transmissions from the helicopter to the surface asset would have not only a direct path, but a portion of the transmitted energy would be reflected from the (sub)surface. Interference between the direct and reflected signals can be used to probe the (sub)surface between the helicopter and the rover, with the depth of penetration depending upon the wavelength (or frequency) used for the telecommunications.

We have constructed a field deployable model of the telecommunications system (900 MHz) for the Mars Helicopter Scout, which is under consideration for flying with Mars 2020 rover at the time of this abstract's submission. We describe a series of tests designed to characterize the performance of this system. As a motivating scenario, we consider the extent to which the bistatic radar technique would be able to probe into recurring slope linea (RSLs) on Mars, specifically whether a helicopter-surface asset system would be capable of distinguishing between "wet" RSLs, i.e., those originating from the flow of a brine, and "dry" RSLs. An attractive aspect of the bistatic radar technique is that it would allow remote sensing of potentially sensitive RSLs.

Finally, while the focus of this work has been a helicopter on Mars, the bistatic radar technique would be more generally applicable to any aerial vehicle at a planet with an atmosphere.

Some of the information presented is pre-decisional, for information and discussion purposes only. Part of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

B4.2-0039-18 WAVE ANALYZER MODULE OF THE MAIGRET INSTRUMENT ONBOARD SURFACE PLATFORM OF THE EXOMARS 2020 MISSION

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The wave analyzer module of the MAIGRET instrument will be placed on the ExoMars 2020 Surface platform. The module is dedicated to the measurement of magnetic field fluctuations in the frequency band from 100 Hz to 20 kHz. The scientific objectives of the wave analyser module will mainly concentrate on electromagnetic emissions of atmospheric origin and possible wave activity originated in electrical discharges in dust storms. The wave activity linked to the interactions of interplanetary plasma medium with Martian ionosphere and Martian magnetic anomalies at the surface and the ionosphere-atmosphere-lithosphere interactions on Mars related to space weather effects will be also investigated. The scientific questions which we plan to address have never been answered by measurements of the fluctuating magnetic fields in the appropriate range of frequencies directly on the surface of the planet. The immediate questions related to these targets are: i) Can we observe electromagnetic radiation propagating from the interplanetary space down to the surface of the planet? ii) Can we observe electromagnetic radiation from electric discharges in the Martian dust storms?

B4.2-0040-18 OVERVIEW AND STATUS REPORT ON THE UPCOMING SUPERCAM INVESTIGATION FOR THE MARS 2020 MISSION

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BACKGROUND Our exploration of Mars began with ground-based observations, followed by flyby missions, then orbiters, and then landed spacecraft capable of making up-close measurements of the composition of matter on its surface. Through a series of rover-based missions, we have discovered a rich variety of Martian micro-environments, some of which may have been conducive to life. The upcoming Mars 2020 mission will seek out and explore such microenvironments at the highest level of spatial and compositional detail possible, with the goal of searching for potential biosignatures, and assembling a cache of samples for return to Earth [1]. The SuperCam instrument suite, which will be capable of making a host of elemental, mineralogical, and textural measurements using remote sensing techniques, will play a central role in this search. SuperCam will also provide highly efficient means for rapidly searching the area around the rover for compositional fingerprints (including vibrational spectral signatures of organic compounds) that warrant further investigation using the rover-arm-mounted instruments SHERLOC and PIXL. And finally, after the very most promising material has been identified and sampled for return to Earth, SuperCam can then also make detailed chemical and mineralogical measurements of the walls of the drill holes that remain after samples are removed.

OVERVIEW OF THE SUPERCAM SUITE SuperCam is a suite of co-boresighted remote optical instruments comprising 1) Laser Induced Breakdown Spectroscopy (LIBS), 2) Raman and time-resolved luminescence spectroscopy (TRLS), 3) visible and near-infrared spectroscopy (VISIR), and 4) high resolution color remote micro-imaging (RMI) [2]. Additionally, SuperCam includes a microphone capable of recording sounds associated with LIBS impacts (useful in determining surface properties) as well as recording sounds from the environment and rover

itself. SuperCam hardware is distributed among three modules on the Mars2020 rover: a mastmounted unit provided by CNES (containing the laser, telescope, imager, IR spectrometer, and microphone), a rover body-mounted unit provided by LANL (containing LIBS/Raman/VIS spectrometers and data processing hardware), and a calibration target assembly near the back of the rover provided by UVA (containing geological samples of primary interest to Mars exploration, targets specifically for calibration of trace element composition, and geometric and color targets for imager and IR reflectance calibration.) Although SuperCam's LIBS, VIS, and RMI capabilities rely heavily on ChemCam instrument heritage from the MSL mission, SuperCam's Raman and IR capabilities are entirely new, providing critical mineralogical observations that complement textural and elemental chemistry data. In the overall context of multi-mission Mars exploration in general, these new capabilities are especially noteworthy, as SuperCam measurements of mineralogy can be compared to IR data acquired from orbit. This data comparison will provide critical ground-truthing of global mineralogical maps of Mars such as those produced by the Mars Reconnaissance Orbiter's CRISM instrument or the Mars Express mission's OMEGA instrument. And in areas where samples are obscured by Mars dust, SuperCam can use its LIBS laser to remove dust prior to analysis.

SUPERCAM OPERATION ON MARS Each of the SuperCam co-boresighted measurement modes function over distinct but overlapping distance ranges. LIBS measurements can be made up to 7 m away from the rover mast, by focusing the SuperCam laser's 1064 nm output to spots approximately 0.3-0.6 mm in diameter on the surface of a sample. And since the LIBS process physically removes sample from a surface (a few microns depth per laser pulse) it is possible to probe sample composition as a function of depth by repeatedly firing the laser up to a thousand times at a single spot. Raman and TRLS measurements can be made at greater distances, up to 10 m, by utilizing the 532 nm output of the SuperCam laser in a collimated 8mm diameter spot. Measurements from both of these "active" laser illumination modes have an 0.67 mrad angular field of view, defined by instrument collection optics (in other words, they collect light from a 1.3 mm spot at 2 m distance, or a 2.6 mm spot at 4 m distance, etc.). SuperCam "passive" measurements that do not require laser illumination (VISIR and RMI) can be performed at even more remote targets, as far away as the horizon. These modes have larger fields of view than the laser measurement modes (1.2mrad for IR and 20mrad for RMI). RMI images are in color, and are higher resolution (pixel FOV 20 µrad) than the corresponding panchromatic ChemCam RMI images.

CURRENT STATUS AND FUTURE OUTLOOK At the time of writing, the SuperCam instrument suite is currently in the final stages of development, following the successful completion of instrument CDR in December 2016. The Engineering Qualification Model (EQM) is currently being assembled at LANL and instrument calibration of the full range of instrument suite functionality will soon begin. Flight instrument delivery is scheduled for November 2018. In this presentation we will provide an updated summary of the latest status and developments in the SuperCam investigation, including information on planned instrument operation on Mars as well as associated mission system and data analysis tools.

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B4.2-0041-18 PLANETARY X-RAY DIFFRACTION BEYOND THE CHEMIN INSTRUMENT.

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X-ray diffraction (XRD) is a reference laboratory analytical technique for mineral identification and quantitative mineralogy. It has been deployed in robotic planetary exploration for the first time with the CheMin instrument in MSL. CheMin established the quantitative mineralogy of the Mars soil, characterized the first habitable environment on another planet, and provided the first in-situ evidence of Martian silicic volcanism. CheMin is now employed in the characterization of the depositional and diagenetic environments of lacustrine mudstones that comprise the lower strata of Mt. Sharp. Powder XRD typically requires samples comprised of small grains (<10 µm) packed in random orientations. In CheMin, vibrated sample cells cause internal flows in a bed of loose powder, improving particle statistics and relaxing the requirement for fine-grained samples. Analysis of soils collected by the scoop or rock powders produced by the percussion drill is possible without any sample preparation other than screening. Nonetheless, CheMin still relies on a complex sample collection and delivery facility, which limits its deployment potential on smaller missions.

XTRA (Extraterrestrial Regolith Analyzer) is miniaturized derivative of CheMin, intended to analyze fines in as-delivered surface regolith. Fine-grained regolith coats the surfaces of most airless bodies in the solar system, and because this fraction is comminuted from the rocky regolith, it can often be used as a proxy for the surface as a whole. Like CheMin, XRD uses a CCD in direct illumination for the collection of XRD and XRF signals. XTRA can be configured either in transmission geometry like CheMin using thin vibrated sample cells, requiring screening to <150 µm, or in reflection geometry using thick vibrated sample cells for as-delivered powders, allowing direct analysis of materials scooped at the surface, and simpler sample delivery. All critical components of XTRA have been developed to high TRL in collaboration with industrial partners: CCD detector in cooled packages, FPGA electronics for low noise CCD operation and embedded data processing, micro-focused X-ray tube, controller and high voltage power supply. XTRA will be proposed for upcoming landed missions targeting remote mineralogical analysis, collection, selection and caching of return-samples, or in-situ resources characterization.

Other XRD concepts are under development. Hybrid-XRD (HXRD) is intended to analyze rocks or soils without sample preparation. Fine grained materials are analyzed with a powder XRD method in reflection geometry using the characteristic K emission of the X-ray tube target, while coarse-grained crystals are analyzed using single crystal Laue patterns obtained from the wide spectrum bremsstrahlung emission. Unlike typical Laue applications, HXRD analyzes the energy of each Laue spot which enables mineral identification. Proof of concept prototypes and dedicated crystallographic software have been developed for this method. Another XRD concept under development aims at improving the capability to resolve complex mineralogies: a Guinier camera powder XRD is used in a compact geometry capable of high 2ϑ resolution normally only achievable in laboratory instruments. This design hinges on the use of a curved 2D detector to cover the angular range of interest. A substantial gain in resolution has been demonstrated. Both reflection and transmission geometries can be developed with this concept and are being explored as part of a PICASSO funded effort.

B4.2-0042-18 A MINIATURIZED VARIABLE PRESSURE SCANNING ELECTRON MICROSCOPE (MVP-SEM) FOR MARS

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A scanning electron microscope is the "go-to" instrument for petrologists, geochemists, and astrobiologists to make an initial assessment of the types of minerals, glasses, metals, and potential forms of life present in a sample. The MVP-SEM is under development to eventually provide this instrument for the surface of Mars. This development is funded by the NASA Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO) Research Opportunities in Space and Earth Sciences (ROSES) and is based on previous miniaturized SEM designs and advancements in the miniaturization of vacuum systems and detectors for low vacuum sample chambers. The variable pressure aspect of the SEM allows for unprepared (uncoated) samples to be analyzed by utilizing the carbon dioxide-rich Mars atmosphere for the neutralization of sample charging from the electron beam. This property of the MVP-SEM makes it ideal for use in locations where complex sample preparation is not desirable, such as the surface of Mars. In addition, the lack of sample preparation needed here simplifies the sample acquisition process and allows caching of the samples for future complementary payload use or eventual delivery to Earth.

The MVP-SEM team is comprised of an Instrument Development Team and a Science Team. The Instrument Development Team is led by NASA Marshall Space Flight Center and its members include the Jet Propulsion Laboratory (JPL), Applied Physics Technologies, and Creare LLC. The MVP-SEM Science Team members include planetary scientists, astrobiologists, members of ongoing Mars rover mission science teams, and research engineers.

Science requirements for the instrument include: 1) an imaging system capable of resolving uncoated objects or phases 100nm in size or better, 2) determination of the geochemistry of uncoated samples to a precision of 2 weight percent per major element, 3) capability to analyze materials with little to no sample preparation, 4) the ability to analyze multiple samples with a reusable sample holder, 5) production of images capable of being downlinked to Earth, and 6) ability to operate on a Mars-landed spacecraft.

The Instrument Development Team constrained the operational conditions of the instrument for imaging by testing with terrestrial SEMs using carbon dioxide gas for the appropriate electron scattering and charge neutralization conditions. Prototype development is nearing completion; testing of the instrument will be completed using a Mars environment chamber at the JPL. The instrument development process and results of testing to date will be presented.

B4.2-0043-18 INTERPLANETARY DUST ENVIRONMENT AROUND MARS AND PARTICLE DETECTION FROM FUTURE ORBITER

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Interplanetary dust in the inner solar system is expected mainly to be originated from asteroid belt beyond Mars and it travels inward towards Sun. On its way, it encounters various planets, which causes incoming dust environment in upper atmosphere of the planet. Mars, being the first in the travel path of Interplanetary Dust Particles (IDPs) from asteroid belt, more particles are expected at Mars than those predicted from existing model. Two plausible sources of incoming dust at Mars are envisaged, viz., first is IDP travelling from beyond the Mars and other is dust which might be originated from Phobos/Deimos. Recently, very high altitude dust from 150-1000 km has been observed by MAVEN mission. However, the source of such dust particles is not understood and their measurements are necessary to explain the possible origination. Further, the existing hypothesis that dust could be in the form of a thin ring around Mars may be confirmed due to long term observations and satellite orbit information. To study origin, abundance, distribution, flux and seasonal variation of IDP at Mars, a Mars Orbit Dust Experiment (MODEX) is proposed and the development of impact ionization dust detector has been initiated at PRL. This presentation discusses the dust at Mars, scientific motivation for dust measurements and developmental aspects of a dust detector along with initial results. The further work is underway.

B4.2-0044-18 ANALOGUE SAMPLES IN AN EUROPEAN SAMPLE CURATION FACILITY - THE EURO-CARES PROJECT.

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The objective of the H2020-funded EURO-CARES project (grant agreement n° 640190) was to create a roadmap for the implementation of a European Extraterrestrial Sample Curation Facility (ESCF) that would be suitable for the curation of samples from all possible return missions likely over the next few decades, i.e. from the Moon, asteroids and Mars.

The return of extraterrestrial samples brought to Earth will require specific storage conditions and handling procedures, in particular for those coming from Mars. For practical reasons and sterility concerns it might be necessary for such a facility to have its own collection of analogue samples permitting the testing of storage conditions, and to develop protocols for sample prepartion and analyses. Within the framework of the EURO-CARES project, we have created a list of the different types of samples that would be relevant for such a curation facility.

The facility will be used for receiving and opening of the returned sample canisters, as well as for handling and preparation of the returned samples. Furthermore, it will provide some analysis of the returned samples, i.e. early sample characterisation, and is expected to provide longterm storage of the returned samples. Each of these basic functions requires special equipment. Equipment, handling protocols and long-term storage conditions will strongly depend on the characteristics of the materials, and on whether returned samples are from the Moon, Mars or an asteroidal body. Therefore the different types and aspects of analogue samples one need to be considered, i.e. the nature of the materials, which analogues are needed for what purpose, what mass is needed, and how should the analogue samples be stored within the facility.

We distinguished five different types of anologue samples: analogue (s.s.), witness plate, voucher specimen, reference sample, and standard. Analogues are materials that have one or more physical or chemical properties similar to Earth-returned extraterrestrial samples. Reference samples are well-characterised materials with known physical and chemical properties used for testing. They may not necessarily be the same materials as the analogues defined above. Standards are internationally recognised, homogeneous materials with known physical and chemical properties that are used for calibration. They can also be used as reference samples in certain circumstances. They may be made of natural materials but are often produced artificially. A voucher specimen is a duplicate of materials used at any stage during sample acquisition, storage, transport, treatment etc., e.g. spacecraft materials (including solar panels), lubricants, glues, gloves, saws, drills, and others. In addition, Earth landing site samples (from the touch down site) would be necessary in case of doubtful analysis, even if normally this type of contamination is not expected. Finally, a witness plate is defined as material left in an area where work is being done to detect any biological, particulate, chemical, and/or organic contamination. It is a spatial and temporal document of what happens in the work area.

Analogue materials could be solids (including ices), liquids or gases. These could contain biological (extant and/or exinct) and/or organic components. They could be natural materials, e.g. rocks or minerals, or could be manufactured, such as mixtures of different components, which may be biologically and/or organically doped. Analogues with appropriate sample size and nature will be well-suited for testing and training of sample handling procedures, and for transport protocols. The training of science and curation teams also requires reference samples and standards. Long-term storage needs special witness plates and voucher specimes. Developing and testing sample preparation protocols needs all sample types.

B4.2-0045-18 A MODEL OF ATMOSPHERIC DRAG EFFECT ON MARS MISSION ORBITER DURING GEOCENTRIC, HELIOCENTRIC AND AREOCENTRIC TRAJECTORIES

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Interplanetary missions are susceptible to gravitational and non-gravitational perturbing forces at every trajectory phase (e.g., geocentric, heliocentric and Martian trajectories/areocentric phases). In this study, we analyzed such perturbing forces and their possible effects on interplanetary and/or Mars mission satellites, before Orbit Insertion. We also model the significance of atmospheric drag force on Mangalyaan Mars orbiter mission around/during perigee passage, as a function of solar and geomagnetic parameters during its 28 days in Earth's orbit, 300 days of heliocentric and 100 days of Martian trajectory, based on Earth-Mars atmosphere density ratio.

B4.2-0046-18 EFFECT OF SOLAR ENERGETIC ELECTROMAGNETIC AND PARTICLE RADIATIONS ON THE UPPER ATMOSPHERE OF MARS AND ITS IMPLICATIONS ON ROBOTIC MISSIONS

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A number of robotic missions have been planned in the near future by international space agencies to study various geological/ atmospheric phenomena including the search for indicators/ signatures of microbial or other forms of life on Mars. Spacecraft pressed for such autonomous pursuits followed up, later by possible manned Mars missions would have to be designed to withstand the total integrated as well as specific solar and cosmic event based radiation environment. While the heavy ion GCR flux and solar proton events (SPE) contribute to the bulk of the radiation doses, the solar activity constitutes an important control parameter of these fluxes which are oppositely correlated with the variations of sunspot numbers. A power law fit of the differential flux provides for the spectral hardness of these energetic radiations and a higher spectral coefficient contributes considerable radiation doses even behind the shielding. Hence the hazards of severe space radiation in deep space particularly for long duration planetary missions need to be appropriately assessed. The possible safeguards from the exposures to the ionising radiations of GCR and SPE are to be built in the design of the shielding and related subsystems of the spacecraft. In order to achieve a better optimisation with respect to the specific materials and structural elements of the shielding technology, it is essential that accurate model to predict GCR and SPE fluences be available around the survey region of Mars specific to a robotic mission. In this paper we develop an integrated GCR/SPE model to provide predicted total radiation environment on Mars. The solar energetic particle radiation and GCR data are obtained from many spacecraft observations during different periods of solar activity to develop the model by using neural networks. Further the partial absorption and attenuation of these radiations by the atmosphere of Mars is also taken into account using the data from MOM, MAVEN and other missions. The model results are validated with available experimental observations.

B4.2-0047-18 IN-SITU LUMINESCENCE DATING OF MARTIAN SEDIMENTS

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Recent discoveries have revealed that Mars possesses a record of diverse surfaces created as a result of geological processes occurring prior to 3 Ga, and recent volcanism, weathering events during the last few 100 Million years. This geological record is yet to be found on Moon or the Earth, and new Mars missions provide an opportunity to address questions regarding planetary evolutionary processes, how and whether life arose elsewhere in the solar system, and the interplay between geological and possible biological history. At present, Mars is too cold with a very thin atmosphere to support the existence of liquid water on its surface. However, images from Mariner 9 and later by Viking orbiters suggested the presence of geomorphic features which might have formed in the past by the action of liquid water flowing along the Martian surface. Further, Mars Global Surveyor images indicated the existence of young, fluvial landforms at latitudes above 30o in both hemispheres. These features might be younger than 1 Million years, as they appear to be relatively fresh, and because of the absence of impact craters on surrounding terrain and their association with young (< few Million years) sand dunes. It is important to study the above mentioned features as the fossil remains of extinct life on Mars, if existing, are likely to be found in areas where there was a source of water. Other important repositories for water on Mars consist of the polar regions, comprising perennial ice, overlain by seasonal CO2 frost caps, and underlain by layered deposits. These deposits are believed to preserve a record of variations in CO2, H2O and dust concentrations over the last 100 million years and are the best archives of recent climatic changes on Mars. Thus, sedimentary deposits are likely to provide important records of paleoclimatic change on Mars. Establishment of a Martian paleoclimatic history requires the development of absolute dating techniques. This presentation proposes determination of a chronology for Martian sediments over the last 2 Million years using optically stimulated luminescence (OSL) dating techniques. Luminescence dating has revolutionized terrestrial Quaternary studies as these methods can be used for dating a variety of earth surface processes and sediments that were conventionally considered undatable. On Mars, OSL dating will provide high-precision age estimates for the laminated polar deposits, aeolian activation periods, and fluvial and lacustrine sedimentation periods.

B4.2-0049-18 NASA'S ASTROMATERIALS ACQUISITION AND CURATION OFFICE: ENABLING 50 YEARS OF LUNAR AND PLANETARY RESEARCH, NOW HEADING TO MARS

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The NASA Astromaterials Acquisition and Curation Office at the NASA Johnson Space Center curates all of NASA's extraterrestrial samples, including 10 unique collections: (1) Apollo lunar samples (1969); (2) Antarctic meteorites from asteroids, the Moon, and Mars (1976); (3) Cosmic dust particles collected in the stratosphere (1981); (4) Microparticle Impact Collection (1985); (5) Genesis solar wind atoms (2004); (6) Comet Wild 2 particles from the Stardust mission (2006); (7) Stardust interstellar particles (2006); (8) Hayabusa asteroid particles (2010);

(9) OSIRIS-REx spacecraft coupons and witness plates (2015); and (10) Mars2020 spacecraft contamination knowledge. The broad range of samples in NASA collections have resulted in growing capabilities to curate large rock samples (Apollo, Meteorite), bulk regolith and coresmixtures of particles ranging from submicron to 1 cm (Apollo), micron-scale particles (Cosmic Dust, Hayabusa), micron-scale particles embedded in aerogel (Stardust), solar wind atoms implanted in various materials (Genesis), carbon-rich samples (Meteorite), spacecraft pieces with embedded astromaterials (Microparticle Impact Collection), and materials that capture contamination knowledge for extraterrestrial samples (Genesis, Stardust, OSIRIS-Rex, Mars2020). The standards of Astromaterials Curation are described by NASA Policy Directive 7100.10F and derivative documents that specifically direct the NASA Curation Office at JSC to implement the ". curation of all extraterrestrial material under NASA control, including future NASA missions", and defines curation to include documentation, preservation, preparation, and distribution of samples for research, education, and public outreach. This policy ensures the proper curation of current and future astromaterials collections, including future samples from Mars, at the Johnson Space Center. Based on this policy, the NASA Astromaterials Curation Office has built an experience base spanning 50 years that encompasses curation facility planning, research and development of sample handling and contamination control protocols, partnering with mission teams, and continuous daily operations [1,2]. The resulting product is the world's most diverse, extensive, best-documented, and least-contaminated extraterrestrial sample collection that supports planetary research by hundreds of researchers around the globe. An average of 1500 samples are allocated to scientists every year. These allocations result in 100s of papers annually, fundamental discoveries about the evolution of the solar system (e.g. [3]), and serve as ground truth for robotic missions such as NASA's Dawn mission to Vesta and Ceres, OSIRIS REx mission to Bennu [1,3], and the rovers on Mars.

Advances in Astromaterials Curation: Today's advanced curation initiatives build on decades of NASA experience developing and executing astromaterials curation facilities and protocols. Lessons from the Apollo missions formed the foundation of NASA's curation effort, including the need for early involvement of curation scientists in mission planning [1], have been applied to all subsequent sample return campaigns. The 2013 National Academy of Sciences report

[4] noted: "Curation is the critical interface between sample return missions and laboratory research. Proper curation has maintained the scientific integrity and utility of the Apollo, Antarctic meteorite, and cosmic dust collections for decades. Each of these collections continues to yield important new science." Today, a large part of NASA Curation's efforts includes planning for samples returned from future missions, including samples from locations designated "restricted Earth return" such as Mars. Key areas of research include: 1) detecting and monitoring all forms of contamination and achieving increasingly high levels of cleanliness (inorganic and organic [5]) in our facilities to enable analysis for all elements and relevant organic species; 2) development of new high precision cleaning and validation techniques for sampling materials and witness plates; 3) continued research on sample handling and containment technologies including cross contamination and robotic sample handling solutions, and concepts for restricted samples (see Calaway et al, this session); 4) development of requirements for cold curation that will enable preservation and handling of samples, including volatiles collected at extremely low temperatures. We are also enhancing sample databases

and documentation of data derived from NASA's astromaterials samples, restoring legacy data sets, collecting and serving high resolution imagery, developing 3D imaging techniques and have established an X-ray CT laboratory [6], and upgrading labs with web-based communication enabling remote access for investigators from around the world. These advances support the continued curation of Apollo samples, our other astromaterials collections, and the future curation of samples from challenging exploration destinations such as the south polar region of the Moon, icy moons of outer planets, comets, and the surface of Mars.

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B4.2-0050-18 MAXIMUM SAMPLE TEMPERATURE FOR MARS SAMPLE RETURN: A HISTORICAL PERSPECTIVE

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Since the first Mars Sample Return (MSR) report published by the Jet Propulsion Laboratory (JPL) in 1974 [1], a series of panels, reports, and white papers have recognized the importance of sample temperature and offered an informed sample maximum temperature (henceforth SMT) limit for returning martian samples to Earth. The Mars Sample Handling and Requirements Panel (MSHARP, 1999) stated that "[t]he main issue in sample preservation is temperature" [2]. More recently, the Mars Exploration Program Analysis Group (MEPAG)'s "Science Priorities for Mars Sample Return" report (2008), declared that "[s]ignificant loss, particularly to biological studies, occurs if samples reach +50°C for three hours", whereby "scientific objectives related to life goals could be seriously compromised" [3]. By contrast, the Mars 2020 mission has adopted a SMT of +60°C as spelled out in Beaty et al., 2016 [4]. Samples will be collected and then deposited on the surface in sealed tubes for possible retrieval and return to Earth. Beaty et al. [4] calculates that the samples will experience maximum temperatures of +30 to +60°C, depending on latitude. At present, there is no mission requirement for the measurement/data logging of sample temperature during this period. We will explore the history of martian SMTs, as they have been recorded since 1974 [1], effectively representing input across multiple generations of Mars scientists. Ten separate publications present SMTs for MSR samples [1-10]. One report [10] is for a mission concept specifically designed to exclude life detection investigations, and recommended an SMT of 50°C. Another did not specify a temperature, recommending "Mars ambient temperature" [5]. Of the remaining eight, SMTs are given as: -30°C [1], -20°C [3], 60°C [4], -73 to 41°C depending on sample type [6], -40°C [7], -43 to 13°C depending on type [2,8], and -33°C [9]. If we restrict the temperatures to samples highlighted in the Mars 2020 mission goals, i.e. organics-bearing and sedimentary rocks, then the average SMT is -28±39°C (n=8). Applying a Dixon's Q Test at P=0.05 (two-tailed), the 60°C SMT [4] fails with Q=0.602 versus Qcrit=0.526. Excluding the outlier produces an average SMT of -40±17°C (n=7). Therefore, the average SMT expressed by the Mars science community over the past 44 years (two generations) is a sample temperature no greater than -40°C. The difference in chemical reaction rates between this average SMT and Beaty et al [4] can be estimated using the Arrhenius equation. Assuming a generic chemical reaction with an activation energy of 50 kJ/mol and a pre-exponential factor invariant with temperature, this reaction will proceed 2300x faster at 60°C than at -40°C. To illustrate the effects of the increased reaction rate, consider 10 ppb of alanine in a Mars 2020 cache, and assume that it becomes unmeasurable if it degrades to 1 ppb, as per the Mars 2020 Organic Contamination

Panel contamination limits [11]. If we illustrate the effect with an arbitrary degradation rate such that the alanine will become undetectable in ten years at -40°C, then the same 10 ppb alanine degrades beyond detectability in only 38 days at 60°C. Further research is required to quantify expected analyte losses in the cached samples due to thermal processing. [1] Jaffe, L.D., et al 1974. JPL Internal Rept., (760-101). [2] Carr, M.H., et al 1999. NASA Tech. Memo, 209145(47), p.1999. [3] Borg L., Des Marais D., Beaty D., 2008. Astrobiology (8,3) 489-535.

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B4.2-0051-18 OVERVIEW OF THE EMIRATES MARS INFRARED SPECTROMETER (EMIRS) ONBOARD THE EMIRATES MARS MISSION

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The Emirates Mars Infrared Spectrometer (EMIRS) is one of three scientific instruments abroad the Emirates Mars Mission (EMM) spacecraft named "Hope". EMM will launch in 2020 and is designed to explore the diurnal and seasonal dynamics of the martian atmosphere on a global scale. EMM has three scientific instruments that provide an improved understanding of climate and weather in the martian lower and middle atmosphere as well as the thermosphere and exosphere. The Emirates eXploration Imager (EXI) and EMIRS instruments will focus on the lower atmosphere constituents, constraining dust and water ice optical depths, while determining the ozone and water vapor column abundances and the thermal structure up to 50 km altitude. The Emirates Mars Ultraviolet Spectrometer (EMUS) will make complementary observations, enabling important links between the lower atmospheric dynamics and the thermosphere and exosphere of the planet.

The EMIRS instrument is an interferometric thermal infrared spectrometer developed by Arizona State University (ASU) and Mohammed Bin Rashid Space Centre (MBRSC). It builds on a long heritage of thermal infrared spectrometers designed, built, and managed by ASU's Mars Space Flight Facility, including the Thermal Emission Spectrometer (TES), Miniature

Thermal Emission Spectrometer (Mini-TES), and the OSIRIS-REx Thermal Emission Spectrometer (OTES). EMIRS collects spectral

data from 6-40+ µm at 5 cm-1 spectral sampling, which is enabled by a diamond beamsplitter and digital servo interferometer control electronics. EMIRS has a 3×3 array of pyroelectric DLaTGS detectors and a scan mirror that enable it make high-precision infrared radiance measurements over a martian hemisphere in 1/2 an hour of observing. The EMIRS instrument performance, spectral coverage, and spatial sampling are optimized to capture the integrated, lower and middle atmospheric dynamics, collecting 60 observations per week (20 images per orbit) at a resolution of 100-300 km/pixel. EMIRS contributes heavily to the scientific objectives of EMM and will provide a new view of the martian lower and middle atmosphere, capturing the sub-seasonal and diurnal evolution of key atmospheric constituents over the entire globe during the EMM two year primary mission.

B4.2-0052-18 SCIENTIFIC PAYLOAD OF THE EMIRATES MARS MISSION: EMIRATES EXPLORATION IMAGER (EXI) OVERVIEW

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The Emirates eXploration Imager (EXI) instrument is one of three scientific instruments abroad the Emirate Mars Mission (EMM) spacecraft, “Hope”. The planned launch window opens in the summer of 2020, with the goal of this United Arab Emirates (UAE) mission to explore the dynamics of the Martian atmosphere through global spatial sampling which includes both diurnal and seasonal timescales. A particular focus of the mission is the improvement of our understanding of the global circulation in the lower atmosphere and the connections to the upward transport of energy of the escaping atmospheric particles from the upper atmosphere. This will be accomplished using three unique and complementary scientific instruments. The subject of this presentation, EXI, is a multi-band, camera capable of taking 12 megapixel images, which translates to a spatial resolution of better than 8 km with a well calibrated radiometric performance. EXI uses a selector wheel mechanism consisting of 6 discrete bandpass filters to sample the optical spectral region: 3 UV bands and 3 visible (RGB) bands. Atmospheric characterization will involve the retrieval of the ice optical depth using the 300-340 nm band, the dust optical depth in the 205-235nm range, and the column abundance of ozone with a band covering 245-275 nm. Radiometric fidelity is optimized while simplifying the optical design by separating the UV and VIS optical paths. The instrument is being developed jointly by the Laboratory for Atmospheric and Space Physics (LASP), University of California, Boulder, USA, and Mohammed Bin Rashid Space Centre (MBRSC), Dubai, UAE.

B4.2-0053-18 EMIRATES MARS ULTRAVIOLET SPECTROMETER (EMUS) OVERVIEW FROM THE EMIRATES MARS MISSION

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The Emirates Mars Ultraviolet Spectrometer (EMUS) instrument is one of three science instruments on board the "Hope Probe" of the Emirates Mars Mission (EMM). EMM is a United Arab Emirates' (UAE) mission to Mars, launching in 2020, to explore the global dynamics of the Martian atmosphere, while sampling on both diurnal and seasonal timescales. The EMUS instrument is a far-ultraviolet imaging spectrograph that measures emissions in the spectral range 100-170 nm. Using a combination of its one-dimensional imaging and spacecraft motion, it will build up two-dimensional far-ultraviolet images of the Martian disk and near-space environment at several important wavelengths: the Lyman beta atomic hydrogen emission (102.6 nm), the Lyman alpha atomic hydrogen emission (121.6 nm), two atomic oxygen emissions (130.4 nm and 135.6 nm), and the carbon monoxide fourth positive group band emission (140 nm-170 nm). Radiances at these wavelengths will be used to derive the column abundance of atomic oxygen, and carbon monoxide in the Martian thermosphere, and the density of atomic oxygen and atomic hydrogen in the Martian exosphere both with spatial and sub-seasonal variability. The EMUS instrument consists of a single telescope mirror feeding a Rowland circle imaging spectrograph with selectable spectral resolution (1.3 nm, 1.8 nm, or 5 nm), and a photon-counting and locating detector (provided by the Space Sciences Laboratory at the University of California, Berkeley). The EMUS spatial resolution of less than 300 km on the disk is sufficient to characterize spatial variability in the Martian thermosphere (100-200 km altitude) and exosphere (>200 km altitude). The instrument is jointly developed by the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado Boulder and Mohammed Bin Rashid Space Centre (MBRSC) in Dubai, UAE.

B4.2-0054-18 LITHOSPACE: AN AUTOMATED SYSTEM FOR IN SITU PETROGRAPHIC THIN SECTION PREPARATION ON MARS

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Optical microscopy in transmitted light is one of the most standard techniques in geology and has been used for more than 150 years. Indeed, atlases of microscopic images of rocks and their characteristic mineralogy and textures are widely used in geological departments [1]. Observation in transmitted light permits identification of rocks having similar chemical and mineralogical compositions but different mineral textures (basalt vs. gabbro for instance). Using polarized light, it permits identification of most rock-forming minerals in thin section [2]. Observation in transmitted light is also essential for micropaleontology since it is the only way to observe individual microfossils or colonies of microfossils, if they are large enough, and to document the mineralogical and textural context in which the biosignatures occur. Nevertheless, optical observation in transmission has never been carried out on Mars. Indeed, although optical microscopes are used in space exploration (e.g. on Mars), thin section preparation in situ on an extraterrestrial body is not easy to do. In particular, on Earth it requires several human manipulations that are difficult to automate.

The aim of the LithoSpace project, supported by the CNES since 2014, is to work on the development of an automated system permitting preparation of petrographic thin sections on extraterrestrial bodies, in particular, on Mars. Several studies and tests have been conducted and most of the problems solved. The final protocol follows the process from obtaining a standardized drill core to observation of a thin section in a fully automated way.

The project is an excellent way to raise student awareness of space science and technology, helped by the fact that it is possible to develop a model for a relatively limited cost. Thus, a preliminary numerical model of the system was designed by fifth year students at the engineering school Polytech'Orléans, University of Orléans, France. They also proposed smart solutions for different critical steps of the preparation. Subsequently, it was decided to constructed the model with the help of students in the BTS (two-year technical degree) course "conception of industrial products", from the Benjamin Franklin high school of Orléans. In this way a group of five students, helped by their teachers, have started the development of a physical demonstration model to be presented during the COSPAR 2018 meeting.

In situ thin section preparation would be an important improvement for the geological and astrobiological exploration of the solar system in general, for Mars as well as for other planetary bodies. The proposed instrument could incorporate new high resolution techniques, such as Raman mapping or micro-LIBS as well as optical microscopic observation in transmitted light.

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SPACE STUDIES OF THE EARTH-MOON SYSTEM, PLANETS, AND SMALL BODIES OF THE SOLAR SYSTEM (B)

JUNO AT JUPITER (B5.1)

B5.1-0001-18 THE NEW JUPITER

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The Juno spacecraft was launched in 2011 and arrived at Jupiter on July 4, 2016. Juno's scientific objectives include the study of Jupiter's interior, atmosphere and magnetosphere with the goal of understanding Jupiter's origin, formation and evolution. The baseline mission utilizes thirty-two polar orbits to effectively map Jupiter both inside and out. Each perijove provides Juno's nine instrument payload a close pass over Jupiter at altitudes as close as 3500 km above the cloud tops. With its unique orbit and unique viewing geometry, Juno peers into Jupiter's deep atmosphere, deep interior and hovers over the polar magnetosphere to reveal for the first time the physics of giant planets. The results have fundamentally changed our understand- ing of Jupiter and are providing a new approach to solar system investigation. An extensive campaign of Earth based observations of Jupiter and the solar wind were orchestrated to complement Juno measurements during Juno's approach to Jupiter and during its orbital mission around Jupiter. This presentation provides an overview of results from the Juno measurements and the collaborative campaign. Scientific results include Jupiter's interior structure, magnetic field, deep atmospheric dynamics and composition, and the first in-situ exploration of Jupiter's polar magnetosphere and aurorae.

B5.1-0002-18 JUNO'S INVESTIGATION OF JUPITER'S MAGNETOSPHERE

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Since its arrival in July of 2016, NASA's Juno spacecraft continues to return invaluable observations regarding Jupiter's dynamic magnetosphere. The polar orbiting spacecraft has an orbital period of 53.5 days, which takes it from just a few thousand kilometers above Jupiter's one-bar "surface" outward to over 100 jovian radii - cutting through Jupiter's polar region as well as its equatorial region. Although these regions are inherently coupled, in this talk we compartmentalize Juno's observations into the auroral and magnetospheric regions and briefly discuss their connections. One of Juno's primary science goals is to investigate the nature of Jupiter's aurora - the most powerful aurora in the solar system. Outfitted on the space- craft are a suite of instruments dedicated to measuring the in situ plasma waves and magnetic fields, charged particles as well as remote sensing the ultraviolet and infrared signatures of the aurora. In concert, these observations have and continue to paint a fundamentally different view of the mechanisms producing the Jovian auroras. Juno's instruments are also sending back new and compelling observations of Jupiter's magnetospheric regions. Examples include: the discovery of a belt of heavy ions residing inside the main ring, new details regarding the magnetopause structure and dynamics, and a more comprehensive survey of the plasma sheet particle populations and dynamics. In this presentation we will briefly summarize some of the major findings from both the auroral and magnetospheric regions and discuss new mysteries and future anticipated observations from Juno.

B5.1-0003-18 HIGHLIGHTS OF THE JADE OBSERVATIONS

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Thanks to Juno's very eccentric orbit (apojove 110 Rj, perijoe 1.05 Rj), JADE observes plasma populations throughout the Jovian magnetosphere: the magnetosheath through the magnetopause; the outer, middle, and inner magnetosphere; and close-in down to the ionosphere. We present here some of the highlights of the JADE observations from the first to the most recent orbits.

Plasma disk crossings in the middle and inner magnetosphere show a mixture of heavy and light ions. A novel analysis technique allows us to separate O+ from S2+ in the TOF spectra. During perijove crossings at high latitudes when Juno was connected to the Io torus JADE-I observed heavy ions with energies consistent with a co-rotating pickup population. At sub-auroral and equatorial latitudes, low energy (<100 eV) ionospheric ion distributions are observed that are distinct from the Io torus population.

The electron pitch angle distributions on field lines connected to the auroral regions change as a function of radial distance. For example, the higher energy electrons (30-100 keV) are mostly isotropic at large distances and mostly trapped closer to Jupiter, while the lower energies (<3 keV) are mostly field aligned at most distances.

Over the polar and auroral regions, JADE observed bi-directional electron beams having broad energy distributions interspersed between beams of upward electrons with narrow, peaked energy distributions, regions void of these electrons, and regions dominated by penetrating radiation. In most instances the electrons show evidence of acceleration via stochastic processes (broad energy distributions) and sometimes via parallel electric fields (inverted-V structures). One of the most surprising and still puzzling results is that the upward energy flux of the electron distributions is typically greater than the downward energy flux, except when Juno is connected to the diffuse aurora equatorward of the main auroral emission.

B5.1-0004-18 JUNO WAVES OBSERVATIONS AT JUPITER

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The Juno spacecraft successfully entered Jupiter orbit on 5 July 2016. One of Juno's pri- mary objectives is to explore Jupiter's polar magnetosphere. An obvious major aspect of this exploration includes remote and in situ observations of Jupiter's auroras and the processes responsible for them. To this end, Juno carries a suite of particle, field, and remote sensing instruments. One of these instruments is a radio and plasma wave instrument called Waves, designed to detect one electric field component of waves in the frequency range of 50 Hz to 41 MHz and one magnetic field component of waves in the range of 50 Hz to 20 kHz. Juno has now made scientific observations on several perijove passes beginning with Perijove 1 on 27 August 2016. This paper presents an update of some of the results from the Juno Waves instrument. Among radio emissions, kilometric, hectometric, and decametric emissions have been observed. We present observations suggesting Juno has flown through or close to several sources of these auroral radio emissions. Remote observations provide source locations for broadband kilometric radiation that are consistent with auroral field lines. Waves observes whistler-mode hiss on auroral field lines and over the polar cap. The hiss sometimes exhibits quasi-periodic intensity fluctuations in the range of a few to a few tens of minutes, similar to that of quasi-periodic (QP) radio bursts and temporal variations in some UV auroral emissions and X-ray hot spots poleward of the main oval. The hiss intensity exhibits a good correlation with upgoing energetic electrons observed by the Jupiter Energetic particle Detector (JEDI). It is enticing to consider the possibility that the hiss and energetic electrons are associated with the quasi-periodic emissions. Juno's perijove passes carry it over mid-latitudes where lightning is known to exist and, consequently, copious numbers of lightning whistlers have been observed, significantly increasing our understanding of lightning occurrence on Jupiter. Proton whistlers have also been observed on a few occasions, a first for this phenomenon in a non-terrestrial locale. Near perijove the Waves instrument observes whistler mode hiss whose upper cutoff is likely at the local electron plasma frequency providing in situ observations of Jupiter's topside ionosphere. Dust is also observed near the jovigraphic equator through hypervelocity impacts with Juno. It is thought that the grains are micron-sized and are the result of material moving inward from Jupiter's ring.

B5.1-0005-18 JUPITER LIGHTNING-INDUCED ELECTROMAGNETIC WAVES FROM THE JUNO WAVES INVESTIGATION

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An intense electromagnetic impulse induced by Jupiter's lightning propagates through the magnetized plasma in the ionosphere and inner magnetosphere producing a low-frequency dispersed whistler emission and a non-dispersed sferic pulse. Jupiter's whistlers were observed by Voyager 1 in a frequency range of a few tens of Hz to 20 kHz, having the restriction of propagation below either the local electron cyclotron frequency or local electron plasma frequency, whichever is lower. A non-dispersed sferic was first captured at Jupiter by the Galileo Probe in a magnetic field waveform between 10 Hz and 100 kHz. Sferic signals at frequencies above 100 kHz were conjectured but no detections of this kind were reported in the Jovian inner magnetosphere using Voyager radio observations in a frequency range from 20 kHz to 41 MHz. Another opportunity to examine the nature of Jupiter lightning is provided by the Juno polar-orbiting spacecraft that arrived at Jupiter on 5 July, 2016. Since then, Juno has maintained a 53-day eccentric polar orbit about Jupiter. During Juno's eight perijove surveys from 27 August, 2016, through 24 October, 2017, we have investigated all waveform snapshots in 122.88-ms intervals from

50 Hz to 20 kHz and in 16.384-ms intervals from 10 kHz to 150 kHz collected by the Waves instrument. We found copious, new types of electromagnetic waves related to lightning at frequencies below 150 kHz, including whistlers below 5 kHz at extremely short time scales and dispersed millisecond pulses below 150 kHz (Jupiter dispersed pulses or JDPs). The number of detected whistlers and JDPs have respectively reached over 1600 and 400 detections, which comprise the largest dataset for Jovian lightning. We have also attempted to compare these observations below 150 kHz with some of high-frequency observations from 600 MHz to 22 GHz made independently by the MWR instrument onboard Juno. In this talk, we highlight our findings and interpretations of the lightning-induced electromagnetic waves detected at Jupiter.

B5.1-0006-18 SYNCHROTRON RADIATION MODELING IMPROVEMENTS FROM JUNO'S MWR OBSERVATIONS

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Ultra-relativistic electrons trapped by Jupiter's very strong magnetic field near the equator and close to planet (RJ< 4), release energy via synchrotron emission. Over the course of Juno's 53-day polar orbit, the Microwave Radiometer experiment (MWR) on the spacecraft observes the Jovian radiation environment from a wide range of viewing angles, at 6 wavelengths from 2 cm to 50 cm. At large wavelengths the synchrotron emission dominates the planetary radiation signature. Synchrotron data collected with the MWR is used to improve and provide new constraints on existing synchrotron emission models, in particular in refining the electron energy distribution parameters utilized in empirical models.

B5.1-0007-18 CAN JUNO DETECT THE GRAVITATIONAL SIGNATURE OF JUPITER'S MERIDIONAL FLOWS AND FREQUENCY-DEPENDENT TIDAL RESPONSE?

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On 7 February 2018, Juno completed its fifth orbit devoted to gravity measurements. The current data set acquired through Juno's state-of-the-art radio system provided insight into the internal structure of the gas giant by suggesting the presence of a diluted core and revealing that the surface zonal winds extend to a depth of thousands of kilometres. The extremely accurate gravity measurements are carried out by measuring the Doppler shift of two-way radio links established at Ka-band (32.5-34 GHz).

The nominal mission will end on 30 July 2021, after a total of 25 gravity orbits. The extended data set will reveal components of the gravity field that are currently not accessible. The fine effects of the wind dynamics can be assessed with the broader coverage in longitude. Meridional variations of the zonal flows, associated with Jupiter's vortices, may be revealed by analysing the tesseral component of the gravity field. The magnitude of the tesseral harmonics provides information on the depth of the non-zonal atmospheric circulation. A larger number of gravity passes will also allow to observe the frequency-dependent response of Jupiter to tidal effects induced by the Galilean satellites and obtain indications on the non-equilibrium response of the planet to external forcing fields. We report on numerical simulations of the gravity experiment and discuss the expected results at the end of the mission.

B5.1-0008-18 A NEW MODEL OF JUPITER'S MAGNETIC FIELD FROM JUNO'S FIRST NINE PERIJOVES

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Characterizing the planetary magnetic field of Jupiter is one of the primary science objectives of the Juno Mission. Juno's 53.5-day capture orbit trajectory carries her science instruments from pole to pole in approximately 2 hours, with a closest approach to within 1.06 Rj of the center of the planet (one Rj = 71,492 km), just a few thousand km above the clouds. Observations acquired during 8 of Juno's first 9 orbits provide the first truly global coverage of Jupiter's magnetic field with a coarse longitudinal separation of 45 degrees between perijoves. Juno measures the vector magnetic field with two magnetometer sensor suites, located 10 and 12 m from the center of the spacecraft. Each contains a vector fluxgate magnetometer (FGM) sensor and a pair of co-located star trackers, providing accurate attitude for the FGM sensors. Observations acquired within 7 Rj of Jupiter during the first 9 polar passes are used to characterize the planetary magnetic field with extraordinary spatial resolution. The magnetic field is represented with a degree 20 spherical harmonic model for the planetary field, combined with an explicit model of the magnetodisc. Partial solution of the underdetermined inverse problem using generalized inverse techniques yields a model ("JRM09") of the planetary magnetic field with spherical harmonic coefficients determined through degree and order 10, providing the first detailed view of a planetary dynamo beyond Earth's. The Jovian magnetic field is unlike anything previously imagined, evidencing a complexity that portends great insight into the dynamo process in general and the dynamics of Jupiter's interior in particular. We present a degree 10 spherical harmonic model of the Jovian magnetic field and illustrate its characteristics via a set of maps of the surface field, and consider implications for particle motion, auroral emissions, and the dynamo.

B5.1-0009-18 THE (UNEXPECTED) RESULTS FROM THE JUNO MICROWAVE RADIOMETER THROUGH TWELVE ORBITS

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The Juno Microwave Radiometer (MWR) has frequencies in six channels ranging from 0.6 to 22 GHz (1.37-50 cm). The sensor was designed to understand the composition and dynamics of the Jovian atmosphere to pressures greater than 100 bars. The microwave channels are primarily sensitive to the ammonia and water vapor concentration with depth in the atmosphere. We will provide an overview of the findings from the Juno Microwave Radiometer though the first twelve orbits focusing on the unexpected results from the atmospheric observations. Our original finding from the first orbits was that ammonia is not uniformly mixed beneath its saturation level in the atmosphere, but enhanced in a band near the equator and depleted in the north and south equatorial belts. This is observed to be persistent with longitude and time over the nearly two years of observations. We will discuss the first detection of high-frequency sferic signals from Jovian lightning and the inferred distribution of moist convection on the planet. Sferic signals from Jovian lightning were previously undetected, despite search with instruments on Voyager and Galileo. These results suggest lightning discharges on Jupiter may be more like terrestrial lightning than previously thought. We find lightning to be strongest and most prevalent in the northern middle to high latitudes. It is preferentially concentrated toward both poles and absent near the equator. We will also show several cases of MWR lightning data overlaid on JunoCam visible imagery revealing types of cloud features associated with lighting at various latitudes. Finally, we will highlight the newest polar maps of multi-spectral brightness temperature constructed from data taken in orbits where the spacecraft spin vector is oriented such that the MWR antenna beam is scanned over the polar cap.

B5.1-0010-18 CONVECTION BELOW THE CLOUDS: WHAT JUNO DIDN'T SEE

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Data from the Juno Microwave Radiometer (MWR) were made into latitude-altitude maps of ammonia abundance down at least to the 100 bar level, which is well below the water cloud base at 5-8 bars and the ammonia cloud base at 0.6-0.8 bars. There were several surprises in these maps: An ammonia-rich band extends around the planet at 0-5°N; its mixing ratio is nearly constant from 1 bar to 100 bars, although there a hint of a local maximum at 2 bars. Outside the band from 0-5°N there is a low-ammonia layer with a local minimum at 6 bars. The mixing ratio at the local minimum is about one-half that at the local maximum in the 0-5°N band. From these maps, Ingersoll et al. (2017) [Geophys. Res. Lett. 44, doi:10.1002/2017GL074277] posed three questions: How is the low-ammonia layer maintained? Why is the belt-zone structure barely evident in the ammonia distribution outside the region from 0-20°N? And how is the internal heat transported upward through the low-ammonia layer to the ammonia cloud base? Here we argue that the answers all contain ultra-fast updrafts and downdrafts that balance the ammonia budgets in the vertical. Because the velocities in the updrafts and downdrafts are much greater than those outside, they occupy much less space than the air outside and are much less visible. Without these hidden convection currents, the vertical transports of ammonia, water, and energy cannot be maintained.

B5.1-0011-18 DETECTION OF DEEP JOVIAN DYNAMICS BY THE JUNO GRAVITY EXPERIMENT

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"How deep Jupiter's zones, belts, and other features penetrate is one of the most outstanding fundamental questions in Jovian atmospheric dynamics. " - This is a key mission goal stated in the Juno Phase A Concept Study Report (2005). In this talk we report major progress in answering this question, based on radio science data from the ongoing Juno Jupiter orbiter mission. The Juno spacecraft is designed for precision measurements of Jupiter's external gravitational potential. Juno is equipped with radio links at Xand Ka-band and a special Ka-band translator system, permitting highly accurate measurement of spacecraft accelerations, which, after extensive modeling of data taken during Juno's periapse passes within a few thousand kilometers of Jupiter's cloud tops, reveal milligal gravity anomalies with good signal/noise. These anomalies are with respect to an a priori model based on classical theory for rapidly-spinning bodies in hydrostatic equilibrium. In strict hydrostatic equilibrium, the jovian external gravity potential should have axial symmetry (no tesseral harmonics apart from tidal distortions), and north-south symmetry (no odd zonal harmonics). Less than midway through the 32 orbit primary mapping mission, symmetry-breaking terms in Jupiter's multipole gravity expansion have been clearly detected by Juno, and correlate with large-scale zonal currents in the observed cloud deck. Despite the north-south extent of jovian zonal wind patterns (thousands of km) and the large surface gravity (over two thousand gal), shallow dynamics-produced gravity anomalies would be undetectable by Juno. The observed anomalies imply that the zonal currents entrain so much mass that they must have very great vertical extent (thousands of km). This is because of a characteristic of the equation of state of compressed hydrogen: its density increases roughly linearly with depth in Jupiter, smoothly transitioning from gaseous densities at the cloudtops to liquid densities as pressures approach megabars.

B5.1-0012-18 JUNO'S CHARACTERIZATION OF JUPITER'S DEEP ROTATION AND STRUCTURE

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Juno's extremely accurate mapping of Jupiter's gravity field and its detection of a north-south asymmetry enables us to characterize the depth of the atmospheric zonal flow and the state of the deeper interior. The combination of thermal wind models and interior models matching both odd and even gravitational moments shows that below about 3000km from the cloud tops, Jupiter's interior rotates nearly as a rigid body. This corresponds to the level at which the electric conductivity becomes large and magnetic drag should suppress differential rotation.

This has several consequences: Owing to its smaller mass, Saturn should have a differentially rotating at least three times more extended than that of Jupiter. Conversely, massive giant planets and brown dwarfs should have smaller differentially regions.

But most importantly, the characterization of differential rotation in the planet should enable us to fully exploit the accuracy of the gravity field determination to better constrain Jupiter's internal structure and composition.

B5.1-0013-18 FROM GALILEO TO JUNO: AN ATMOSPHERIC COMPOSITION PERSPECTIVE

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"Flyby, orbit, land" has been the guiding philosophy of NASA's planetary exploration in order to address such fundamental questions as the origin and evolution of the solar system. This led to the Galileo entry probe at Jupiter to determine the abundances of the heavy elements (mass>helium), their isotopic ratios as well as the abundance of helium, which is a tracer of the interior processes in the multi-megabar pressure region. While only the topmost clouds of ammonia ice have ever been identified spectrally [1], thermochemical models predict a multicomponent, multi-layer cloud structure extending down to 5-10 bars of pressure [2] with the clouds of ammonium hydrosulfide (or ammonium sulfide) solid, water ice and aqueous-ammonia solution lying below the ammonia cloud layer. Thus, in principle, the heavy elements can all be determined below approximately the 10-bar level, the expected region of well-mixed atmosphere. The Galileo probe met its objective of measuring the heavy elements and isotopes, except for oxygen. This was derived from the abundance of water, where bulk of Jupiter's oxygen is sequestered and was found to be sub-solar even at 22 bars, but rising. The oxygen elemental abundance is a critical missing piece of the puzzle of Jupiter's formation models, however, as water was presumably the original carrier of the heavy elements and could have made up one-half to two-thirds of Jupiter's core mass. Since Juno's arrival at Jupiter in July 2016, its microwave radiometer (MWR) instrument [3] has been carrying out observations to measure and map the composition, particularly the water and ammonia abundances, to deep atmosphere. Serendipitous data on lightning collected by the MWR have significantly extended the statistics on the known lightning in Jupiter's atmosphere [4] and support the assertion that the global water abundance in Jupiter is at least 1x solar [5], not the sub-solar value measured in the entry site of the Galileo probe. The global distribution of ammonia measured by the MWR reveals a complex structure extending to more than 100 bars, not just the comparatively shallow pressure levels sensed by the Galileo probe and the VLA, and reveals that Jupiter's well-mixed region is much deeper than 10 bars [6,7]. Like ammonia, atmospheric dynamics [8] is expected to govern the distribution of water as well, which implies that it is essential to probe much deeper than was possible before Juno in order to measure the well-mixed abundance of water, hence the oxygen elemental abundance in Jupiter. The MWR observations are in fact sensing down to several hundred bars of pressure. This talk will elaborate on the above perspectives of Jupiter's composition and how Juno has challenged our thinking of the formation of Jupiter and its atmosphere.

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B5.1-0014-18 CONSTRAINTS ON THE FORMATION OF JUPITER FROM JUNO

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Jupiter's formation in the protoplanetary disk of our solar system had a primary impact on the disk's subsequent evolution and the formation of the other planets. Jupiter must have formed early, within the first few million years when the gaseous disk was present, but how early is not understood. Thanks to its large gravitational field, Jupiter also played a primary role in the scattering of bodies up to Mars size in the inner solar system during the formation of the terrestrial planets, which occurred during and after the depletion of the nebular gas according to isotopic evidence.

The Juno mission provides clues to Jupiter's formation via several key pieces of evidence, including the global abundance of water, the size and nature of the core, and the total amount of non-hydrogen and -helium elements in the interior. In each case, the parameter value does not need to be precise to provide significant information. For example, it is useful to know whether water is above or below the protosolar value, and if the former, is it mildly (2-5 times) or grossly (exceeding 5 times) solar? A global fit of all the key measurements by Juno (total heavy-element abundance, core mass, O enrichment) along with Galileo probe data provide constraints on the physical and chemical conditions for Jupiter's formation. This includes constraining planetesimals/pebbles composition, the growth history, and discriminating among disk and nucleated instability.

Finally, comparing the enrichment of the major elements (C,O) in Jupiter (relative to the protosolar value) to the equivalent in giant exoplanets will be possible thanks to several observing programs planned for JWST. Understanding the relation between stellar and planetary heavyelement enrichments for multiple giant planets would provide an unprecedented opportunity to determine the uniqueness of Jupiter's origin.

B5.1-0015-18 JUPITER OBSERVATIONS AT INFRARED WAVELENGTHS BY JUNO

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The Jovian InfraRed Auroral Mapper (JIRAM) [1] on board the Juno [2,3] spacecraft, is equipped with an infrared camera and a spectrometer working in the spectral range 2-5 m. JIRAM was built to study the infrared aurora of Jupiter and to map the planet's atmosphere in the 5 μm spectral region. Its spectroscopic observations in the 2-5 μm range can be used for studying atmospheric dynamics, clouds and measuring the abundance of certain trace species that are important to atmospheric chemistry, microphysics and dynamics such as water, ammonia and phosphine and for the formation of the infrared aurora like the ion H3+. The instrument has operated during most of the Jupiter flybys since science mission started in August 2016 performing several observations of the of the planet from the equator to poles. Unprecedented views of the polar atmospheric structures and auroras have been observed for the first time thanks special nature of Juno's orbit. We present an overview of the most significant observations done by the instrument since the start of the mission.

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B5.1-0016-18 JUNO-UVS OBSERVATIONS OF JUPITER'S AURORA AND AIRGLOW EMISSIONS

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The Ultraviolet Spectrograph (UVS) on Juno observes Jupiter's northern and southern auroras for several hours each during every perijove pass. On each pass the 7°-long slit of UVS is used to observe the jovian aurora in a series of swaths, with one swath for each 30-s spin of the Juno spacecraft. During these perijove periods, the range of Juno to the aurora drops from 6 RJ to 0.3 RJ (or less) in the north - and then reverses this in the south - so that spatial resolution and coverage change dramatically. A scan mirror points the UVS boresight at up to 30° from the Juno spin plane to enable targeting of different features or to build up context images by rastering over the auroral region. In addition, during the time period between observations of the northern and southern auroral regions, low-latitude airglow observations are possible. Since Juno perijove altitudes are only 3500-8000 km above the cloud tops, UVS is able to study Jupiter's airglow from

within Jupiter's upper atmosphere. A variety of auroral forms and activity levels can be identified in the Juno-UVS data; some of these have been described before with HST observations, but others are new. One new result is that a large expanse of polar emissions may be excited by low-energy ionospheric electrons (and thus would be unrelated to precipitating particles). Recent results and comparisons with simultaneous Chandra observations at x-ray wavelengths will be presented here. In addition, we will also report on UVS airglow observations to date, with special attention to the Lyα emissions of atomic hydrogen.

B5.1-0017-18 JUNOCAM IMAGES OF JUPITER: SCIENCE AND ART

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The Juno mission to Jupiter carries a visible imager on its payload primarily for outreach, and also very useful for jovian atmospheric science. Lacking a formal imaging science team, members of the public have volunteered to process JunoCam images. Lightly processed and raw JunoCam data are posted on the JunoCam webpage at https://missionjuno.swri.edu/junocam/processing. Citizen scientists download these images and upload their processed contributions.

JunoCam images through broadband red, green and blue filters and a narrowband methane filter centered at 889 nm mounted directly on the detector. JunoCam is a push-frame imager with a 58 deg wide field of view covering a 1600 pixel width, and builds the second dimension of the image as the spacecraft rotates. This design enables capture of the entire pole of Jupiter in a single image at low emission angle when Juno is 1 hour from perijove

(closest approach). At perijove the wide field of view images are high-resolution while still capturing entire storms, e.g. the Great Red Spot.

Juno's unique polar orbit yields polar perspectives unavailable to earth-based observers or most previous spacecraft. The first discovery was that the familiar belt-zone structure gives way to more chaotic storms, with cyclones grouped around both the north and south poles [1, 2]. Time-lapse sequences have enabled measurement of the rotation rates and wind speeds of these circumpolar cyclones [3].

Other topics are being investigated with substantial, in many cases essential, contributions from citizen scientists. These include correlating the high resolution JunoCam images to storms and disruptions of the belts and zones tracked throughout the historical record. A phase function for Jupiter is being developed empirically to allow image brightness to be flattened from the subsolar point to the terminator. We are studying high hazes and the stratigraphy of the upper atmosphere, utilizing the methane filter, structures illuminated beyond the terminator, and clouds casting shadows. Numerous high altitude clouds have been detected and we are investigating small-scale dynamics that could be their cause.

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A. et al. (2017) Nature, in press.

B5.1-0018-18 CHARACTERIZING JUPITER'S ATMOSPHERE FROM OBSERVATIONS OF THERMAL EMISSION BY JUNO AND GROUND-BASED SUPPORTING OBSERVATIONS

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A network of Earth-based observations of the Jovian environment continues to expand and enhance the science return of the Juno mission. This report focuses on joint discoveries made using thermal-emission observations by Juno instruments: the Microwave Radiometer (MWR) and the Jupiter Infrared Auroral Mapper (JIRAM), together with supporting thermal-infrared ground-based observations made from the Infrared Telescope Facility (IRTF), the Subaru Telescope, the Very Large Telescope (VLT) and the Gemini North Telescope. These results are supported by observation of Jupiter's cloud field from the JunoCam instrument and Earth-based observations from the Hubble Space Telescope, the IRTF and the Gemini North Telescope. The thermal observations are capable of determining the spatial and temporal variability of temperatures, clouds or gaseous constituents. Examples of results include the following. Earth-based measurements of the temperature field in Jupiter's polar regions show a remarkable coincidence of the boundaries of a cold polar vortex, extending from the troposphere through the stratosphere, with the

boundaries of polar haze layers. Measurements of auroral-related stratospheric heating show that they are completely enclosed within the classical auroral oval and coincide with UV emission by particles associated with open field lines of the magnetosphere. Ground-based mid-infrared observations of the Great Red Spot (GRS) support the assertion that the variability in radiance detected by the MWR near the 0.7-bar level arises as much from variability in temperatures as from variability in the NH3 humidity. To date, we find a high but incomplete correlation of radiances associated with Jupiter's 5-μm hot spots, with no measurements to date of radiances we would expect from the extremely desiccated conditions in the Galileo probe entry site; this is most likely due to incomplete MWR resolution of the hot-spot features.

B5.1-0019-18 DEVELOPMENT OF THE JOVIAN MAGNETODISK ANALYTICAL MODELS WITH DIFFERENT DEPENDENCES OF THE CURRENT DENSITY ON THE DISTANCE FROM THE PLANET.

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A large-scale structure in the form of a thin current disk exists in the Jovian magnetosphere. This structure, called magnetodisk, or plasmadisk, is arises due to the Io plasma production and the fast Jupiter's rotation, and is located close to the dipole magnetic equator. Inside the radial distance 20RJ, plasma almost rigidly corotates with the planet. Behind this radial distance, which coincides with the Alfven radius, the Jovian magnetospheric plasma begins to lag behind the corotation due to the radial outflow, which leads to the magnetic field lines stretching. At a radial distance of 50 60RJ, the current sheet becomes non-rigid and begins to respond to changes in the solar wind conditions.

In general, the mechanism for the magnetodisk formation can be described as follows: an increased plasma density near the Io orbit leads to the interchange instability development and to the plasma radial drift from the inner magnetosphere to the outer magnetosphere. Corotation electric field, which is generated due to the daily rotation of the ionosphere, leads to the plasma acceleration in the azimuthal direction to the velocity which is close to the angular velocity of Jupiter's rotation, J. The centrifugal force acting on the plasma leads to the field lines stretching until the moment, when the tension of the field lines balances the centrifugal force. Then, beyond the Alfven radius, the kinetic energy of plasma begins to dominate over the energy of the Jovian internal magnetic field, which leads to the formation of radial expansion of the plasma in a relatively thin current disk.

We have developed and compared with observations the analytical models of the magnetodisk having different spatial scales and different dependences of the current density azimuthal component on the distance. To develop these models we have used a spherical coordinate system with Z axis, parallel to the Jovian dipole axis, polar angle ϑ and azimuthal angle ϕ, which was measured in the direction of the planetary rotation. We consider simple models of an infinitely thin current disk azimuthally symmetric with respect to the magnetic dipole axis. Magnetodisk in the models is located in the magnetic equatorial plane. Its magnetic field depends on the distances to the inner and outer edges and on two parameters, which determine the current density radial profile in the disk. We consider the linear and square dependences j 1/r and j 1/r2, and also their linear combination:

j a 1/r + b 1/r2, where a and b are coefficients, defining the total current in the disk. The current, proportional to j 1/r, is related to the interchange instability, while in the case of j 1/r2, the flux of the magnetic field of the disk BMDr 2πr2 is conserved in the northern and southern hemispheres, which corresponds to the free plasma expansion. We assumed, that the magnetodisk current has only azimuthal component jMDϕ. This assumption simplifies the development of the models, because in this case the magnetic vector-potential of the magnetodisk AMD has only one nonzero component - AMDϕ.

The radial profiles of the magnetic field latitudinal component Bϑ obtained in calculations were compared with Juno as well as Ulysses and Galileo magnetometer data.

B5.1-0020-18 RESULTS FROM JUNO'S RADIATION MONITORING INVESTIGATION

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Juno's Radiation Monitoring (RM) Investigation measures the high-energy particle environment at Jupiter by making use of noise signals from penetrating high-energy particles as an in situ observable. The implementation approach was born out of knowledge gained during the development of Juno's instruments and spacecraft which must withstand the incredibly harsh radiation environment at Jupiter. Images and housekeeping data from several of Juno's heavily shielded instruments are actively planned, retrieved, and analyzed to extract the characteristic signatures of penetrating high-energy electrons and ions during each of Juno's science orbits. Collaborative observation campaigns are performed to simultaneously collect "radiation images" and penetrating particle counts from multiple instruments in previously unexplored regions of the magnetosphere [Becker, H.N., et al. (2017), Space Sci Rev, doi: 10.1007/s11214- 017-0345-9; Becker, H.N. et al. (2017), Geophys. Res. Lett., 44, doi:10.1002/2017GL073091].

This presentation will provide a summary overview of the Investigation's key findings since Juno's arrival at Jupiter in 2016.

B5.1-0021-18 JUNO/MWR'S SUPPORTIVE OBSERVATIONS OF DOWNWARD FIELD-ALIGNED MEV ELECTRONS AT JUPITER

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Since August 2016, the Juno MicroWave Radiometer (MWR) has continuously measured the radiation emitted by Jupiter and the surrounding environment, over a frequency range from 0.6 to 22 GHz, from Juno's highly elliptical 53-day polar orbit about Jupiter. The contributors to the strongest radio signals at the shorter frequencies are the thermal, cosmic microwave background, and synchrotron emission produced by the inner electron belt. Weaker but perceptible signatures in MWR are also reported at the shortest frequency during perijove 1 (PJ1) and PJ3-PJ11. Some of them are identified as a source of synchrotron emission produced by downward field-aligned MeV electrons in the middle magnetosphere. In this paper, we present a synthesis of the spatial distributions of the microwave radiation observed at six wavelengths. We focus on synchrotron emissions originating from regions beyond Io's plasma torus that we believe to be linked to auroral activity. To support our findings, we discuss the results of a multi-instrument analysis of radio (MWR, WAVES), field (Juno magnetometer), extreme and far-ultraviolet auroral emission (Juno/UVS), plasma and energetic electron (JADE, JEDI) datasets, and background radiation signatures in Juno's ASC instrument for PJ1. Our data analysis raises the question how electrons with energies of 10's of MeV are populating, transported, and accelerated within the middle magnetosphere to become part of the auroral current circuit at Jupiter.

B5.1-0022-18 MONITORING JOVIAN SYNCHROTRON EMISSION WITH THE NASA DEEP SPACE NETWORK

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As part of Juno mission support, we monitored Jovian synchrotron emission at 2.3 GHz (13 cm) using the NASA Deep Space Network. NASA's DSN is a sensitive network of ground based radio telescopes, either 70m or 34m in diameter, dedicated to tracking spacecraft that are exploring deep space. The network telescopes are also available for use in radio astronomy. This DSN, with complexes in the USA, Australia and Spain, is capable of monitoring sources uninterrupted for an entire day. We used this unique ability to monitor Jupiter continuously for 30 hours.

Our Jupiter monitoring program is linked with the Jupiter Patrol observations currently being performed by the educational programs GAVRT, STARS, and PARTNeR, based in the USA, Australia and Spain, respectively. The DSN partially supports these education programs by providing time on the network's 34m telescopes, thereby involving students in space research and exploration. Students contribute to Juno science and the radiation environment modelling by providing the necessary microwave radiometer data, and by participating in June science lessons.

B5.1-0023-18 RETRIEVAL ACCURACY OF JOVIAN CONSTITUENT PROFILES DEVELOPED USING A NEURAL NETWORK SURROGATE APPLIED TO DATA FROM THE JUNO MWR

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The Juno Microwave Radiometer (MWR) has six channels ranging from 1.36-50 cm and has the ability to peer deep into the Jovian atmosphere. A two step retrieval algorithm has been developed using a surrogate neural network for Jovian constituent profiles using Juno MWR data. An artifical neural network algorithm is used as the surrogate for the Juno Atmospheric Microwave Radiative Transfer (JAMRT) model in this minimization. The neural network is trained by simulating emissions at the six wavelengths computed using JAMRT. By exploiting the speed of this surrogate model, retrievals for Jovian constituents profiles, such as ammonia, can be rapidly and accurately performed. Retrieved abundance profiles for the first eight perijoves during which the Juno MWR was operational will be presented. Additionally a detailed analysis of uncertainties in the retrievals will be discussed.

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B5.1-0024-18 LIMB OBSERVATIONS OF H3+ IN THE MIDAND LOW LATITUDE JOVIAN ATMOSPHERE WITH THE JIRAM SPECTROMETER

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The Jupiter Infrared Auroral Mapper (JIRAM) instrument, onboard the NASA's Juno mission, is composed of a camera in the L and M bands, and a spectrometer covering the 2-5 µm region. During the period from August 2016 to March 2017, when five mission flybys were completed, it was possible to observe with JIRAM the Jupiter's atmosphere in a very slant perspective, allowing sampling the stratosphere at different altitudes. We took advantage of H+ emissions in the 3-4 µm spectral band, observed with JIRAM in the above reported period, to retrieve the H3+ densities and temperatures, through the inversion method described in Dinelli et al. (2017), at altitudes from 200 to 700 km above the 1-bar level, and in the latitude region from 60° equatorward, in both hemispheres. Retrieved volume mixing ratios are on average higher in the Southern hemisphere than in the Northern, in accordance with previous observations in the auroral region (Adriani et al. 2017). Temperature values increase quite uniformly with altitude in both hemispheres, and are generally in agreement with temperature fields retrieved with Cassini/CIRS at 200-300 km (Sinclair et al. 2017). Finally, H3+ concentrations decrease from about 106 mol/cm3 at 200-300 km to 3x105 mol/cm3 at 600 km.

Although the coverage of analysed data does not allow investigating the H+ variability with respect to local time, the available data potentially allow to retrieve a 3-dimensional structure of the atmosphere in the 200-700 km altitude range, which has not been well addressed by previous ground-based and space observations.

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B5.1-0025-18 JUNO AND THE NEW RENAISSANCE

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There is an intangible societal need to connect with the universe. This is why the space program is so popular. Through the space program the people of the world can touch the universe, touch infinity. Spacecraft reconnaissance of our solar system continues a legacy of exploration ingrained in our psyches. As a human race, we explore. We ask, Who am I and where do I come from? In the process of this exploration the aura and soul of NASA's Juno mission to the planet Jupiter, like the Medici of the Renaissance, has inspired, facilitated and embodied a broad spectrum of human creativity, including not only science and technology, but also history and literature, art and music, and visualization and public engagement. Indeed, through Juno the world is witness to a remarkable convergence of art and science, witness to a New Renaissance. Juno is an ambassador to the universe of this New Renaissance. In my paper I will unveil Juno's intimate link to history, literature, music, art, and stunning visualization experiences, and to its public engagement program called Science in a Fishbowl. The Science in a Fishbowl program encourages public participation in processing, in often artistic ways, imaging data taken of Jupiter by JunoCam, the camera on Juno. I will show some of the best of these citizen scientist works of art. I will also assemble and describe a 3-D scale model of the orbital mission of Juno at Jupiter. The scale of the model is 1" = 2 RJ. In summary, I will unveil a dimension of the Juno mission to the planet Jupiter that will appeal to a broad sector of the global public.

B5.2-0001-18 NEW DISCOVERIES IN CASSINI'S GRAND FINALE YEAR

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The Cassini-Huygens mission ended in a science-rich blaze of glory on September 15, 2017. Covering a period of roughly ten months, the Grand Finale and Ring Grazing orbits marked the final phases of Cassini's 13-year mission, ending with the first time in-situ exploration of the region between the rings and planet. On its final orbit, Cassini plunged into Saturn's atmosphere at 126,000 km/hr (35 km/sec), vaporizing and satisfying planetary protection requirements, while sending back its final bits of unique science data.

Ring Grazing Orbits. On November 29, 2016, a single Titan flyby sent Cassini into a series of 20 highly inclined, elliptical Ring Grazing orbits with peripases just outside Saturn's main rings at distances within 10,000 km of Saturn's F ring. These orbits provided high-resolution views of Saturn's F and A rings, providing prime viewing conditions of fine scale ring structures such as propellers, and included the closest flybys of tiny ring moons.

Grand Finale Orbits. A final close flyby of Titan on April 22, 2017 propelled Cassini across Saturn's main rings. In its 22 Grand Finale orbits, the spacecraft repeatedly dove between Saturn's innermost rings and upper atmosphere to answer fundamental questions that were unattainable earlier in the mission. The Grand Finale was like a brand-new mission, exploring a region of the Saturn system that was unexplored by any previous outer planet spacecraft.

Saturn's gravitational and magnetic fields were measured to unprecedented accuracy, providing information from which constraints on the interior structure of the planet, mass distribution in the rings, and the structure of the internal magnetic field could be obtained. The Grand Finale orbits provided the highest resolution observations ever of both Saturn's C and D rings and Saturn's atmospheric weather layer. Direct in-situ sampling of the ring particle composition, upper atmosphere and the innermost radiation belts was also achieved.

Cassini's Final Orbit. During the final plunge into Saturn, Cassini became the first atmospheric probe with all of fields and particle instruments gathering data for as long as possible.

This talk will present key science findings and new mysteries gleaned from the Ring Grazing and Grand Finale orbits. The research described in this paper was carried out in part at the Jet

Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

B5.2-0002-18 HUYGENS AND TITAN'S EXPLORATION: MAIN SCIENTIFIC RESULTS

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On January 14, 2005, Huygens, the first atmospheric probe designed to explore Titan, successfully entered in its atmosphere and descended to its surface where it smoothly landed and continued working for more than three hours. The four hours of measurements done by the six scientific instruments (2 ½ hours of descent and 72 minutes on the surface), relayed to Earth via Cassini, provided a unique data set complementary to the one obtained by Cassini at Titan during its 144 flybys. The Huygens scientific payload provided in situ results concerning the atmosphere - from the exosphere to the low troposphere - of Titan, its surface and even its subsurface and internal water ocean. This paper presents some of the key scientific results obtained by the Huygens probe on Titan, their complementarity to the Cassini orbiter observations and their implications on the vision we now have of Titan, the largest satellite of Saturn.

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B5.2-0003-18 CASSINI'S GRAND FINALE GRAVITY AND RING HIGHLIGHTS

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During Cassini's Grand Finale orbits, the spacecraft repeatedly dove between the rings and Saturn, providing an unprecedented opportunity to measure the gravitational field of Saturn and its rings, and to probe the rings by radio occultations at very close range. Acquiring these observations was a remarkable feat in its own right, involving careful planning, precise navigation, and international engineering support involving NASA's Deep Space Network and the European Space Agency's ESTRACK network. This presentation will review the extraordinary scientific and engineering highlights of Cassini's Grand Finale gravity and ring experiments.

B5.2-0004-18 CASSINI UVIS TOP TEN DISCOVERIES

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Enceladus icy jets spew 200kg/sec of water, with no significant variations over the mission. The strongest jets are more variable, though.

Titan's airglow is primarily from sunlight and photoelectrons, but the weak night airglow is from magnetospheric particle impacts.

An atomic oxygen torus surrounds Saturn, peaking at its source, Enceladus.

The Europa atmosphere is dominated by atomic oxygen at low density, inconsistent with water plume activity at the time of the Cassini Jupiter flyby. The Enceladus plumes are significantly different from those found at Europa.

UVIS observations of propellers, gaps, ghosts, kittens, self-gravity wakes indicate ongoing aggregation in Saturn's rings; ring statistics, wavelet analysis, haloes, small particles show aggregation/disaggregation on an orbital time scale; we can understand this with an analogy to a predator-prey ecosystem.

UVIS and VIMS comparisons find small particles in the outer A ring, and other regions that are strongly perturbed by moon resonances.

The UV spectrum of Saturn's rings can be matched by pure water ice polluted over the age of the solar system by material having the reflectance of Comet 67P (as measured by Rosetta's Alice). Using Cassini results for the ring mass from RSS and the polluting flux from CDA, we constrain the ring age to less than about 200 million years.

A solitary wave is excited by the Janus-Epimetheus swap, when Janus moves inward every 8 years. This is evidence for non-linear dynamics, and may limit the application of previous conclusions based on a linear theory.

UVIS star and solar occultations quantify the profiles of aerosols, nitriles and organics in Titan's atmosphere; and show that Saturn's thermosphere breathes in and out. It was 'in' at the Grand Finale.

UVIS sees the auroral 'footprint' of Enceladus and also time varying arcs and spots that indicate magnetospheric variations. Bombarding charged particle radiation may explain the dark color of the polar hexagon.

B5.2-0005-18 WHAT CASSINI HAS TAUGHT US ABOUT SATURN'S RINGS

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Saturn's rings are not only among the most beautiful structures in the Solar System, but are also powerful tools that can help address a wide variety of questions in planetary science and astrophysics. Cassini's extensive observations of Saturn's rings have revealed many ring structures that can either be used to probe the rings' dynamical environment or examine processes operating in other, more remote astrophysical disks. For example, certain features in Saturn's rings appear to be generated by asymmetries and normal-mode oscillations inside Saturn itself, and so are yielding novel insights into the planet's internal structure .At the same time, objects have been found embedded within the rings whose orbits vary over time in a manner that is likely analogous to planetary migration in protoplanetary disks. More than anything, the rings illustrate just how complicated astrophysical disk systems can be. Indeed, the end of the Cassini mission revealed a surprisingly rich array of fine scale structures whose origins are just beginning to be explored, while new measurements of the ring's total mass have implications for the rings' age and origins.

B5.2-0006-18 THE DUST ENVIRONMENT OF SATURN WITHIN SATURN'S D RING: CDA RESULTS OF THE GRAND FINALE OF CASSINI

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The Grand Finale of the Cassini spacecraft with its unique proximal orbits allowed fantastic scientific discoveries between April and September 2017. Cassini crossed the ring plane 22 times at a distance which was so close, that it touched the clouds of Saturn. The Cosmic Dust Analyzer observed unexpected high densities of tiny dust grains. On the other hand, larger grains above one micrometer were found to be highly depleted. The mass distribution of the grains detected peaks well below 70 nm and is cut off by the calibrated mass threshold. The dust density varied along the trajectory with overall consistent results during different ring plane crossings. Significant number of particles were detected above the ring plane, in the ring plane and below the ring plane at latitudes between +/-45 degrees. The measured density profiles are compared with latest models of nanograins ejected by the B and C ring. This paper summarizes the current understanding of this "Ring Rain", starting at Saturn's main ring and ending in Saturn's atmosphere. Density profiles, mass distributions and early compositional variations are reported.

B5.2-0007-18 CASSINI GRAND FINALE PERIAPSE RADIO OCCULTATIONS OF SATURN'S RINGS

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Cassini's final and daring 22 orbits ("Grand Finale") provided opportunities for capturing radio occultations of Saturn's rings of unprecedented observation geometry. The closest approach period of 6 of the 22 orbits (May to July 2017) were dedicated to Cassini Radio Science observations of Saturn's gravity field and companion occultations of the main ring system, the latter are the focus of this presentation. On each of the 6 orbits and for about 26 minutes starting immediately after orbit periapse, roughly the time Cassini plunged through a "free-space" gap separating Saturn's upper atmosphere from the D Ring, three radio signals transmitted from Cassini back to Earth (0.94, 3.6, and 13 cm-wavelength) swept radially through the main ring system from the inner D Ring to well beyond the F Ring. These "periapse" ring occultations were the closest (about 0.2 to 1.5 Rs) throughout the Cassini mission lifetime and were among the fastest (about 35 to 55 km/s radial velocity). The relatively small spacecraft distance to the rings implies small Fresnel scale of diffraction and small high-gain antenna (HGA) footprint, hence high spatial resolution measurements of both the direct and forward scattered signals. The large radial velocity limits achievable SNR, however. The occultations nicely complement in geometry an optimal set of diametric ring occultations implemented near the beginning of the Cassini mission (March to August 2005). Both sets were acquired when the rings opening angle was relatively large (20 to 27°), making them especially valuable for characterizing structure and physical properties of optically thick ring regions, the B and A Rings in particular. The 12-year time separation provides an opportunity to search for potential time variability.

Particularly striking in spectrograms of the observed near-forward scattered 3.6 cm-wavelength signal (X-band) of the 6 periapse occultations is the clear signature of 100 to 200 m wavelength quasi-periodic ring structure, likely due to gravitational overstability. Acting like a giant diffraction grating that spatially modulates the background optical depth, diffraction diverts part of the incident signal power into grating lobes the strongest of

which are observed in spectra of the Earth received radio signal as modulation side-bands centered on the carrier component. The measured frequency separation from the carrier and knowledge of the occultation geometry determine the structure wavelength. The gravitational overstability structure is clearly detectable in the inner A Ring, and in regions B1 and B2 of the B Ring. It is marginally detectable in region B4. The structure was first identified in spectrograms of the 2005 diametric ring occultations (Thomson et al., GRL, Dec 2007), however, the large radial velocity of the periapse ring occultations, hence large Doppler spread, and the proximity of the spacecraft to the rings, hence large incident power per unit ring area, appear to enhance prominence of the overstability structure in the 2017 periapse ring occultations. We use the measured spectrograms to characterize variability of structure wavelength and other properties with ring radius and optical depth, and compare with the 2005 results to search for potential variability of structure properties with time. We carry out similar comparison of optical depth morphology and scattering properties of other prominent ring features of various spatial scales across the ring system.

B5.2-0008-18 CLUMPS AND HOLES IN SATURN'S RINGS FROM CASSINI UVIS STELLAR OCCULTATIONS

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Observations of star occultations by Saturn's rings with the Cassini Ultraviolet Imaging Spectrograph (UVIS) High Speed Photometer (HSP) provide direct measurements of ring structure at small spatial scales. Depending on the geometry of the occultation and star brightness, this can provide direct measurements of self-gravity wakes and viscous instabilities in the rings with spatial scales as small as 10 meters. In addition to this direct measurement of clumps and gaps in the rings, the occultation data provide additional insights into the small-scale structure of the rings through higher-order moments of the time series of the observed stellar signal through the rings. The variance of the data can be related to the probability that two independent measurements of light passing through the rings are correlated, which in turn depends on the size of a shadow cast by ring particles. Larger shadows, due to larger individual particles or to agglomerations or overlapping ring particle shadows, results in a larger, or excess, variance in the occultation data than would be observed if the ring particle sizes were vanishingly small. The excess variance thus provides a measure of the largest clumps or particles in the rings. This measure varies widely across the ring system, sometimes with abrupt transitions at ring boundaries, and other times varies quite gradually even over large gradients in ring optical depth. The next higher moment of the data, the skewness, provides additional information that can help identify whether the rings are punctuated by large clumps or large holes in the spatial distribution of particles. This measure also shows that different ring regions have different clumping characteristics, something that is also seen in the highest resolution images of the rings. We will explore the distribution and properties of ring clumps and holes throughout the ring system as revealed from Cassini UVIS occultation observations and discuss implications for ring dynamics and evolution.

B5.2-0009-18 RINGAND MOON-ASSOCIATED ENERGETIC PARTICLE DROPOUTS OBSERVED BY MIMI-LEMMS DURING CASSINI'S RING-GRAZING ORBITS

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During December 2016-April 2017, the Cassini spacecraft performed 19 orbits with periapses just outside Saturn's main rings. These ring plane crossings allowed magnetic field lines threading the outer regions of the main ring system to be sampled close to the equatorial plane. Trapped energetic particles have been previously shown to provide valuable information on the presence of moons, rings, and incomplete ring arcs that complements the data provided by remote sensing instruments. We report on observations of this region by the LEMMS sensor of Cassini's Magnetospheric Imaging System, MIMI. We concentrate on results relevant to the region surrounding the moons Janus and Epimetheus at 2.4 to 2.8 Saturn radii from the planet's centre. We present the inferences that can be drawn about this region from absorption signatures due to those moons plus the ring material that orbits near to them, slightly complicated by the northward offset of Saturn's magnetic equator.

B5.2-0010-18 CIRS HIGH-RESOLUTION THERMAL SCANS AND THE STRUCTURE OF SATURN'S B RING

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Cassini's 126th flyby of Titan on 29 November 2016, sent the spacecraft on a trajectory that would take it within 10,000 kilometers of Saturn's F ring before a subsequent encounter on 22 April 2017 would send it on ballistic trajectory carrying it between Saturn's cloud tops and the planet's D ring. This geometry has proven very beneficial for high-resolution studies of the rings, not just because of Cassini's proximity to the rings, but also because of the spacecraft's high elevation angle above the rings, which reduces the foreshortening that tends to degrade resolution in the ring plane.

We will report on several observations made by Cassini's Composite Infrared Spectrometer of Saturn's main rings at the high spatial resolutions enabled by the end-of-mission geometry, particulary the B ring, during the F-ring and proximal orbits. CIRS' three infrared detectors cover a combined spectral range of 10 to 1400 cm−1 (1 mm down to 7 μm). We focus on data from Focal Plane 1, which covers the 10 to 600 cm−1 range (1 mm to 16 μm). The apodized spectral resolution of the instrument can be varied from 15 to 0.5 cm−1 (Flasar et al. 2004). FP1's wavelength range makes it well-suited to sensing thermal emission from objects at temperatures typical of Saturn's rings.

Correlating temperatures retrieved from scans of that face of the rings exposed to direct solar illumination (the lit face) and the opposite (unlit) face with ring optical depth suggests differences in ring structure or particle transport between the lit and unlit rings in different regions of the B ring. We find that the temperature differential between the lit and unlit faces of the rings varies from 2-3 K in the most optically thin sections of the B ring's B1 region (ring radii of 92,000-99,000 km) up to 20 K in the optically thick portions of the B2 region of the B ring (ring radii of 99,000-104,500

km). Moreover, temperatures on the unlit side of the B ring's B3 region vary (ring radii of 104,500-110,000 km) by 5-6 K and are correlated with slight optical depth variations. There are no such correlated temperature variations on the lit side of the B3 region for reasons that are not yet clear. Ferrari et al. (2013) and Pilorz et al. (2015) published thorough analyses of the thermal throughput across this optically thick ring. We will discuss these recent CIRS rings observations and their implications in the context of such work. (B ring region definitions are taken from Colwell et al. (2009).)

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with NASA.

B5.2-0011-18 SCIENCE HIGHLIGHTS FROM THE CASSINI MAGNETOMETER INSTRUMENT

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Highlights from the Cassini magnetic field observations made during the orbital tour at the Saturn system will be described. These discoveries encompass topics including the magnetosphere and its aurora, Saturn's internal dynamo magnetic field, the icy satellites of Saturn (and Enceladus in particular), as well as the large moon Titan.

B5.2-0012-18 MAGNETOSPHERIC HIGHLIGHTS FROM CASSINI

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The Cassini spacecraft entered Saturn orbit in 2004 and for many particles-and-field sensors made nearly continuous measurements until 2017. In this talk, we will describe some of the highlights of magnetospheric discoveries made by Cassini. The talk will be organized by advances in our knowledge of structure: such as radiation belts, boundaries, corotating plasma, high latitude regions, warped current sheet, and tail, and of dynamics: such as periodicities, largeand small-scale injections, and pulsations. Other subjects that received considerable attention by the MAPS community were Saturn's ionosphere and aurora, interactions between magnetospheric populations and rings, moons, and neutrals, interactions of Saturn's magnetosphere with the highly variable solar wind, the Enceladus source and its consequences, the interaction with Titan, the effects of solar cycle and seasons and coordination with remote studies.

B5.2-0013-18 INSIGHTS INTO COUPLING BETWEEN SATURN AND ITS MAGNETOSPHERE FROM RADIO AND PLASMA WAVE OBSERVATIONS DURING CASSINI'S GRAND FINALE

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In its Grand Finale phase, Cassini traversed a region of the Saturnian system not explored in the preceding 12 years in orbit. These high inclination, highly eccentric orbits took Cassini through the source regions of Saturn kilometric radiation (SKR) on auroral magnetic field lines, across field lines that tie the planet to its magnetosphere, the ring system, and through the topside ionosphere near the sub-solar equator just below the ring system. The Radio and Plasma Wave Science (RPWS) instrument studied the conditions in the SKR source region that had only been traversed twice in the entire preceding mission. Near 5 kHz intense narrowband emissions are observed in the Z mode at latitudes above about 10°. Plasma wave phenomena known as VLF saucers were observed on field lines threading both Enceladus and the ring system, providing evidence of electron beams and quite possibly currents connecting these members of the Saturnian system to the planet. The RPWS found only very small numbers of micronsized dust grains in the region between the rings and the atmosphere. Perhaps some of the most important measurements were of plasma densities and temperatures in Saturn's equatorial topside ionosphere, providing important information for understanding how the ring system and the ionosphere interact. These observations revealed small-scale structures in the ionospheric densities and large-scale asymmetries associated with ring shadowing. The ionosphere revealed a new plasma wave phenomenon apparently driven by a lower hybrid instability. This paper will summarize evidence of coupling between Saturn, the rings, and the more distant magnetosphere afforded by Cassini's Grand Finale orbits.

B5.2-0014-18 THE LOW FREQUENCY SOURCE OF SATURN'S KILOMETRIC RADIATION

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Understanding the generation of planetary auroral radio emissions, the powerful non-thermal radiations produced by all the magnetized planets explored so far, and actively searched from exoplanets and more massive objects, requires in situ measurements from within their source region. During the ring-grazing high-inclination orbits spanning late 2016 to early 2017, the Cassini spacecraft sampled at three occasions the top of Saturn's Kilometric Radiation (SKR) emission region, whose intensifications have long been used as a sensitive proxy of large-scale magnetospheric dynamics. The narrow-banded radio sources were crossed at frequencies of 10-20 kHz, all in the northern dawn-side sector. They hosted extraordinary mode emission, radiated quasi-perpendicularly to the local magnetic field from 6-12 keV electron-beams consistent with the Cyclotron Master Instability and embedded within regions of upward currents themselves coincident with the main auroral oval. Overall, the SKR low frequency sources appear to be strongly controlled by time-variable electron densities.

B5.2-0015-18 SURPRISES FROM SATURN: CAPS ELS RESULTS ON MAGNETOSPHERE, MOONS AND RINGS

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The Cassini mission at Saturn has provided many surprises on Saturn's rapidly rotating magnetosphere and its interaction with the diverse moons, as well as its interaction with the solar wind. One of the early discoveries was the water-rich composition of the magnetosphere. Its structure and dynamics indicate remarkable injections, periodicities and interchange events. Enceladus, orbiting at 4 Rs, was found to have plumes of water vapour and ice which are the dominant source for the inner magnetosphere. Charged water clusters, charged dust and photoelectrons provide key populations in the 'dusty plasma' seen here, as well as chemical complexity in the plume material. Direct pickup is seen near Enceladus and field aligned currents create a spot in Saturn's aurora. At Titan, orbiting at 20 Rs, one of the significant surprises of the mission was heavy negative and positive ions seen in the ionosphere, as well as neutrals, all of which have surprising chemical complexity. These provide the source for Titan's haze. Ionospheric plasma is seen in Titan's tail, enabling ion escape to be estimated at 7 tonnes per day. Saturn's ring ionosphere was seen early in the mission, which was oxygen rich and produced photoelectrons. At Rhea, pickup positive and negative ions indicated weak atmospheres sustained by energetic particle impact, seen in the neutrals also. A weak atmosphere was also seen at Dione. The exosphere production process operates at Jupiter's moons also. At Hyperion, surface charging was seen on a body beyond our Moon for the first time. Here we review some of the key results from CAPS, concentrating on key ELS contributions, and discuss the implications for other solar system contexts.

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B5.2-0016-18 THE SURPRISING GRAVITY FIELD OF SATURN

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During six of the 22 Grand Finale orbits, Cassini acquired Doppler data for the determination of the gravity field of the gas giant. In addition, the unique geometry of the last phase of the mission, when the spacecraft flew between the planet and its rings, broke the correlation between the weak gravitational signal from the rings and Saturn's even zonal harmonics, thus enabling a dynamical determination of their mass.

The gravity field measurements were carried out by establishing two-way radio links with NASA's and ESA's ground antennas at X-band (7.2-8.4 GHz). The tracking of Cassini was established continuously for 24-36 hours around the closest approach. The analysis revealed that Saturn's gravity deviates significantly from earlier theoretical expectations and requires a strong differential rotation extending deep into the planet.

In addition, Cassini revealed an unexpected component of Saturn's gravity, possibly ascribable to a time-varying field. The physical phenomena that could provide such a time-variable field include axially asymmetric deep flows and oscillation modes of the entire planet. Some of these modes have already been observed through the analysis of the perturbations induced on Saturn's rings. We discuss the magnitude of the unexplained accelerations and relate them to possible geophysical sources.

B5.2-0017-18 INSIGHTS INTO TITAN'S ATMOSPHERE AND SURFACE AT THE END OF THE CASSINI MISSION

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Titan observations during the F-Ring and Proximal Orbits that brought the Cassini mission to a close provided key insights into this enigmatic moon. Here we highlight observations of the surface and atmosphere and interpretations and implications thereof for understanding Titan as a system.

Cassini ISS and VIMS documented seasonal cloud distributions, morphologies, behavior, and altitudes from late southern summer in 2004 through early northern summer in 2017 (e.g., Corlies et al. 2017; Kelland et al. 2017; Rodriguez et al. 2011; Turtle et al. 2011). Atmospheric circulation models predicted cloud activity would increase at high northern latitudes as early as 2010 as northern summer approached (e.g., Schneider et al. 2012), similar to activity at high southern latitudes upon Cassini's arrival. Elongated cloud streaks began to appear frequently at 55°N in 2016, and small clouds appeared 15-40°N, a few years later than predictions. However, only small isolated cells were observed near Titan's North Pole through the end of the mission in 2017. The stronger preference for clouds at midrather than high-northern latitudes is consistent with recent models that include polar wetland methane reservoirs

beyond concentrations in the maria (Faulk et al. 2017; Mitchell Lora 2016; Lora et al. 2015), suggesting that a broader subsurface polar methane table is accessible to the atmosphere.

A surprise in 2016-2017 north-polar observations was VIMS detection at 2.1 µm of apparent cloud features that were not seen at 2.0 or 5.0 µm or by ISS at 0.94 µm (Turtle et al. 2016), spectral characteristics that differ from typical clouds and are currently unexplained.

Cassini's final observations of Titan's surface also brought important insights and completed ISS and VIMS maps. Photometric analysis of the entire ISS equatorial (±30°) dataset has improved the signal-to-noise ratio by a factor of 4-5, along with the effective resolution, and produced calibrated surface albedos (Karkoschka et al. 2011). VIMS' global-scale hyperspectral mosaic is empirically corrected for the atmospheric contribution and improves coverage and resolution of the northern lake district (Le Mouélic et al. 2018). RADAR observations of high northern latitudes on Cassini's final close flyby of Titan provided altimetry and bathymetry measurements of Titan's lakes, constraining depths to be >100 m (Mastrogiuseppe et al. 2017) and demonstrating that lakes are hydrologically connected but perched hundreds of meters higher than the equipotential surface of the maria (Hayes et al. 2017). SAR observations of Ligeia Mare did not detect the transient "magic islands" observed previously, leaving the most likely explanation to be waves, bubbles, or floating or suspended solids (Hofgartner et al. 2017). Comparison of all three datasets suggests shallow ponds may have desiccated during the Cassini mission (MacKenzie et al. 2018).

Our understanding of Titan has been completely revolutionized by Cassini-Huygens, nevertheless, there remain many unanswered questions about the surface and atmosphere (Nixon et al. 2018).

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B5.2-0018-18 TITAN'S ATMOSPHERE EVOLUTION DURING THE CASSINI MISSION AND COMPARISON WITH THE VOYAGER DATA

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We have monitored Titan's seasonal evolution in the neutral atmosphere, during the CassiniHuygens mission. We present here an analysis of nadir spectra acquired by Cassini/CIRS (Jennings et al., 2017, App. Opt. 56, 5274) at high resolution in the past years and describe the temperature and composition variations. During the first years of the mission, Titan's stratosphere was still enhanced in the North. The equatorial and mid-latitudes do not show a lot of variation. In 2010, we have returned to the same season as for the Voyager 1 encounter with Titan in 1980. We will discuss the data comparison between CIRS and V1/IRIS. Since 2010, with CIRS, we have observed at Titan's south pole a strong temperature decrease and the onset of a strong enhancement of several trace species such as complex hydrocarbons and nitriles (Coustenis et al. 2016,Icarus 270, 409 and references therein). This is due to the transition of Titan's seasons from northern winter in 2002 to summer in 2017 and the advent of winter in the south pole. During this transition period species with longer chemical lifetimes linger in the north undergoing slow photochemical destruction, while those with shorter lifetimes decrease and reappear in the south. An opposite effect was expected in the north, but was not observed until recently. From 2013 until 2016, the northern temperature increased by 10 K, while the south has shown a more significant decrease (up to 25 K). While the south polar region is continuously enhanced since about 2012, the chemical content in the north is finally showing a clear depletion for most molecules only since 2015 (Coustenis et al., 2018, submitted). This can set constraints on photochemical and GCM models.

B5.2-0019-18 A POST-CASSINI VIEW OF TITAN'S METHANE-BASED HYDROLOGIC CYCLE

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The methane-based hydrologic cycle on Saturn's largest moon, Titan, is an extreme analog to Earth's water cycle. Titan is the only planetary body in the solar system, other than Earth, that is known to have an active hydrologic cycle. With a surface pressure of 1.5 bar and temperatures of 90-95 K, methane and ethane condense out of a nitrogen-based atmosphere and flow as liquids on moon's surface. Exchange processes between atmospheric, surface, and subsurface reservoirs produce methane and ethane cloud systems, as well as erosional and depositional landscapes that have strikingly similar forms to their terrestrial counterparts. Over its thirteen-year exploration of the Saturn system, the Cassini-Huygens mission revealed that Titan's hydrocarbon-based hydrology is driven by nested methane cycles that operate over a range of timescales, including geologic, orbital (e.g., Croll-Milankovitch cycles), seasonal, and that of a single convective storm. We will review the discoveries made by the CassiniHuygens mission, including several new findings derived from Cassini's final flyby of Titan, and present a post-Cassini view of Titan's methane-based hydrologic system, describing the dominant exchange processes that operate over season, orbital, and geologic timescales.

Titan's methane-based hydrologic cycle is a complex, diverse, and multifaceted system that is both similar to and distinct from Earth's water-based hydrologic cycle. A fast physical (phasechange) cycle drives active weather and fluvial processes over seasonal to orbital timescales, a medium-paced chemical cycle siphons off methane for photochemical synthesis, depositing the products on the surface, over timescales of millions of years, while a geologic cycle may sporadically inject methane into the system from Titan's interior over the age of the solar system. Although the Cassini mission's exploration of Titan's methane cycles has ended, ground-based observations can continue to monitor Titan's weather until future missions map fluvial features at a higher resolution and characterize the composition of surface material (including the lakes and seas) through in-situ exploration.

Understanding Titan's methane-based hydrologic system also provides us with a potential window into Earth's distant future and, despite being based on methane as opposed to water, is a useful analog for understaning the climate evolution of the terrestrial planets in general. Titan's methane is essentially free to diffuse into the stratosphere where it is either photolyzed or escapes the atmosphere. This is in contrast to the Earth's modern water cycle, in which the very cold tropopause traps water vapor and limits diffusion into the stratosphere. As the Sun's luminosity increases over the next billion years or so, however, the final state of Earth's hydrologic cycle might resemble the current state of Titan's in that Earth's ocean would be largely gone with only some polar water remaining.

B5.2-0020-18 COMPOSITION AND DEPTHS OF TITAN HYDROCARBONS LAKES REVEALED BY THE CASSINI RADAR ALTIMETER

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During the last fly-by of Titan (April 22, 2017) Cassini made a unique observation of the Northern polar terrains in an area rich of small - medium size (10 - 50 km) hydrocarbon lakes previously imaged by the Cassini RADAR. A dedicated processing procedure previously applied to altimetric data acquired over Ligeia Mare where the radar revealed the bathymetry and composition of the sea is exploited to demonstrate that these liquid bodies can exceed one-hundred meters of depth. We present detailed investigation of their depth and liquid composition. The analysis of the backscattering shows that all the observed lakes have similar composition to each other and Ligeia Mare, being methane dominated.

B5.2-0021-18 A COMPLETE ANALYSIS OF TITAN'S CLOUDS AS OBSERVED BY CASSINI VIMS

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Saturn's largest moon, Titan, possesses a thick atmosphere composed of nitrogen and methane and is the only other place in the solar system to have an active hydrologic cycle. As one of the few direct observables of this cycle, clouds have long been monitored, both with Cassini and from Earth, however, only a small number of these systems have been modelled in detail.

We present a complete analysis of the characteristics of 150+ clouds observed on Titan with the Visual and Infrared Mapping Spectrometer (VIMS) aboard the Cassini-Huygens spacecraft. Understanding the location, frequency, and characteristics of clouds can place important constraints on general circulation models (GCMs), inform about the transport of volatile material in Titan's atmosphere, and provide glimpses into the nature of atmosphere/surface interactions on Titan. We find that clouds generally reside at 5-25 km in altitude, which is in agreement with altitudes expected from convective formation. Cloud optical depths are found to follow an exponential distribution, suggesting that the strongest storms are rare. We find no significant dependence of cloud properties on either location or season, suggesting a universal formation mechanism for clouds on Titan. Assuming convective formation, cloud altitude can provide constraints on the convective available potential energy (CAPE) necessary for formation, which can then place constraints on local surface humidity. Furthermore, combining the sizes and optical depths allows for estimates of the mass (and therefore volatile content) in the cloud. Together these estimates place constraints on the intensity of storms on Titan and can inform the likelihood of precipitation, which in turn influences the surface as well as the local dynamics that drive the cloud formation.

Although clouds have long been observed, to date, only few clouds have been modelled in detail. We employ here a radiative transfer code developed to model Titan's atmosphere, PyDISORT, built around the discrete ordinates method (DISORT), which allows for fast atmospheric retrievals. Clouds are modelled by inserting an additional atmospheric layer into the model. To simulate self-consistent scattering properties, Mie scattering is used to determine the phase function, single scattering albedo, and optical depth for the cloud layer. Free parameters include the optical depth assigned at a reference wavelength (typically 2.0 m) and altitude at which the layer is inserted. The drop size distribution is modelled using a log-normal distribution with an average drop radius of 100 m. We employ a combination of systematic and gradient-minimization search algorithms to quickly and accurately find the best-fit parameters for each cloud.

The analysis here can be tied to and constrain models at both mesoscales and global scales. Multiple observations of cloud systems allow for the evolution to be monitored, which can place further constraints on the mechanisms that influence cloud formation (e.g. surface interactions, winds, etc.) in mesoscale models. Comparison of the modelled clouds (e.g. location, frequency, and characteristic) throughout the datasets can also place valuable constraints on GCMs such as local humidity, wind profiles, and the net transport of volatile material in Titan's atmosphere.

B5.2-0022-18 TITAN CLOUDS OBSERVABLE ONLY IN THE NEAR-INFRARED

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In Cassini's fourteen-year mission, several rare clouds were observed in Titan's methane and nitrogen atmosphere that bring new insights to both the chemistry of Titan's atmospheric circulation and the radiation balance through its thick troposphere. These clouds in Titan's atmosphere were detected by Cassini's Visible and Infrared Imaging Spectrometer (VIMS) but not in its Imaging Subsystem (ISS). Closer analysis shows that these clouds are novel for both their atmospheric properties and for constraining the particular observational synergy between VIMS and ISS. This study constrains these clouds to high altitudes and low opacities where Cassini's instruments can detect them only in the near-infrared.

Designated "Now You See Them, Now You Don't" clouds (NYSTNYD), these clouds appear in the near-infrared methane bands at 1.6, 2.1, 2.8, and 4.9 microns while they are absent in ISS's photometric bands between 0.8 and 1.0 microns. This is not typical for the clouds on Titan observed thus far. These discrepancies between Cassini instruments are opportunities to explore the particular cloud properties and viewing geometries that lead to clouds observable only in the near-infrared. We implement a detailed signal-to-noise model in combination with a radiative transfer model to constrain the cloud opacities and altitudes at which a cloud is observable in either VIMS or ISS but not the other.

In this study, we fit the NYSTNYD cloud properties and model the signal-to-noise ratio (SNR) for the cloud detection that the VIMS and ISS instruments would observe. We fit the VIMS spectra using a chi-squared minimization in an opacity-altitude parameter space generated by libRadtran's DISORT radiative transfer model (Mate, et al. 2016, Icarus). After we constrain the haze, opacity, chemical abundances, and altitude for the NYSTNYD clouds in their particular viewing geometry, we find the sigma of detection for these clouds at various altitudes and thicknesses. The discernable parameter space detectable for both VIMS and ISS wavelengths is quantized and compared to show relative blind-spots in ISS's photometry bands given the modeled cloud spectra. These results have implications for future missions to Titan where it will be crucial to optimize the wavelengths of photometry cameras and spectrometers to resolve the fine structure of Titan's atmosphere.

B5.2-0023-18 THE WEIRD AND WONDERFUL ICY MOONS OF SATURN

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Everyone who contributed to the success of Cassini

From the moment it arrived in the Saturn system Cassini began to reveal the wonder of Saturn's moons, and the results are both numerous and astonishing. The answer to the long held question as to whether Enceladus is active was spectacularly answered by observations of plumes erupting into space and high heat flow on its surface. While in contrast evidence is mounting against the long-held belief that Dione is active too. Although there is evidence to suggest both Dione and Mimas, like Enceladus, might have oceans deep beneath their surface.

Evidence for ancient rings was discovered on the surface of Iapetus (in the form of a 20-km high equatorial ridge), and perhaps on Rhea too (blueish markings along high promontories along Rhea's equator). Images of Iapetus brought its color dichotomy into sharp focus, and the composition of its dark material (and that on Phoebe) was discovered to be a mixture of hydrated iron oxides and space weathered nano-metallic iron mixed with crystalline water ice. Strange surface colorations were found on Tethys, in the form of still unexplained redstreaks that appear to cut across a multitude of geological features. "PacMan" color and thermal anomalies were discovered on Mimas and Tethys, while contrary Dione showed hints at a similar anomaly but only in the thermal analysis. The cause of the "PacMan" anomalies is believed to be surface alteration by high-energy elections, which preferentially bombard the anomalous regions.

Cassini's final gift to us was a chance to observe Saturn's ring moons (some of which were only discovered using Cassini images earlier in its mission) in unprecedented detail. The images showed they were not to be outdone by their larger neighbors, and that these small icy moons were intriguing too! Their densities are all low enough to be consistent with the accretion of ring particles, but their appearances vary wildly. Some appear smooth with seemingly gravity-defying "aprons" around their equator, while others appear more rounded and heavily cratered. Coloration variations were also observed, particularly between 0.35 and 0.55 microns, probably due to differences in the relative amounts of surface contamination from the reddish chromophore (from the ring system itself) and the bright icy E-ring grains. Measurements of the radiation environment of these moons also had some surprises; they showed that some moons have times in their orbit where surface bombardment by energetic electrons actually ceases.

We will discuss the details, context and implications of these results from Cassini, and more!

B5.2-0024-18 THE SEARCH FOR ACTIVITY ON DIONE AND TETHYS WITH THE CASSINI VISIBLE INFRARED MAPPING SPECTROMETER (VIMS)

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One of the major open questions towards the end of the Cassini mission was whether there was any type of residual geologic activity on Dione or Tethys. The discovery of intriguing red streaks on Tethys, which seemed to be painted onto its surface (Schenk et al., 2015) suggested some sort of recent or ongoing outgassing. But the bulk of the remaining mission resources was focused on Dione, because of the number of hints at low-level activity on this moon coming from a variety of instruments. Burch et al. (2007) found evidence for the injection of plasma streams into the Saturnian magnetosphere from both Tethys and Dione. Khurana et al. (2007) presented magnetometer data that were consistent with a mass loading of 0.72 kg/s neutrals from Dione, about 0.3% of that from Enceladus; this amount could not be explained by sputtering from the surface alone. Three of the five targeted flybys of Dione were devoted to gravity analysis, and two independent teams inferred a subsurface ocean (Beuthe et al., 2016; Hemingway et al., 2016). Another significant result was the detection in December of 2004 of an atmospherelike aura surrounding Dione that was detected by VIMS (Clark et al., 2008) and by CAPS in October 2005 (Simon et al., 2011). Also compelling is the existence of possible cyrovolcanic features on Dione surrounding by regions that appear to be volcanic deposits. Finally, fossilized "tiger stripes" appear to crisscross parts of the moon.

Because no clear evidence of activity was detected during the mission, in spite of these several lines of evidence for it, time was devoted during the F-ring and Proximal orbits in the last year of the mission to obtain high-phase observations of Dione, during which any plume, jet, or atmosphere on the moon would be emphasized in forward-scattered radiation. We overview the results of these observations from the VIMS measurements, as well as a close inspection of

VIMS images of Dione to search for the reappearance of a transient atmosphere similar to the one observed in 2004.

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P. et al., 2015, EOS (abst.), P21B-02. Simon, S. 2011. Geophys. Res. Lett. 38, CiteID L15102. Government funding acknowledged.

B5.2-0025-18 THE SEASONAL EVOLUTION OF TITAN'S STRATOSPHERIC ICE CLOUDS AS OBSERVED BY CASSINI CIRS

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Over the course of Cassini's 13-year mission, the Composite InfraRed Spectrometer (CIRS) observed numerous ice clouds in Titan's stratosphere. This includes the v6 band of HC3N near 506 cm−1 [Anderson et. al. (2010) Icarus, 207, 914-922], as well as the v8 band of C4N2 at 478 cm−1, in which solid-state photochemistry was invoked as a plausible formation mechanism

[Anderson et. al. (2016) Geophys. Res. Lett., 43, 3088-3094]. CIRS also observed geometrically thin ice clouds spanning latitudes 85°N to 60°S during northern winter, which we call the 160 cm−1 ice clouds, with broad spectral dependences peaking at 160 cm−1 [Anderson and

Samuelson (2011) Icarus, 212, 762-778]. Laboratory experiments indicate that these ice clouds are spectrally compatible with co-condensed mixtures of HCN and HC3N. As Titan transitioned into northern spring/southern fall, these ice clouds vanished, and eventually, a massive cloud system developed in Titan's mid stratosphere at high southern latitudes. This is the ice cloud we have named the High-Altitude South Polar (HASP) cloud, which is at least an order of magnitude more intense than the 160 cm−1 ice cloud system, with a different spectral signature.

Laboratory experiments show the HASP cloud is spectrally compatible with an HCN-C6H6 cocondensed ice mixture.

CIRS also observed a spectrally broad and intense unidentified emission feature in Titan's stratosphere that spectrally peaks at 221 cm−1, which we call the Haystack. The Haystack was observed to persevere during northern winter at latitudes poleward of 50°N, with diminishing emission at high northern latitudes as Titan transitioned out of northern winter. During Titan's mid southern fall season, CIRS then observed the Haystack's reappearance at high southern polar latitudes [Jennngs et. al. (2012), ApJ Letters, 761:L15].

In this presentation, we will review the numerous time varying physical and chemical characteristics of Titan's CIRS-observed stratospheric ice clouds. A companion paper (21314) by

Nna-Mvondo et al. will detail our dedicated laboratory efforts to identify their chemical compositions, structural characteristics, and formation mechanisms.

B5.2-0026-18 THE ENIGMATIC CIRS-OBSERVED TITAN'S STRATOSPHERIC ICE CLOUDS STUDIED IN THE LABORATORY

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Stratospheric ice clouds have been repeatedly observed in Titan's atmosphere by the Cassini Composite InfraRed Spectrometer (CIRS) since the Cassini spacecraft entered into orbit around Saturn in 2004. Most of these stratospheric ice clouds form as a result of vapor condensation processes, composed of a combination of pure and mixed nitriles and hydrocarbons. So far, the crystalline cyanoacetylene (HC3N) v6 band at 506 cm−1 (Anderson et al., 2010) and a co-condensed nitrile ice feature at 160 cm−1, dominated by a mixture of HCN and HC3N ices

(Anderson and Samuelson, 2011), have been identified in the CIRS limb spectra. However, the presence of other CIRS-observed stratospheric ice emission features, such as the v8 band of dicyanoacetylene (C4N2) at 478 cm−1 and the unidentified Haystack emission feature at 220 cm−1, are puzzling since they have no associated observed vapor emission features. As well, recently, a massive stratospheric ice cloud system, called the High-Altitude South Polar (HASP) cloud, was discovered in Titan's early southern winter stratosphere at high southern latitudes, with an emission feature peaking near 210 cm−1 (Anderson et al., 2017). We are investigating in laboratory these perplexing observed stratospheric ices to better understand their formation mechanisms, identify their chemical compositions, and determine their optical properties. We have performed transmission spectroscopy of thin films of pure and mixed nitrile ices, as well as -CN ices combined with benzene, from the nearto far-infrared spectral region (50 cm−1 to 11700 cm−1), using the SPECTRAL high-vacuum chamber. Their respective vapors were deposited at low temperatures from 30 K to 150 K and the resulting ices were analyzed at different times after deposition, from immediately after dosing to up to 24 hours post-dosing. Their spectral evolution with time and temperature were studied, the ice phase formation identified, and their optical constants computed. The first surprising yet significant result reveals that the libration mode of HCN (166 - 169 cm−1) is drastically altered by the surrounding molecules when mixing occurs in a co-condensed phase. For propionitrile ice, we observe peculiar temperature and time-driven ice phase transitions, revealed by significant spectral changes in the midand far-IR until a stable crystalline phase is achieved. Comparing our laboratory spectra to the CIRS data, we found that a HCN-C6H6 mixed ice is a good match for the HASP cloud emission feature. We present a summary of our findings obtained so far.

B5.2-0027-18 THE GEOMORPHOLOGY AND COMPOSITION OF TITAN'S SURFACE: COMBINING THE SPATIAL INFORMATION OF CASSINI RADAR WITH THE SPECTRAL INFORMATION OF CASSINI VIMS

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Operating from 2004 to 2017, the Cassini-Huygens mission acquired compositional information and high resolution images of the surface of Saturn's largest moon, Titan, by using the Visual and Infrared Mapping Spectrometer (VIMS) and RADAR instrument. VIMS took more than 36,000 spectral cubes of Titan at 16nm resolution from 0.9 to 5 microns, though it mapped

<5% of the surface at spatial scales > 5km. RADAR mapped 45% of Titan at a resolution of 350m and 75% at 2km or below, though only at a single wavelength (2.1cm) and with low temporal cadence. In this work, we combine the spatial information from the Cassini RADAR with the spectral information and temporal coverage of VIMS to investigate the correlation between geomorphologic and compositional signatures on Titan. We do this by clustering atmospherically corrected VIMS data [1] into RADAR defined geomorphologic units [2-4] and statistically determining the degree of compositional separability [5,6] of the same processed defined units. By utilizing the entire VIMS data regardless of resolution and collecting them into physically significant groups, we achieve global compositional coverage of Titan with a high temporal cadence to examine ongoing processes on Titan's surface. Using this methodology, we investigated whether the same geomorphologic units defined in the northern and southern polar terrain showed similar degrees of compositional separability regardless of hemisphere. Atmospheric haze formed

through photolysis, will sediment out of Titan's atmosphere and accumulate unless washed into drainage basin by rain or swept into dunes by wind [7,8]. In older, drier areas the depth of the deposited hazes could become substantially optically thick in the IR. Therefore, we searched for morphologic units which show separation in one hemisphere but not in the other which may be caused by an optically thick layer of deposited haze which transcends morphologic boundaries. We connect our findings with the conclusion of Birch 2017 that the north and the south were formed through similar process, but that the paucity of fluvial features and the abundance of mountainous features in the south compared to the north is explained by pole-to-pole fluid transport which follows Titan's 100,000-year apsidal precession [2,9,10].

Corlies et al., 2017 Determining Titan's Cloud Altitude and Opacity in The Cassini Vims.

Birch et al., 2017 Geomorphologic mapping of titan's polar terrains: Constraining surface.

Lopes et al., 2016 Nature, distribution, and origin of Titan's Undifferentiated Plains [4] Malaska et al., 2016 Geomorphological Map of the Afekan Crater Region, Titan: Terrain.

[5] Kruse et al., 1993 The spectral image processing system (SIPS) interactive visualization and. [6] Rousseeuw 1987 Silhouettes: A graphical aid to the interpretation and validation of cluster. [7] Lorenz et al., 2006 The sand seas of Titan: Cassini RADAR observations of longitudinal dunes [8] Atreya et al., 2006 Titan's methane cycle [9] Aharonson et al., 2009 An asymmetric distribution of lakes on Titan as a possible. [10] Lora et al., 2015 Simulations of Titan's paleoclimate

B5.2-0028-18 ASTROBIOLOGY OF TITAN & ENCELADUS: OBSERVATIONS, SIMULATION EXPERIMENTS AND SPECULATIONS

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The Cassini-Huygens mission has unveiled many new aspects of Titan confirming the huge astrobiological importance of the largest satellite of Saturn. The mission has also discovered a new body of prime interest for Astrobiology: Enceladus. However, many questions of astrobiological importance still remain, such as: 1) Complex organic chemistry is one of the many astrobiologically important aspects, of Titan. Solid atmospheric particles seem to play a key role in this chemistry, allowing the formation and evolution of complex organics. What is the chemical nature of these aerosols and their potential evolution after sedimentation on Titan's surface? Laboratory simulation experiments based on Cassini-Huygens observation try to answer these questions. How pertinent are their answer, to which extent can we extrapolate the results obtained from laboratory analogues to the Titan's case? 2) Titan's lakes are mainly made of liquid methane and other low molecular weight hydrocarbons. The possibility of an exotic life in these lakes, involving a biochemistry without O-atoms has been speculated. What are the pros and cons of such an hypothesis and what is the scientific pertinence of such speculation? 3) Both satellites have an internal water ocean. Titan's internal ocean is sandwiched between two layers of ice, but may have been resting on a rocky bottom in its early history. Enceladus's internal ocean is still today in this rocky configuration, which has frequently been considered as privileged for the emergence and development of life. Now new scenarios on the origin of life on Earth imply the involvement of UV radiations, incompatible with deep seas and internal oceans environments. Thus the question of life in these internal oceans must be reexamined taking into account these new scenarii. This presentation will discuss these three points of important astrobiological consequences.

B5.2-0029-18 TITAN AS A SEDIMENTARY WORLD

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We performed a detailed mapping and analysis of Titan's geomorphological units to determine the sources and sinks of Titan's sediment cycle. Our global mapping is consistent with past work that suggests that Titan's equatorial dune sands are made from organic material derived from atmospheric photochemistry. The dune sands are transported away from the equator to form the vast mid-latitude plain deposits, possibly as a loess-like terrain unit derived from fragmented dune materials. Some materials deposited in the lower polar latitudes/high mid-latitudes also migrate equatorward to converge with the mid-latitude plains deposits of organic materials. The lack of observed, large high-order collective channels and extensive liquid-filled basins in the equatorial zone and mid-latitudes suggests that surface liquids either evaporate, or percolate into a porous regolith over timescales shorter than the timescale to form a stable channel. The overprinting of eolian deposits is consistent with the mid-latitudes and equatorial region of Titan being dominated by eolian compared to fluvial processes. In the polar regions, there is little evidence for eolian morphology; most of the geomorphology is best explained by fluvial, lacustrine, and even karstic dissolution processes. The enigmatic labyrinthic terrains found mostly in the high latitudes are testament to the production of thick stacks of presumed organic materials that have been deposited and later eroded through eolian, fluvial, or dissolution processes. Our overall synthesis is that Titan is a sedimentary world where the original icy crust has been mantled by organics and eroded to create sediments that were transported and modified by eolian, fluvial, dissolution, and even tectonic processes.

B5.2-0030-18 RAISED RIMS AROUND TITAN'S SMALL LAKES

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Saturn's largest moon Titan is the second known solar system body on which standing bodies liquid are maintained, the first being Earth. Under Titan's current climatic conditions, stable surface liquids (predominantly a methane-ethane-nitrogen ternary mixture) are restricted to the polar regions. There, liquids pond within two distinct type of depressions: open basins like Kraken Mare or Jingpo Lacus, where evaporation/infiltration is counter-balanced by surface runoff. These larger basins appear to have developed through inundation of a preexisting well-drained landscape, and their formation is relatively straightforward.

The remainder of liquids are contained within sharp edged depressions (SEDs) form topographically closed depressions with no evidence, at the 300-m resolution of SAR images, of terrain features that would suggest inflow or outflow of fluid on the surface, and presumably retain a filled state via subsurface infiltration. SAR images have shown that SEDs are found throughout both polar regions, and show no obvious planview orientation or spatial patterns. Further, the floors of many SEDs are relatively smooth, while the curvature of their perimeters is consistent with growth via uniform scarp retreat. Compared to the larger seas, SED formation is poorly understood. New topographic data, however, is now allowing for more detailed studies of their 3-dimensional forms, and permits more detailed models of formation.

Dissolution of a soluble substrate, as noted in previous studies of Titan's SEDs, can successfully explain all the above observations, and remains a particularly attractive model for their formation. However, new topographic data has revealed the presence of hundred-meter high raised rims around the perimeters of a

subset of these features that defy explanation, and add serious complications that cannot be explained by dissolution erosion alone. Here, we perform a comprehensive study of the rims of Titan's SEDs using a combination of SAR image, and high-resolution topographic data.

Cassini topographic data is available through 3 different processes, with the altimeter being the most useful because of its order-of-magnitude better vertical (<35 m) resolution. This resolution is further increased by another factor of 2 through super-resolution processing of the returned signal, providing the best possible topographic data on Titan available from the Cassini mission. For the 8 flybys where Cassini acquired altimetry data over the polar regions, we can compare directly these topographic profiles to the SAR images. Specifically, the T30, T91, and T126 profiles all crossed one or more SEDs and thus allowed us to investigate the topographic profiles of these features in the highest detail possible. For the 15 SEDs that had a topographic profile, all but 2 had elevated rims. For many of these, a peculiar pattern also appeared, where the elevated portion repeatedly exhibits a distinctive bright-dark pairing, suggestive of elevated topography.

The high probability, albeit with a limited sample size, of SEDs with rims in topographic data, along with the repeated correlation of elevated topography with a visible feature necessitated an inspection of the remainder of Titan's SEDs. To do this, and remain confident that identified features are in fact real, we restricted ourselves to SEDs that have been imaged at least twice from different azimuth and/or incidence angles. By using multiple images, of the same SED, and at differing viewing geometries, we can observe how the bright-dark pairing changes.

For example, if we look at the same SED from two opposing azimuth angles (180° different), then the bright-dark pairing should invert itself. Similarly, for higher incidence angle observations, the pattern should differ from more nadir observations. For high incidence angle observations, the returned power from the leeward side (closer to the spacecraft) of a rim should be relatively high compared to a more nadir observation, where a rim is less obvious. Therefore, if a given feature appears exactly same even though viewing geometries change drastically, then we conclude that the given SED does not have a rim. The opposite is true if the bright-dark pairing does change. For intermediate cases, where geometries are similar, the pattern should remain self-consistent, in which case we also conclude that a SED has a rim.

Using the criterion described above, we found 191 SEDs that were covered by multiple SAR swaths with varying viewing geometries. This represents 30% of Titan's north polar SEDs. Of these, 75% have an observable rim, with a preference for larger SEDs to have more observable (larger) rims. This pattern is consistent with the altimetry statistics, indicating that most SEDs have rims, and that rims may be constructional.

B5.2-0031-18 RIVERS ON TITAN - NUMERICAL MODELLING OF SEDIMENTARY STRUCTURES

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On Titan surface one can expect a few geomorphological forms, e.g. fluvial valley and river channels. In our research we use numerical model of rivers to determine the limits of different fluvial parameters that play important roles in evolution of the rivers on Titan and on the Earth. We have found that transport of sediments as suspended load is the main way of transport on Titan [1]. We also determined the range of the river parameters for which a braided river is developed rather than a meandering river. Similar, parallel simulations for rivers deltas are presented in [2].

Introduction

Titan is a very special body in Solar System. It is the only moon that has dense atmosphere and flowing liquid on its surface. The Cassini-Huygens mission has found meandering rivers on Titan and indicated processes of erosion, transport of solid material and its sedimentation. This work is aimed to investigate the similarity and differences between these processes on Titan and on the Earth.

Numerical model

The dynamical analysis of the considered rivers is performed using the package CCHE adapted for the specific conditions on Titan. The package is based on the Navier-Stokes equations for depth-integrated two dimensional, turbulent flow and three dimensional convection-diffusion equation of sediment transport. For more information about equations see [1]-[4].

Parameters of the model

We considered our model for a few different parameters of liquid and material transported by a river. For Titan we consider liquid corresponding to a Titan's rain (75% methane, 25% nitrogen), for Earth - the water. Material transported in rivers on Titan is the water ice, for Earth - quartz. Other parameters of our model are: inflow discharge, outflow level, grain size of sediments, etc. For every calculation performed for Titan's river similar calculations were performed for the corresponding terrestrial river.

Results and Conclusions

The results of our simulation show the differences in behaviour of the flow and of the sedimentation on Titan and on the Earth. Our preliminary results indicate that suspended load is the main way of transport in simulated Titan's conditions. We also indicate that braided rivers appears for larger range of slope S on Titan (e.g. S=0.01-0.04) than on Earth (e.g. S=0.004- 0.009). Also, for the same type of river, the grain size on Titan is at least 10 times larger than on Earth (1 cm for Titan versus 1 mm for the Earth). It is very interesting that on Titan the braided rivers appear even for very low discharge (e.g. Q=30 m 3 s 1) and for very large grain size (e.g. 10 cm). In the future we plan the experimental modelling in sediment basin to confirm results from computer modelling.

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B5.2-0032-18 TITAN'S MAJOR GEOMORPHOLOGICAL UNITS: THEIR SPECTRAL AND MORPHOLOGICAL NATURE

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We investigate the surface of Titan using spectro-imaging near-infrared data from the Visual and Infrared Mapping Spectrometer (VIMS). We use a radiative transfer code to determine the contributions of atmospheric haze to the spectrum and retrieve the surface albedo [1]. We focus on the major geological units identified in [2;3;4] from SAR data: mountains, plains, labyrinths, impact craters, dune fields, and alluvial fans. We find that all the different regions classified as being the same geomorphological unit in SAR show a similar spectral response after the VIMS data analysis, thus suggesting a good correlation in the classification between SAR and VIMS. Exceptions are the undifferentiated plains, which present two different types of spectral responses. In addition, by matching the extracted albedos with candidate materials for Titan's surface [5], we find that all regions of interest fall into one of three main compositional groups of major candidate constituents: water ice-like, tholin-like, or an unknown, very dark material. More specifically, we find that part of Titan's surface appears to be dominated by a tholin-like and/or a dark unknown (most likely organic) material, and that some fraction of the surface is covered by atmospheric/organic deposits. Material with a spectral response similar to water ice is also present at a number of regions as major constituent at latitudes higher than 30ºN and 30ºS. The surface albedo differences and similarities among the various geomorphological units constrain the implications for the geological processes that govern Titan's surface and interior (e.g. aeolian, cryovolcanic, tectonic). Our results show that Titan's surface composition has a significant latitudinal dependence [6].
[1] Solomonidou et al.: JGR, 119, 1729-1747, 2014;

[2] Lopes et al.: Icarus, 205, 540-558, 2010; [3] Lopes, et al.: Icarus, 270, 162-182, 2016; [4]

Malaska et al.: Icarus, 270, 130-161, 2016; [5] http://ghosst.osug.fr; [6] Solomonidou et al.: JGR-Planets, in press.

B5.2-0033-18 GLOBAL CLIMATE MODELING OF SATURN'S TROPOSPHERE AND STRATOSPHERE, WITH APPLICATIONS TO JUPITER

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The Cassini mission has opened many science questions related to Saturn's atmospheric dynamics: jet-streams (including the hexagonal-shaped northern polar jet), giant convective storms, stratospheric equatorial oscillations, interhemispheric transport. This inspired our group to develop a Global Climate Model for Saturn that couples a massively-parallel icosahedral-grid hydrodynamical solver with detailed physical parameterizations (notably correlated-k radiative transfer) for Saturn's troposphere and stratosphere. Multiple test simulations led us to determine the best modeling settings to run simulations in which (amongst other requirements) the conservation of angular momentum is ensured with good accuracy. Multi-year simulations carried out with a spatial resolution of 1/2° in latitude/longitude allowed us to analyze the mechanisms accounting for jet acceleration (and possible latitudinal migration) in the troposphere and the stratosphere of Saturn, the formation of large-scale vortices and waves, and the occurrence of a zonostrophic regime. The perspectives for improvements of the reference Saturn simulations will be reviewed. We will also present simulations carried out for Jupiter (presently observed by the Juno mission) with the exact same modeling platform, to discuss comparative dynamics between both gas giants.

B5.2-0034-18 EXTENDING CASSINI SCIENCE: THE NEED FOR SATURN PROBE IN SITU MEASUREMENTS

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The Cassini mission gave us 14 years of spectacular atmospheric observations. However, some quantities can only be measured through direct sampling in the atmosphere. Most important of these are the noble gas abundances, as they are non-reactive and have no spectral signature. Constraining the noble gas abundances is crucial for distinguishing between solar system formation models, including determining when and where Saturn formed in the protosolar nebula. Additionally, several methods have attempted to constrain helium through indirect means and remote sensing, but a ground truth measurement would help to validate these retrieval techniques. Although the other elements (C, N, O, S) are more easily detected by their spectral signature, remote sensing measurements may not be sensitive to their deeper well-mixed values, and also require in situ validation. In situ measurements of the noble gas and elemental (and isotopes of both) abundances form a complete picture of the role Saturn played in gas giant migration, a key component to understanding the structure of our present day solar system.

In situ measurements of wind, temperature, and pressure beneath the cloud deck also tie the cloud top motions to deeper structure, essential to providing ground truth for global circulation models. Even a single location's profiles are crucial to understanding local and global circulation and advancing our modeling capability; the Galileo probe's Jupiter profile is the initial condition for most Jupiter models despite having entered a non-representative location. Measurements of the temperature profile and cloud particles are also needed to validate remote sensing retrievals of cloud structure from imaging data. A major concern with retrievals from remote sensing is their ability to uniquely constrain the cloud layers. Further knowledge of cloud locations and local composition and dynamics, in even one location, is critical to gaining confidence in the inferences provided from remote imaging.

B5.2-0035-18 THE SATURN PROBE INTERIOR AND ATMOSPHERE EXPLORER (SPRITE) ENTRY PROBE MISSION CONCEPT

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To improve models of Solar System formation and to provide an improved context for exoplanet systems, measurements of the atmospheric composition, structure, and processes within the atmospheres of the giant planets are essential. In particular, measurements of the abundances of noble gases and isotope ratios of hydrogen, carbon, oxygen, and nitrogen, as well as the thermal profile, cloud structure, and dynamics of Saturn are needed. The SPRITE (Saturn PRobe Interior and aTmosphere Explorer) entry probe mission concept would address these important science priorities and would provide ground truth for remote sensing to improve understanding of Saturn's interior structure and composition, and by proxy those of extrasolar giant planets.

The SPRITE mission concept comprises a Carrier Relay Spacecraft (CRSC) and an entry probe descending to at least ten bars in less than 2 hours. The primary scientific instrument payload of the SPRITE probe would include two spectrometers - a Quadrupole Mass Spectrometer and a Tunable Laser Spectrometer, and an Atmosphere Structure Instrument including both a nephelometer and a Doppler Wind Experiment for measuring and characterizing Saturn's tropospheric thermal, cloud, and dynamical structure. The Atmospheric Structure Instrument would also include accelerometers to measure entry accelerations from which the probe entry trajectory and descent location could be reconstructed and for characterization of the thermal structure of the upper atmosphere. The solar powered CRSC carries a Multi-Channel Imager for pre-entry imaging of the probe entry location, and to provide local and global context imaging for the probe measurements.

SPRITE would follow an Earth-Venus-Earth-Earth gravity assist trajectory to reach Saturn in ten years. The SPRITE probe would enter Saturn's atmosphere at a relative velocity of 27 km/s, experiencing a peak heat flux near 3000 W/cm^2 and a peak deceleration up to 45 g's. The aeroshell would be released above the tropopause, initiating the descent science sequence and permitting up to 2 hours for the probe to reach and pass through 10 bars. To ensure low risk data return, the descent probe design is fully-redundant with a dual-channel telecommunication system powered by primary batteries. After the probe science data is collected by the flyby Carrier Relay Spacecraft, the probe data and Carrier imaging data would be downlinked to Earth multiple times through the Deep Space Network

In the context of giant planet science provided by the Galileo, Juno, and Cassini missions to Jupiter and Saturn, a small, relatively shallow Saturn probe capable of measuring noble gas abundances and isotopic ratios of key atmospheric constituents, and atmospheric structure including pressures, temperatures, dynamics, and cloud locations and properties not accessible by remote sensing would serve to test competing theories of solar system and giant planet origin, and chemical and dynamical evolution.

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Predecisional information for planning and discussion only.

B5.2-0036-18 PREDATOR-PREY ANALOGS FOR SATURN'S NON-LINEAR RING DYNAMICS

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Cassini observations of straw, gaps, ghosts, kittens, propellers, solitary waves and the edge disruption of the Keeler gap by Daphnis may all indicate non-linear dynamics in Saturn's rings. This dynamical behavior cycles ring material into and out of transient aggregations: We see the rings changing before our eyes! How can we understand the structures seen by Cassini and the rapid times scales? Numerical simulations cannot yet capture all the relevant physics, the multiple spatial scales or the asymptotic behavior at long time scales. An ecological analogy of a predator-prey model provides a non-linear model, including aggregation by sweep-up, disk instability and the stochastic collisions of clumps. In this model, the aggregate mass is the prey, and the dispersion velocity is the predator, since the dispersion 'feeds' off the aggregates stirring the system. This, in turn, limits the growth of the 'prey'. In some cases, the system shows the dynamics of a driven pendulum or of the Duffing oscillator. For specificity, we adopt the 'twogroup' model of Goldreich for proto-planetary disks, with the 'groups' being the ring particles and their aggregates. This provides a simplification of the size and velocity distributions. Our analysis gives the phase plane trajectories, the equilibrium points and the size distribution of the largest aggregates. Forcing at mean motion resonances creates non-linear density waves, which increase the surface mass density and decrease the relative velocity in their crests. We use Toomre's criterion to check for disk instability. This triggers aggregation, which is out of phase with the forcing, explaining the 'straw' and associated gaps seen between density wave crests. The largest objects have a steeper size distribution, because of the difficulty of accretion in the tidally influenced regime near the Roche limit. The knee in the size distribution of F ring 'kittens' (at about 700m) may therefore be associated with the transition from adhesive growth to collisional gravity-dominated accretion. The predator-prey model thus provides an intuitive description of the non-linear dynamics that leads to the structures seen in Cassini UVIS and ISS observations.

B5.2-0037-18 STATUS OF THE POST-CASSINI SATURNIAN SATELLITE EPHEMERIDES

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Prior to the Cassini Tour of the Saturnian system Jacobson (2004 AJ 128, 492) determined the orbits of the Saturnian satellites from Earth-based astrometry and observations acquired with the Pioneer 11 and Voyager spacecraft. We have been extending that work to include additional Earth-based astrometry, and Doppler tracking, radiometric range, very long baseline interferometry, and imaging from the Cassini mission (Jacobson et al., 2006 AJ 132, 2520). Our basic procedure is to repeat the Cassini navigation reconstructions together with reconstructions of the Pioneer 11 and Voyager encounters but with a common set of ephemerides. Data from the spacecraft trajectory reconstructions are combined with other non-spacecraft data sets to update the ephemerides. We call this our "global" solution.

Cassini entered orbit about Saturn on 2004 July 1. After touring the system for 270 orbits, it had its final flyby of Titan on 2017 April 22 and began its proximal orbits, a series of 22 orbits with periapses between the innermost D-ring and the upper layer of Saturn's atmosphere. It plunged into Saturn on 2017 September 9. During the tour there were 3 Enceladus flybys, 3 Dione flybys, 2 Rhea flybys, and 10 Titan flybys dedicated to acquiring measurements of the satellite gravity fields. Saturn's gravitational field strongly perturbed the proximal orbits; tracking through periapsis of 5 of these orbits was acquired to improve knowledge of Saturn's gravity. Accurate knowledge of the gravitation environment of the Saturnian system is crucial to our ephemeris development. In addition to the gravity flybys, Cassini had another 116 Titan flybys as well as flybys of every major satellite. Tracking of the spacecraft before and after each of these satellite encounters provided an indirect measure of the satellite position at the km level. For the determination of the satellite orbits, Cassini also contributed 5766 imaging observations to the existing set of 600 from the two encounters. The Cassini data are highly accurate and cover multiple orbits of the satellites.

The Cassini Navigation Team has completed preliminary reconstructions for all of the spacecraft orbits from the start of Saturn tour through the final Saturn plunge, and we have collected all of the data needed for our final post-Cassini determination of the satellite orbits. Our analysis of the data and its inclusion in the "global" solution is underway and is expected to be completed before the end of the year. This paper reports on the current status of the work.

B5.2-0038-18 TITAN'S POLARIZATION PHASE CURVES WITH CASSINI/ISS

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The sunlight reflected by Titan's atmosphere is strongly polarized at phase angles near quadrature. This Rayleigh-like behavior has been a key clue for the understanding of the aggregate nature of Titan's ubiquitous atmospheric haze. We are preparing Titan's polarization phase curves with data collected with Cassini's Imaging Science Subsystem. The Cassini/ISS dataset covers the spectrum from the UV to the NIR, and phase angles from nearly zero degrees (full illumination) to 150 degrees, thereby extending the observations made by the Voyager and Pioneer spacecraft decades ago. The Cassini/ISS dataset confirms the older trends in Titan's polarization, but also shows new insight thanks to the relatively good phase sampling and to the availability of data at wavelengths affected by methane absorption. Since we now how spectrally-resolved phase curves in both brightness and polarization, we are investigating the optimal way to combine that information towards the optimal characterization of Titan's atmosphere. The question is also relevant to the prospective characterization of exoplanets.

B5.2-0039-18 AN EMPIRICAL MODEL OF TITAN'S MAGNETIC ENVIRONMENT DURING THE CASSINI ERA: EVIDENCE FOR SEASONAL VARIABILITY

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Based on the magnetic field data collected during the Cassini era, we construct an empirical model of the ambient magnetospheric field conditions along the orbit of Saturn's largest moon Titan. Observations from Cassini's close Titan flybys as well as 191 non-targeted crossings of Titan's orbit are taken into account. For each of these events we apply the classification technique of Simon et al. (2010) to categorize the ambient magnetospheric field as current sheet, lobe-like, magnetosheath, or an admixture of these regimes. Independent of Saturnian season, Titan's magnetic environment around noon Saturn local time is dominated by the perturbed fields of Saturn's broad magnetodisk current sheet. Only observations from the nightside magnetosphere reveal a slow, but steady change of the background field from southern lobe-type to northern lobe-type on a time scale of several years. This behavior is consistent with a continuous change in the curvature of the bowl-shaped magnetodisk current sheet over the course of the Saturnian year. We determine the occurrence rate of each magnetic environment category along Titan's orbit as a function of Saturnian season and local time.

B5.2-0040-18 NONAXISYMMETRICAL COMPONENT OF SATURN'S MAGNETIC FIELD DERIVED FROM CASSINI RADIO AND MAGNETOMETER DATA

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A dipole model ("birotor dipole") was proposed for Saturn's inner magnetic field: this dipole presents the particularity to have North and South poles rotating around Saturn's axis at two different angular velocities; this dipole is tilted and not centered. The spin rates and the associated rotation phases are derived from a continuous wavelet transform analysis of the intensity of the Saturnian kilometric radiation (SKR) signal received at 290 kHz between July 2004 and June 2012 by the radio and plasma wave science (RPWS) experiment on board Cassini. 57 revolutions of the spacecraft, the periapsis of which is less than 5 Saturnian radii, have been selected for this study. For each of these chosen orbits, it is possible to fit with high precision the measurements of the MAG data experiment given by the magnetometer embarked on board Cassini. A nonrotating external magnetic field completes the model. This study suggests that Saturn's inner magnetic field is neither stationary nor fully axisymmetric. These results can be used as a boundary condition for modelling and constraining the planetary dynamo and they can be a starting point for the study of Saturn's inner structure and the comparison with the interior of Jupiter. An average of the birotor dipole magnetic potential is performed on the azimuthal angle revealing an average axisymmetrical component which can be compared with the published zonal models proposed for Saturn's magnetic field. The presence of a "birotor quadrupole" is required in the present model to improve the agreement for the third order Gauss coefficient.

B5.2-0041-18 MEMORIES OF SATURN'S RADIATION BELTS: SPATIAL DISTRIBUTION OF BIT-ERRORS ON THE CASSINI SOLID STATE RECORDERS

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Cassini's science data was accumulated in two Solid State Recorders (SSRs) before being downlinked to Earth. Each of these recorders, state of the art for their time (early 1990's) contain 2.5 Gigabits of dynamic random access memory. The DRAM devices were tested to 50 kRad dose, and are shielded by >1cm of aluminium. Additionally, an Error Detection and Correction (EDAC) routine 'washes' through the entire memory once every 9 minutes, using a Hamming code (7 code bits for every 32 data bits), allowing it to detect Double Bit Errors, and detect and correct Single Bit Errors (SBEs). The counts of SBEs DBEs every hour have been collected throughout the Cassini mission, and are highly variable, from typically a couple of dozen per hour, to thousands. These spikes in occurrence take place near periapsis, when the spacecraft passes through Saturn's radiation belts. Thus the SSR housekeeping serves as an independent measurement of Saturn's trapped particle environment, albeit with low temporal (and thus spatial) resolution. The SSR rates are compared with model predictions and data from the MIMI instrument on Cassini.

B5.2-0042-18 PROBLEMS OF RIVERS CLASSIFICATION ON THE BASIS OF RIVERS EVOLUTION ON EARTH AND ON TITAN

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The present classifications of the rivers are based on the terrestrial rivers. However, mission Cassini indicates existence of river systems also on Titan. We use numerical modelling of river evolution on the Earth and Titan. We are looking for differences and similarities of evolutions on these celestial bodies. The numerical analysis is performed using the package CCHE. The package is based on the Navier-Stokes equations for depthintegrated two dimensional, turbulent flow and three dimensional convection-diffusion equation of sediment transport. More information is given in [1]-[4]. For calculation of rivers on Titan some adaptation are used.

We have found that transitional rivers are a very common type. Such rivers could be a single channel river in a part of considered domain and a multiple channel river in the rest of domain. In other simulations transitional rivers reveal the features of multiple channel river for some time but later they reveal the features of single channel river. We conclude that to solve the problem of rivers' classification one have to use for classification some time scale and some spatial scale. These scales are determined by dimensionless numbers.

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B5.2-0043-18 ANALYZING THE DYNAMIC AND MORPHOLOGICAL CHARACTERISTICS OF CLOUDS ON TITAN USING THE CASSINI VIMS

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Introduction: Titan is characterized by a complex methane cycle analogous to the Earth's hydrological cycle. In 1995, this concept was strengthened by the first observational evidence of methane clouds inferred from albedo increases in specific spectral windows. Today, using data collected by the Visible and Infrared Mapping Spectrometer (VIMS) on board the Cassini spacecraft, we are able to produce high spatial-resolution images which can be used to visually inspect for tropospheric clouds on Titan. We have executed a manual search throughout the entirety of the VIMS dataset (>20,000 applicable cubes) to document cloud occurrence and morphology, providing an opportunity to analyze the global distribution, physical size, duration, and temporal variability of cloud location and geometry.

Methods: In order to identify clouds, we generate a set of three images for each VIMS cube: an RGB image and its grayscale counterpart as well as a stratospherically-corrected tropospheric image. In order to produce the RGB images, we classified specific wavelength channels based on their observational sensitivity to either surface, tropospheric, or stratospheric features. After acknowledging the disadvantageous signal-to-noise ratio (SNR) of the five-micron window, we reduced our channel set to those classified in previous identification efforts. By assigning green to surface, blue to tropospheric, and red to stratospheric, tropospheric features appear as bright blue due to their relatively significant brightening along the wings of the methane windows (the common location of said channels). Using this color scheme, we created stratospherically corrected tropospheric images simply by subtracting the red image from the blue image.

After processing all VIMS cubes, we designed a graphical user interface (GUI) in order to simultaneously analyze the images produced for each observation. This provides greater confidence throughout the cloud selection process, as the GUI allows for both multiple method verification and reference to previous identification efforts. In addition to the displayed images, the software contains a spectral plotting tool which allows the user to compare the albedo spectra of Titan's surface and a candidate tropospheric feature as well as a five-micron toggle which allows users to view cubes in the generally excluded long wavelength channels. These tools provide for the distinction between true clouds and artifacts associated with observations of bright surface features or a consistent difference in albedo caused by proximity to the terminator. Furthermore, our stratospherically corrected images mitigate the problems of hiding and blurring linked to limb-proximal cloud observations.

Results and Discussion: Our analysis spans all VIMS observations from flybys T-A through T-126 (October 2004 to April 2017). Within this dataset, we have identified and characterized tropospheric cloud features in more than 2000 cubes representing hundreds of unique clouds. We observe notable groupings of clouds throughout the southern hemisphere as well as scattered mid-latitude clouds in the northern hemisphere and a high-frequency north polar hood spanning all longitudes. Furthermore, our observations catalogue a significant density of clouds throughout the south polar region alongside scattered clouds in the northern mid-latitudes followed by a delayed transition to dense coverage in the north polar region. These distributions both support and further constrain predictions made by current global circulation models (GCMs) of Titan.

Selecting the complete expanse of every cloud visible in the VIMS dataset regardless of prior observation generates information from which properties can be derived. The GUI employs selection indices which allow for the distinction between multiple features within a single image cube, and extracting the spatial resolution corresponding to selected pixels lets us calculate the total observable area (in km^2) of each individual cloud. We witness an exponential decrease in relative frequency with respect to increasing area. Furthermore, our repeated selection of clouds imaged in multiple cubes provides two benefits: first, it allows for an analysis of the morphologic evolution of the cloud, which can inform on formation mechanisms, and second, it allows for tracking of cloud speed through repeat observations (provided significant spatial resolution) to further constrain wind speed estimates. Using radiative transfer (RT) modelling of Titan's atmosphere, we can also obtain the altitudes of certain observations. By reporting cloud altitude as a function of displacement speed, we can construct altitudinal wind speed profiles which contribute to understanding the complex dynamics of Titan's atmosphere. Although our ability to measure cloud velocity is limited to observations in which a feature's displacement is resolved, the incorporation of ISS data allows for the determination of slower speeds due to a higher global resolution. We report velocities ranging from 1.5 to 23 m/s over the entire extent of the RT model's operable altitudes, 1.5 to 48 km. Our cloud speed data does not display a strongly discernable trend, but decomposing the values into meridional subsets will allow for the analysis of wind speeds across the entirety of Titan.

B5.2-0044-18 SATURN RINGS ORIGIN: MAGNETIC PRESSURE AND QUANTUM TRAPPING OF SUPERCONDUCTING ICED PARTICLES BY THE MAGNETIC FIELD LEAD TO THE STABLE RINGS SYSTEM

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It is demonstrated how superconducting iced particles of the protoplanetary cloud of Saturn are coming to magnetic equator plane and create the stable enough rings disk. There are two steps. First, after appearance of the Saturn magnetic field due to Meissner phenomenon all particles orbits are moving to the magnetic equator plane. Finally they become distributed as rings and gaps like iron particles around magnet on laboratory table. And they are separated from each other by the magnetic field expelled from them. It takes up to few tens of thousands years with ten meters rings disk thickness. Second, due to their quantum trapping all particles become to be trapped within magnetic well at the magnetic equator plane due to Abrikosov vortex for superconductor. It works even when particles have small fraction of superconductor. During the rings evolution some contribution to the disk also could come from the collision-generated debris of the current moon and from the geysers like it happened due to magnetic coupling of Saturn and Enceladus. The rings are a relic of the earliest days of the magnetic field of Saturn system.

B5.3-0001-18 YEARNING TOWARD THE GLOOM WITH VENTUROUS GLEE: A SWINBURNIAN TOUR OF OCEAN WORLDS EXPLORATION

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Though not intended as such, A.C. Swinburne's "On the Verge" provides an abundance of metaphors for the remarkable nature of ocean worlds, as good as any a way to vignette through a subject now much too large for a COSPAR-length overview talk. Here begins the sea that ends not til the world's end: Globe-girdling oceans of liquid water have been detected beneath the surfaces of five moons, using diverse techniques that required missions to fly repeatedly past their targets. Shines and darkens, wanes and waxes: The brightness of Enceladus' plume is tied to the moon's orbital period, providing the key to the mechanism of its emission and a clue to the plausibility of the assertion that the plume composition tells of the ocean beneath. Gazing hence, we see the water that grows iron round the pole: What is the nature of the colored material that paints Europa's water ice surface? If endogenous, what might this tell us of the material Europa Clipper might find, especially if plumes at high southern latitude are present? Ere our eyes and brows be fanned round with airs of twilight: As Cassini ended its mission, northern summer solstice on Titan revealed a variety of intriguing cloud features in the wettest (with methane as liquid) part of Titan's surface. Do these provide a clue to the nature of the lake/sea interactions with the atmosphere, and the annual stability of the smaller lakes? Nor may seas declare nor skies unroll what has been from everlasting, or if aught shall always be: Is the ocean of Europa as old as the moon itself? Are the seas of Titan remnants of an ancient methane ocean, or the result of an outgassing event in the last billion years? How long has Enceladus had an ocean? These questions have important implications for the astrobiology of these targets. But here [wo] man's heart leaps, yearning toward the gloom with venturous glee, though [her] pilot eye behold nor bay nor harbor, rock nor shoal: Future exploration of the oceans and seas of the ocean worlds will require imagination, daring, scientific passion, and novel ways to reduce trip times while not escalating cost.

B5.3-0002-18 OASES FOR LIFE BENEATH ICE-COVERED OCEANS: HYDROTHERMAL EXPLORATION OF OCEAN WORLDS

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This paper will present recent research results from a NASA PSTAR program designed to help inform future exploration for life beyond Earth with a particular emphasis on seafloor fluid flow, its ability to sustain chemosynthetic ecosystems and their ability to propagate biosignatures upward from the seafloor into the overlying ocean and/or ice-shell. One particular focus of our work was centered on a field program to the Arctic Ocean in Fall 2016 in which we deployed a new proto-type underwater vehicle called NUI (Nereid Under Ice) as both a fully autonomous vehicle (AUV) and, using a single unarmored optical fiber, as a remotely operated vehicle (ROV) to conduct detailed seafloor mapping, photographic surveys and seafloor sampling. This project was nested within a larger program that also conducted extensive and ultimately successful exploration for evidence of hydrogen-rich submarine venting on the ultra-slow Gakkel Ridge. In parallel, our research has also been pursuing development of a continuous 3-D physical model that can faithfully reproduce the dispersion of a well characterized deep sea hydrothermal plume (from the Axial Seamount, Juan de Fuca Ridge) to provide a continuous digital workspace within which we can test and optimize algorithms for future robotics-based exploration for hydrothermal activity in unknown oceans. While we have already pioneered such AUV-led exploration work, successfully, in Earth's oceans, an ability to eliminate support ships from such exploration would be a massive win-win for the future of both Ocean and Ocean World Exploration. We will close with an outline of future plans, including (a) upgrades to the NUI vehicle that are in progress to enable it to reach any under-ice ocean environment on Earth and (b) future plans for a return to the Arctic to conduct detailed investigations of the newly discovered vent-sites there and test our newly developed vent-exploration search strategies.

B5.3-0003-18 EXPLORING EUROPAN ANALOGS OF THE MCMURDO SOUND AND ROSS ICE SHELF

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The NASA-funded RISE UP program (Ross Ice Shelf Europa Underwater Probe) is a threeseason project to build future exploration technologies for ocean worlds that facilitate the exploration of analogs for ice-ocean processes in Antarctica. Key focuses of this work include basal ice conditions, ice-ocean interactions, and environmental conditions from the ice to the sea floor beneath the McMurdo sound sea ice, the McMurdo Ice Shelf, and the Ross Ice Shelf. Enabling this science to be achieved is the novel and scientifically capable Icefin hybrid AUV/ROV vehicle that conducts surveys from the ice to the seafloor to provide an integrated picture of the conditions below the ice. With one field season now complete in 2017-18, the project will extend its observations in the 2018-19, and 2019-20 austral summers. In cooperation with the Antarctica New Zealand Ross Ice Shelf Programme, PI Christina Hulbe, RISE UP will also deploy Icefin through a borehole through the Ross Ice Shelf to access previously unmapped regions of the sub-shelf water column.

I will highlight the first results of RISE UP's first field season from October 2017 to early January 2018. This season includes data collection at three sea ice locations: two that allow us to swim Icefin underneath the ice shelf, and one at the Erebus Glacier Tongue. Onboard Icefin, we collected data from two sonars, two cameras, a DVL/ADCP, and sensors for conductivity temperature, depth, pH/ORP, DO, CDOM/FDOM and turbidity. In 2018, Icefin will also carry a custom built cell counter, and a microscope, water sampling and ice sampling systems are being designed. The highlights of the scientific data collected this season include the first detection of new boundary layer interactions between the ice and ocean, observations of forming marine ice beneath the MIS, and observations of ice-ocean interactions within an ice shelf rift. In addition to describing Icefin and its observations of the basal ice, oceanographic properties below the sea ice and ice shelves, and seafloor, I will describe how these new data provide information that allows us to better frame our understanding of Europa's ocean and its potential interactions with the ice shell.

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B5.3-0004-18 INSIGHTS INTO THE CHEMICAL EVOLUTION OF OCEAN WORLDS FROM OBSERVATIONS OF DWARF PLANET CERES WITH THE DAWN MISSION

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Ceres, the most water-rich (in volume fraction) body in the inner solar system, has recently been recognized to have astrobiological importance. Chemical and physical measurements obtained by the Dawn mission enable quantification of key parameters constraining the habitability of the inner solar system's only dwarf planet. Current knowledge indicates that Ceres once had water, energy sources, and redox gradients. Furthermore, bounds on elemental C (Prettyman et al., 2017) and direct detection (De Sanctis et al. 2017) support the possibility that organic compounds are widespread within the subsurface. The surface chemistry and internal structure of Ceres testify to a protracted history of reactions between liquid water and rock (Ammannito et al. 2016; Prettyman et al. 2017). Arguably, the most significant finding from the Dawn mission is unambiguous evidence for oceanic material exhibited on Ceres' surface, associated with recent cryovolcanic features (Zambon et al. 2017; Carrozzo et al. 2018). The degree to which prebiotic chemistry, liquid water, and other environmental factors may have combined to make Ceres a habitable world is left for future missions to explore. Dawn's observations confirmed earlier predictions for a volatile-rich shell and a warm and liquid-bearing interior, akin to icy moons. Indeed, Ceres' structure is similar to that of an icy satellite that has almost entirely frozen (Ermakov et al. 2017; Fu et al. 2017). The prospect that a relict ocean may have survived into the present led to Ceres' classification as a "candidate" ocean world in the Roadmap for Ocean Worlds (Hendrix et al. 2017). Similarities with Enceladus' plume dust composition (Postberg et al. 2011; De Sanctis et al. 2016) suggest Ceres falls in the same category of bodies that have hosted an alkaline environment for part (or all) of their history (Zolotov et al. 2007). More generally Ceres' surface chemistry is consistent with the chemical evolution expected in relatively large ice-rich bodies (McKinnon and Zolensky 2003; Neveu et al. 2017). We review the clues on chemical composition, temperature, and prospects for the present occurrence of liquid and chemical gradients in Ceres and explore how cross-pollination of knowledge between this dwarf planet and ocean worlds in the outer solar system improves our general understanding of large volatile-rich bodies.

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B5.3-0005-18 IMPLEMENTABLE PROGRAM FOR EFFICIENT OCEAN-WORLD EXPLORATION

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The next US planetary Decadal Survey's mission priorities will emerge in 2022-23. Current US law requires NASA to implement a "virtual" Ocean Worlds Exploration Program (OWEP) using a mix of mission classes. NASA and ESA are currently developing large missions to explore Europa and Ganymede, respectively; NASA is also formulating concepts for a potential large mission to search for biosignatures on the Europa surface. Small-class mission concepts for Titan and Enceladus were proposed in 2010 and 2014, but not selected; NASA awarded

$25M in 16 technology-development projects pertinent to Europa and other ocean worlds; recently NASA evaluated four medium-class OWEP mission in the New Frontiers program and has advanced one to Phase A. OWEP technical challenges are formidable: 1) almost a dozen diverse ocean worlds of varying priority, with key pieces of the ocean-world scientific puzzle are distributed among them; 2) power limitations at the Jovian and Saturnian ocean worlds;

3) standard launch and in-space propulsion impose half-decade (to Jupiter) or decade-long (to Saturn) transfers; and 4) the oceans are beneath kilometers of cryogenic ice. A virtual program of disparate initiatives is unlikely to cohere into an efficient OWEP. First, OWEP technologies outside the framework of individual missions have uncertain funding; the $25M allocated in FY17 is but a small down-payment, and enhanced investment would compete against many other solar system objectives. Second, the medium-class OWEP mission concepts compete against unrelated science objectives in a selection process whose outcome cannot be predicted. The MEP (Mars Exploration Program) offers one successful exemplar for a strategic program. Yet none of six key conditions underpinning the MEP over the past 15 years apply to a virtual OWEP. In particular, NASA has no mission-opportunity class comparable to the MEP backbone of MGS, Odyssey, and MRO: directed, medium-class missions supporting broader strategic objectives. Progress would be fastest if NASA could adapt three MEP program characteristics: 1) major technology investments separate from mission projects; 2) directed medium-class missions that conduct pivotal investigations on a sustained roadmap; and 3) multi-mission technical infrastructure that "lowers the bar" for individual missions. The most important OWEP example is space transportation, e.g., heavy-lift launch, and high-power solar-electric propulsion, to minimize trip times into Saturn and Jupiter orbit. This analysis treats the governing programmatic constraints, technical uncertainties, and policy gaps for an OWEP, then lays out multiple options for maximizing progress on the highest priority science objectives.

B5.3-0006-18 TRITON'S PLUMES - INSIGHTS INTO TRITON'S OCEAN WORLD STATUS

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Introduction: Triton's young surface with relatively few craters stands out among moons in the solar system and puts it in a class with geologically active Io, Europa, Titan and Enceladus. Particulate plumes rising 8 km above the surface were imaged by Voyager in 1989, in Triton's southern spring [1]. Dark fans deposited on the surface were attributed to deposits from similar, no-longer-active plumes. The plumes were modeled as insolation-driven expulsions of nitrogen carrying particles entrained from the surface [2, 3].

Triton's warm interior: Triton's surface age of <10 MY is derived from the lack of craters on its surface [4], likely erased by surface yielding, deformation and viscous relaxation. A new model of Triton's interior suggests that the combination of radiogenic heating with ongoing tidal heating due to Triton's obliquity could sustain a long-lived subsurface ocean even without invoking substantial ammonia; thus remnant heat from Triton's capture into orbit around Neptune is not required to sustain endogenic geological activity [5].

Source of the plumes: Are Triton's plumes solar-driven or do they come from a subsurface ocean? Are they more like the endogenic eruptions at Enceladus or the seasonal gas jets of Mars? Solar-driven activity - the Mars analogy. Triton's nitrogen atmosphere is in vapor pressure equilibrium with surface ices, and will form polar caps in the winter. The solar-driven model for Triton's plumes relies on a solid state greenhouse forming in/below a seasonal layer of nitrogen ice. A 4 K rise in temperature causes a 10x increase in vapor pressure, and this temperature difference is easily achieved [3]. The discovery of the fans and modeling of the plumes on Triton inspired the solar-driven model for the origin of the fan-shaped deposits imaged on Mars' sea-sonal CO_2 polar caps from seasonal CO_2 gas jets [6]. Mars Reconnaissance Orbiter High Resolution Imaging Science Experiment (HiRISE) images have largely substantiated this model [7]. The combination of HiRISE images and updated models of the jets have allowed us to quantify parameters such as gas exit speeds (20-300 m/sec), mass flux (30-150 gm/sec), height achieved (50-100m), volatile storage requirements, and lifetimes < 2 hr [8]. Eruption from the interior - the Enceladus analogy. We now have another possible comparison, with the Cas-sini discovery that Saturn's moon Enceladus spews water vapor and ice particles from fissures across its south pole [9, 10, 11]. Enceladus showed that it is possible to have regionally confined geophysical activity, driven by tidal energy [12]. Observations indicate vapor exiting at speeds up to 1-2 km/sec in collimated jets [13]. Vapor mass flux is on the order of 200- 300 kg/sec [7]. Solid particle flux is 50 kg/sec [14]. Pluto comparison. Pluto has an N_2 atmosphere in vapor pressure equilibrium with surface frost, similar to Tri-ton. Although the New Horizons flyby of Pluto was at a season in which solar-driven fans could have been active none were imaged [15].

Summary: The solar-driven model has been the accepted explanation for many years for Triton's plumes. The distribution of fans is consistent with that model, the timing of the eruptions coincided with southern spring, and it is eminently plausible in terms of energetics. Challenges with gas storage and the required layered surface structure were considered surmountable [3]. More recent data and models however motivate a re-examination of the source of Triton's plumes. The age esti-mate for Triton's surface and recent tidal models incorporating obliquity were not available in the Voyager era. Study of Mars' jets has allowed us to characterize and quantify solar-driven processes on that planet. The discovery of tidally-driven eruptions confined geographically on Enceladus and measurements such as vapor mass flux and exit speeds have expanded possible scenarios for Triton. The possibility that Triton's plumes could be endogenic and sourced from sub-surface liquid is deserving of further investigation and would solidify Triton's identity as an ocean world.

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B5.3-0007-18 GEOLOGIC ACTIVITY AND LIQUID WATER WITHIN THE ICE SHELLS OF OCEAN WORLDS

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The outer solar system may be brimming with oceans, making it a high priority target for exploration and the search for extant life. Europa and Enceladus, in particular, are thought to have global, subsurface oceans under their geologically active icy shells. Such activity may enable material transport within the shell that can help supply nutrients to a biosphere within the ocean. However, much is unknown about how geologic features on the surfaces of Europa and Enceladus form and what those features imply about the presence of liquid water and material transport within their ice shells. Furthermore, despite having many similarities, geologic activity on Europa and Enceladus manifest in different ways. Understanding what has caused these differences is critical to understanding the long-term geophysics and habitability of all icy, ocean worlds.

Europa's young surface displays globally-distributed geologic activity of two main types. Tectonic features alter the surface through the formation of fractures and subsequent modification of those fractures to create double ridges, dilational bands, and zones of convergence. Tidal stresses caused by Europa's eccentric orbit have been implicated in the formation of fractures, particularly arcuate fractures called cycloids, but modification of fractures may be more related to processes within the shell. Endogenic features disrupt the surface from beneath and display a variety of sizes and morphologies; such features include large-scale chaos (100-200 km across) and microfeatures such as pits and domes that are typically less than 10 km across. Both tectonic and endogenic features have been linked to shallow liquid water within the ice shell. In addition, recently reported evidence of plumes in different regions of Europa also implies liquid water near the surface. However, moving water from the ocean into the shell is challenging due to the lower density of ice compared with liquid water.

Enceladus also displays recent tectonic activity, but it is highly localized near the south pole; tectonic activity becomes older and sparser with distance from the south pole and is concentrated at certain longitudes. The activity at the south pole is complex, with many generations of overlapping fractures. The most prominent set, dubbed Tiger Stripes (TSFs), are associated with high heat flows and appear to be the sources of Enceladus' large, active plumes. The timing of plume eruptions has been linked to tidal stresses, which change in magnitude and direction throughout Enceladus' eccentric orbit. Material within the plumes strongly suggests that the source fractures tap a reservoir of liquid water, and that the water is in contact with rock (i.e. an ocean). If correct, the TSFs represent the most direct example of ice-ocean interactions yet discovered. Curiously, Enceladus does not display any of the endogenic features observed on Europa (i.e. chaos). Fractures at the south pole do have double ridges, but no dilational bands, convergence bands, or cycloids have been identified. This suggests that these two ice shells interact very differently with the oceans beneath them, although the causes are unknown.

In this talk, I will review the models that invoke shallow liquid water to form Europa's surface features, describe the limitations and implications of those models, and discuss the role that thermal-orbital evolution has played in modifying Europa's surface and ice shell. I will also discuss how these processes may have operated differently on Enceladus in order to produce the very different styles of activity from what is observed on Europa. This work benefitted from thoughtful discussions with members of the Ocean Worlds Collaborative, attendees of the Europa Deep Dive workshop, and numerous colleagues.

B5.3-0008-18 TECTONIC MATERIAL TRANSPORT WITHIN THE OUTER ICE SHELLS OF ICY SATELLITES

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On Europa and Ganymede, the scars of tectonic activity are imprinted in water ice shells tens of kilometers thick that are inferred to overlay water oceans about an order of magnitude deeper. The origin and formation of tectonic terrains on icy satellites is tied to processes that link the ice shell and the ocean, such as spreading, rifting, subduction, and cryovolcanism, causing the ice shell to evolve through time. Understanding the tectonic material exchange mechanisms between the surface and the ocean is critical to understanding the potential habitability of these ocean worlds. Some of the most prevalent tectonic terrains on Europa and Ganymede are inferred to occur from extension in the ice shell, commonly producing long, linear "bands," an umbrella term we use to include both bands on Europa and groove lanes (sulci) on Ganymede. These bands have been proposed as ice-analogues to mid-ocean ridge spreading on Earth. Further, evidence for subduction-like convergent tectonics has raised the possibility of a buoyantly driven cycle of tectonic resurfacing and lithosphere recycling on Europa and Enceladus. In this study, we present 2D numerical models of band formation with the outer ice shells of Europa and Ganymede, and track "fossil ocean," ocean material frozen into the ice shell and deformed through geologic time. We predict which band morphologies are most likely to expose fossil ocean material, and the conditions under which those bands form. In addition, to understand whether a plate-tectonics-like cycle of resurfacing and recycling could facilitate band formation and material transport from the surface back into the interior ocean, we perform a basic feasibility test for buoyantly driven subduction and spreading on Europa, Ganymede, and Enceladus. Overall, we find that ocean material can be transported upward into the ice shell through convection and advection, and fossil ocean may be exposed at smooth bands on Europa, but not at highly tectonized bands or groove lanes on Ganymede. We also find that buoyancy forces are unlikely to contribute to subduction or spreading in the outer ice shells of these icy satellites. Thus, we find that the convergent tectonics that might recycle surface material into the ice shell interior, and eventually the ocean, require large exogenic forces.

B5.3-0009-18 TIDAL DISSIPATION IN EUROPA'S SILICATE MANTLE: IMPLICATIONS FOR SEAFLOOR ACTIVITIES AND POTENTIAL OBSERVATIONS BY EUROPA CLIPPER.

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The level of endogenic activities possibly occurring at Europa's seafloor at present day is conditioned by the amount of energy produced in the silicate mantle by tidal dissipation. In the present study, we model the viscoelastic deformation of Europa's mantle using an Andrade rheology and testing various bulk compositions consistent with available geophysical constraints. We show that, for viscosity values consistent with the expected range near the melting point of peridotite, the heat production by viscous tidal friction exceeds the present-day radiogenic heating. Maximal tidal heating rate is obtained at the base of the mantle, with an increase in the polar region and maximal values exceeding locally ten times the typical volumetric radiogenic heating rates expected assuming chondritic rocks. As a consequence, preliminary analysis based on scaling laws indicates that significant partial melting should occur at present in Europa's mantle. In order to further test the impact of tidal heating on the thermal state of Europa's mantle, we perform 3D simulations of thermal convection including heat production by tidal friction, melt production and extraction. We will discuss the implications of these model results in terms of seafloor activities and potential detection from gravity, topography and compositional data by NASA's planned Europa clipper mission.

B5.3-0010-18 GEOTHERMAL ENERGY IN PLANETARY ICY LARGE OBJECTS VIA COSMIC RAYS MUON-CATALYZED FUSION

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In this brief paper, we propose the possibility that p+-d+ and d+-d+ fusions intermediated and catalyzed by the elementary particles muons (μ-), produced by cosmic rays, might hypothetically add energy to geothermal reservoirs in the interior of planetary icy large objects of the Solar System, and of other extra-solar planetary systems, interesting for astrobiological considerations. Well, it is known, since the discoveries in the planetary Solar System by the NASA's Voyagers 1 and 2 spacecraft in the l980's decade, that the four gaseous giant Jovian planets - Jupiter, Saturn, Uranus and Neptune, possess natural satellites displaying on their surfaces (mostly icy ones) recent geologic activity [17]. These moons include Jupiter's Io, Europa and Ganymede, respectively with its active volcanoes, its internal saline seas, and its rugged surface indicating a possible internal ocean of liquid water. Other moons are Saturn's Titan and Enceladus, respectively with its liquid CH4 and C2H5 seas and with its water vapor geysers and global internal ocean of liquid water. Uranus' Miranda, which displays on its icy surface a complex geology, and Neptune's Triton which shows present-state geological activity as geysers expelling dark material from its subsurface. A major heat source for icy satellites of the giant planets is tidal dissipation via orbital resonances [14] [17]. And heat within these objects is also generated by the radioactive decay of internal elements left over from the time of their initial formation. In July 14, 2015, the John Hopkins University's Applied Physics Laboratory - Southwestern Research Institute - NASA's New Horizons spacecraft made the first close flyby over Pluto and its system of 5 moons, being Charon the largest one. Initial data from New Horizons flyby were analyzed by the mission team, and first results were completely intriguing. We are learning that Pluto (and to a lesser extent, Charon) show complex, dynamical, present geologic activity [17]. Models involving tidal dissipation, which would indicate geologically "quiet" worlds, do not account for such present geological activity at Pluto, as for the existence of tidal dissipation is necessary orbital eccentricity, which is practically zero in the Pluto-Charon system. Besides such forms of geothermal energy sources as tidal and radiogenic heating, there is another one, fusion of protons in planetary interiors which was mentioned in the literature [9] [10] [13] [27]. It is usually assumed that such nuclear reactions occur only in the stars interiors, but there is an elementary particle, muon (μ-), that can intermediate such reactions in the low-temperature planetary conditions (as compared as to temperatures inside stars) [16]. This natural phenomenon is known as muon-catalyzed fusion (MCF). MCF was first theoretically proposed in the 1940-50's decades [6] [28], and experimentally observed since the 1950's decade [2] [3] [12] [22]. When a muon (μ-), which lifetime is 2 x 10-6 s, interacts with a proton (p+) and/or a deuteron (d+) (forming a p+-μ–p+, a p+-μ–d+ or a d+-μ–d+ molecule, during 10-11 s), it approximates them to a distance about 207 times smaller than in a H2 molecule with electrons, a catalysis sufficient for their fusion. The reaction ddμ → 3He + n + μ yields a Q = 3.3 MeV, with a reaction rate r (ddμ) 3.5 x 1010 s-1. The reaction pdμ → 3He + + μ yields a Q = 5.5 MeV, with a reaction rate r (pdμ) 1.8 x 105 s-1 [8]. The number of reactions one muon can catalyze was experimentally observed to be about 150, due to the alpha-particle sticking problem [8], but this can be overcome by multiple collisions, which occur normally in icy worlds temperatures. Thus, for just one muon it can yields a minimum of Q

= 500 MeV during its multiple reactions until it disintegrates. But where can we find so many muons for their reactions to give some thermal energy inside icy worlds? The most abundant source for muons is cosmic rays, which origins are solar, galactic and extra-galactic. Daily on planet Earth, an enormous quantity of high (102 MeV) to extremely high (> 100 TeV), and higher energy (1019 eV) protons and nuclei strike nuclei of atoms in the atmosphere, producing cascades of pions (other elementary particle) which decay into muons. Such muons arrive at the Earth surface with energies ranging typically from 10 GeV to 100 TeV and, depending on their energies and on the material, they can penetrate most deeply into liquid and ices than into rocks. For instance, for Eμ = 10 GeV it can penetrate 0.05 Km, and for Eμ = 10 TeV it can penetrate 6.09 Km into rocks [19]. Inside the ices of Antarctica it was measured many muons as deep as 7 km [5], and inside the Baikal lake it was measured muons at 6 Km deep [4], and at the Mediterranean sea it was measured muons at > 10 Km deep [20]. Muons also lose energy by ionization and by radiative processes which adds energy throughout their trajectories. Thus, at a depth of 1 km of rocks their flux is 10-6 than at the Earth's surface. About data on cosmic rays in the Solar System, we are fortunate because the two Voyagers are in operational status. The Voyagers' cosmic ray subsystem measured a somewhat spatial steady flux of cosmic rays throughout their trajectories in the Solar System, but varying in time and anti-correlated with sunspots activity [18]. The measured fluxes began to rise in the outer regions of the heliosphere, where the Sun's magnetosphere is weaker due to the distance

[11] [18] [21]. For objects in the outer Solar System, an enormous quantity of muons are daily produced by an enormous quantity of cosmic rays striking the icy surfaces of the Jovian moons, and of the Trans-Neptunian Objects (TNOs) as the dwarf planet Pluto. During the flybys of the Jupiter and Saturnian systems by the Voyagers, they collected data on the energy and flux of high-energy cosmic rays protons trapped into the Jovian magnetospheres, fed constantly [23] [25]. The trapped protons energies of 102 Mev to 1 GeV in the leading and trailing sides of both planets [24] [26] bombards constantly their moons, creating continuous showers of muons into their interiors. As for planet Mars, cosmic rays measurements by space-craft [17] indicate the production of muons at a similar to or higher rate than on Earth's surface [15] due to the lack of a Martian global shielding magnetic field, thus many muons go into the interior of Mars. For more MCF to occur it is necessary the existence of a large quantity of deuterons. Due to equilibrium and kinetic dynamical factors, it is modeled that icy ob-jects that formed farther out in the Solar System (and other extra-solar planetary systems [17]) should generally have higher

deuterium content in their ice than objects that formed closer to the Sun, and objects that formed in the same source regions and at similar times should have accreted ice with similar hydrogen isotopic compositions [1]. The observed D/H ratio in the inner Solar System is 10-4 [7], which are believed to be higher in the outer Solar System [1], perhaps with D/H 10-3. These ratios are small, but due to the fact the icy bodies are so abundant in the Solar System, the quantity of deuterons might be sufficient for regular MCF to occur via cosmic rays muons. So, integrating time over 4 Gyrs, there was enough time for many muons to have intermediated catalyzed fusion via pdμ and ddμ reactions, yielding regular energy for the interiors of large icy objects in the Solar System. Even being so small in geological energy terms (1 GeV = 1.6 x 10- 10 J) such MCF energy might have being significant for the energy balance inside the primitive Earth, Mars, the Jovian icy moons, the icy TNOs, and icy worlds of extra-solar planetary systems. Such deposited fusion energy might hypothetically be significant for geological activities observed on the surfaces of the Jovian moons and Pluto, with <Ts> 110 K and <Ts> 44 K, respectively [17], and other icy TNOs. In such low temperatures, a small quantity of fusion energy might appear on the surface as geological activity. And we also propose that MCF might also be significant for the energy balance in the formation of geothermal reservoirs (with liquid water) inside those icy large objects (hydrated minerals, ponds, small lakes and seas), long enough in time for the maintenance of internal chemistries interesting for astrobiology. References: [1] Alexander C. M. O'D. et al (2012) Science, 1223474. [2] Alvarez L. W. et al. (1957) Phys. Rev., 105 (3), 1127. [3] Balin D. V. et al. (2011) Phys. of Particles and Nuclei,

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B5.3-0011-18 MODELING THERMAL EVOLUTION OF OCEAN WORLDS WITH CONVECTIVE ICE SHELLS

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Heat transportation inside a planet is the most fundamental process in planetary evolution. Previous numerical calculation methods for the thermal evolution considering thermal convection, however, are either time consuming or less accurate.

This study provides a calculation method of the convective temperature profile with a low calculation cost and a high accuracy. I apply this method to investigate the thermal evolution of two Saturnian icy satellites with subsurface oceans, Dione and Enceladus, under a wide variety of parameter conditions.

From the results, I find that each satellite requires several ten GW of heat to possess a severalten-km thick subsurface ocean. Dynamical tides may be able to account for such an amount of heat, though the reference viscosity of Dione's ice and the ammonia content of Dione's ocean need to be very high. This means that a nominal icy satellite model, which has been adopted by many previous studies, would not be appropriate for Dione. Note that such an extreme condition is necessary only when Dione has a thick subsurface ocean. Consequently, the results obtained in this study may indicate that Dione does not possess a thick subsurface ocean. If this is the case, it implies that the ice shell of Dione is stiff and is not in a minimum-stress state.

The major part of this study is published in JGR-Planets [1].

[1] Kamata, S. (accepted), One-dimensional convective thermal evolution calculation using a modified mixing length theory: Application to Saturnian icy satellites, J. Geophys. Res. Planets, doi:10.1002/2017JE005404.

B5.3-0012-18 WHAT CONTROLS THE CONCENTRATION OF SEA SALT IN PLANETARY OCEANS?

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Sea salt (sodium chloride or NaCl) is the most abundant dissolved constituent in the oceans of Earth and Enceladus [1]. It is also widely suspected to be a key component of the Europan ocean [2-4]. The NaCl concentration in terrestrial seawater is 0.47 mol/kg, and the Enceladus ocean is inferred to contain 0.05-0.2 mol NaCl/kg [1]. The NaCl content of Europa's ocean is presently unknown. It is important to understand the geochemical and geophysical controls on oceanic NaCl, as this constituent seems to be the general driver of ocean salinity (total dissolved salt content). This affects other properties of the ocean that are of broader interest including the liquid density, freezing point depression, electrical conductivity, and the activity of H2O. Building on my previous work [5], I have constructed geochemical mass balance models to explore the relevant parameter space. There are two primordial sources of chlorine on ocean worlds: rocky and icy materials. Releasing Cl from rocks requires water-rock interaction (Enceladus) or volcanic outgassing (Earth). Chlorine can be acquired in accreted ices if they form at low enough temperatures to allow the condensation of HCl hydrates (Enceladus) [6]. The example of Earth shows that having a very low planetary water/rock ratio greatly facilitates the formation of a salt-rich ocean. Also, the sub-chondritic total Cl abundance and its distribution on Earth [7] emphasize the important roles of outgassing and volatile loss. Nominally, I find that Earth's Cl is 90% outgassed, but only 10% of that was retained. On Enceladus, a key factor influencing the chlorinity is the ice/liquid water ratio, because ice (particularly as it ages) has a much lower capacity for storing passive brines. The Europan hydrosphere system is especially interesting and likely to be highly informative for developing a more general understanding, because it appears to provide a system that is intermediate to Earth and Enceladus. A preliminary prediction for Europa's ocean is an NaCl concentration of mol/kg, reflecting Europa's assumed formation under warm conditions (consistent with its relatively rock-rich composition), modest outgassing and loss of chlorine, and an assumed average ice shell thickness of 20 km. The corresponding electrical conductivity from dissolved NaCl is 5 mS/cm at 273 K. These and other model results will be detailed at the conference, as well as future mission tests. References: [1] Postberg et al., 2009, Nature 459, 1098-1101. [2] Hand and Carlson, 2015, GRL 42, 3174-3178. [3] Brown, 2001, Icarus 151, 190-195. [4]

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B5.3-0013-18 FATE OF SULFATE IN EUROPA'S OCEAN: HYDROTHERMAL REACTIONS, EXPERIMENTAL INSIGHTS, AND IMPLICATIONS FOR FUTURE MISSIONS

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Recent observations of Europa's surface suggest that a large quantity of exogenic sulfate originated from Io would have been supplied into its subsurface ocean. Despite the importance of sulfate to Europa's oceanic chemistry, little is known about its fate within the ocean. Here we report our experimental results on sulfate reduction in hydrothermal environments under the conditions comparable to Europa's seafloor. Using a newly-developed experimental system capable of performing on-line sampling of hydrothermal fluids during the experiments at 130 MPa and 300 deg.C., we first obtain the reaction rates of sulfate reduction under Europa's hydrothermal conditions. By introducing the experimental results into thermochemical equilibrium calculations of water-rock reactions, we also show that, if Europa's seafloor rock is basaltic, exogenic sulfate would be effectively consumed by hydrothermal reactions, leading to occurrence of a Na, Mg, H2S, and Cl-rich ocean. On the other hand, if Europa's rock is still chondritic, sulfate would accumulate within the ocean, resulting in occurrence of a Na and SO4-rich ocean. We propose that identification of salts on Europa's surface and in plumes through future missions would be critical to constrain Europa's rock composition and possible occurrence of hydrothermal activity.

B5.3-0014-18 THE GLOBAL GEOLOGY OF EUROPA: UNITS, THEIR DISTRIBUTION, AND IMPLICATIONS FOR FORMATION PROCESSES

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Understanding the age relations and distribution of the geologic terrains on Europa is paramount to gaining insight into the potential habitability of this icy world. To this end, we have generated a geologic map at the scale of 1:15 million that incorporates data at all resolutions collected by the Voyager and Galileo missions, allowing us to constrain global geologic and tectonic relations. Ten major geologic units are identified which includes the following: Low Albedo Ridge Material (lam)-low albedo material that irregularly surrounds large (>20 km) ridge structures; Ridged plains (pr)-distributed over all latitudes and characterized by subparallel to cross-cutting ridges and troughs visible at high resolution (<100 m/px); Band material (b)-linear to curvilinear zones with a distinct, abrupt albedo change from the surrounding region; Crater material (c), Continuous Crater Ejecta (ce) and Discontinuous Crater Ejecta (dce)-features associated with impact craters including the site of the impact, crater material, and the fall-out debris respectively; Low Albedo Chaos (chl), Mottled Chaos (chm) and High Albedo Chaos (chh)-disrupted terrain with a relatively uniform low albedo, patchy/variegated albedo, and uniform high albedo appearance respectively; and Knobby Chaos (chk) - disrupted terrain with rough and blocky texture occurring in the high latitudes.

In addition to the geologic units, our mapping also includes structural features-Ridges, Cycloids, Undifferentiated Linea, Depression Margins, Bands, and Troughs. We also introduce a point feature (at the global scale), Microchaos, to denote small (<20 km diameter) patches of discontinuous chaos material.

The completed map constrains the distribution of the different Europa terrains and provides a general stratigraphic framework to assess the geologic history of Europa from the regional to the global scale. Based on crosscutting relationships, we find the ridge plains are generally the oldest followed by bands. Chaos and microchaos cut all other features indicating they are the youngest terrains. Initial analysis of the distribution of microchaos suggests that it is not uniformly distributed across Europa, instead, it appears

to show an increase in density associated with the bands. We are currently assessing this relation as it implies disruption of the crust and communication between the subsurface and surface. In this presentation we will discuss the global-scale geologic terrains as well as our preliminary findings regarding the distribution of microchaos.

B5.3-0015-18 EVIDENCE OF A PLUME ON EUROPA FROM GALILEO MAGNETIC AND PLASMA WAVE SIGNATURES

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The icy surface of Jupiter's moon, Europa, is thought to lie on top of a global ocean. Signatures in some Hubble Space Telescope images have been associated with putative water plumes rising above Europa's surface. However, all telescopic detections reported were made at the limit of sensitivity of the data, thereby calling for a search for plume signatures in in-situ measurements. Here we report in-situ evidence of a plume on Europa from the magnetic field and plasma wave observations acquired on Galileo's closest encounter (E12) with the moon. On this flyby that dropped below 400 km altitude, the magnetometer recorded a 1000 km scale field rotation and a decrease of over 200 nT in field magnitude and the Plasma Wave Spectrometer registered intense localized wave emissions indicative of a brief but substantial increase in plasma density. Based on numerical modeling using a 3D multi-fluid magnetohydrodynamic (MHD) model, we show that the location, duration, and variation of the magnetic field and plasma wave signatures are consistent with the interaction of Jupiter's corotating plasma with Europa if a plume with characteristics inferred from Hubble images was erupting from the region of Europa's thermal anomalies. Our results provide strong independent evidence of the presence of plumes at Europa.

B5.3-0016-18 QUANTIFYING THE ACCESS OF JUPITER'S MAGNETOSPHERIC PLASMA TO EUROPA'S SURFACE THROUGH A MULTI-FLUID MHD MODEL

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Europa's space environment is controlled by the wobbling of Jupiter's magnetic field, the magnetic response to this wobbling induced in the conducting subsurface ocean, and the interaction of Jupiter's magnetosphere with Europa's ionosphere and extended exosphere. We have developed a multi-fluid MHD model for Europa's plasma interaction which self-consistently solves for the bulk properties of 3 ion fluids and the electromagnetic fields in the vicinity of the moon. To validate our model, we have simulated the Galileo E4 Flyby using the observed plasma and magnetic field conditions. Our model has accurately reproduced Galileo magnetometer observations along the flyby trajectory, and provides full 3D density and velocity fields for O+ and O+ ionized from Europa's neutral O2 exosphere, and the thermal, corotating O+ from Jupiter's magnetosphere. Based on the three-ion-fluid MHD model, we have mapped the distribution of the magnetospheric plasma that was able to penetrate the plasma interaction to reach Europa's surface. We find that while the majority of downward flux impinges on the upstream hemisphere, the surface impact by the ambient magnetospheric O+ ions exhibits a slight preference towards the anti-jovian hemisphere due to the influence of the convectional electric field. Under the E4 flyby conditions, we estimate that about 13% of the available upstream O+ ions precipitate to Europa's surface. Most of the ambient plasma is instead diverted around the moon due to the plasma interaction with the ionosphere. This precipitation represents the contribution of thermal plasma to the sputtering interaction with Europa's icy surface which replenishes the O2 exosphere.

B5.3-0017-18 LABORATORY SIMULATION OF EUROPA'S SURFACE PROPERTIES UNDER RADIATION ENVIRONMENT

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Among the ocean-worlds targets, Europa has the most dynamic environment. Gravitational fluxing, radiation from Jovian magnetosphere, and potential subsurface ocean/mantle interface. It is important to understand surface properties and estimate their composition vs. physical properties for both remote sensing and in-situ missions to Europa. The Jovian magnetosphere consists of ions such as H+, O+, S+, and electrons at MeV energies. Electrons penetrate by far the deepest with estimates of a few centimeters to tens of centimeters on the trailing hemisphere of Europa, where electron energies up to 25 MeV are expected to reach the surface. Electrons with higher energy than 25 MeV would land on the leading hemisphere, though their flux drops exponentially [1]. In order to quantify this effect under realistic Europa trailing hemisphere conditions, we devised, built, tested, and obtained preliminary results using our ICE-HEART instrument. Our Ice Chamber for Europa High-Energy Electron And Radiation-Environment Testing (ICE-HEART) operates at 100 K. The telescopic chamber can accommodate ice cores up to 110 cm in length and diameters of 6 cm. We use a novel Halbach cylindrical mag- net to remove electrons allowing only X-rays to pass through, giving us unique opportunity to determine the role of secondary X-rays on Europa's near-surface habitability. Using this ICE-HEART instrument at the NIST Medical and Industrial Radiation Facility (MIRF), we conducted electron bombardment studies to simulate Europa's trailing hemisphere at electron energies between 10 MeV and 25 MeV. We determined surface hardness, electron-penetrating depths and secondary X-ray production, and coloration of both pure ice and hydrated salts of NaCl and MgSO4. Our preliminary results show that NaCl and MgSO4-containing ices that are thought to be relevant to Europa [2] show different hardness changes as well as secondary X-ray yields compared to pure water ice. Results from these studies will be presented and the relevance to the Europa lander mission concept will be discussed.

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B5.3-0018-18 SALINIBACTER RUBER, A MODEL TO STUDY THE HABITABILITY OF EUROPA'S OCEAN

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Life on Earth can develop in environments considered extremes when compared to the conditions in which most of life forms on Earth develops. The organisms that proliferate in these environments are called extremophiles. As some of the extreme environments possess conditions like those described for some bodies of astrobiological interest in the solar system, the organisms that thrive in extreme environments are then a good model to understand the limits of terrestrial life when they are exposed to those conditions [1]. Of our interest is Europa, one of the satellites of Jupiter. With temperatures between 50 and 125 K, a thin atmosphere composed mostly of molecular oxygen (O2), and a vast liquid water ocean found under its icy surface and enriched with sulfated salts like MgSO4 and Na2SO4, it is one of the places where habitability conditions can be evaluated [2][3].

We take Salinibacter ruber as our biological model to study the adaptation strategies of halophilic organisms when exposed to sulfated salts. S. ruber is an extreme halophilic bacterium whose growth and adaptation to different concentrations of NaCl and MgSO4 have been previously studied in our group [4]. Now, it was exposed to different concentrations of MgSO4and Na2SO4. Growth curves were used to determine the optimal growth concentration on each salt condition, the growth rate, and the duplication time. The presence of compatible solutes was evaluated by quantitative NMR, and the expression of proteins in different saline stress conditions was identified by electrophoresis and shotgun proteomics.

The experimental evidences will be used to propose arguments about the habitability of the salty ocean of the satellite Europa, and about the tolerance and adaptation strategies that can be used by this or other halophiles in an extraterrestrial scenario.

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B5.3-0019-18 TITAN'S GLOBAL GEOLOGY FROM CASSINI: IMPLICATIONS FOR THE GEOLOGIC HISTORY

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We investigate the geologic history of Titan through mapping and analyzing the distribution of observed geomorphologic features using a combination of Cassini data collected by RADAR, VIMS (Visual and Infrared Mapping Spectrometer), and ISS (Imaging Science Subsystem). Determining the spatial and superposition relations between geomorphologic units on Titan leads to an understanding of the likely time evolution of the landscape and gives insight into the process interactions that drove its geologic history. We have used all available datasets to extend the mapping initially done by Lopes et al. (2010, Icarus, 205) and Birch et al. (2017, Icarus, 282) to a global map at 1:800,000 scale in all areas covered by the RADAR Synthetic Aperture Radar (SAR). We show how we are extending the map to regions not covered by SAR, to produce a 1:1,500,000 scale map compatible with USGS standards. We use the map to infer the stratigraphic relations among Titan's different terrain types, which in turn allows us to establish the sequence of geologic processes that have shaped the satellite's surface.

Continuing the initial work described in Lopes et al. (2010, Icarus, 205) and the detailed mapping of the Afekan region by Malaska et al. (2016, Icarus, 270) and of the polar regions by Birch et al. (2017, Icarus 282), we have established the major geomorphologic unit classes on Titan. These broad classes are: hummocky/mountainous terrains, labyrinth terrains, dunes, plains, craters, and lakes. We have also mapped individual features such as craters, channels nd their deposits, and candidate cryovolcanic features. We have found that the hummocky/mountainous terrains are the oldest units on the surface and appear radiometrically cold, indicating icy materials (Janssen et al., 2016, Icarus, 270). The labyrinth terrains consist of highly incised dissected plateaux with medium radar backscatter and appear radiometrically warm, indicating organic materials. Dunes are the youngest units and appear radiometrically warm, indicating organic sediments (Janssen et al., 2016, Icarus 270). The plains are younger than both the mountainous/hummocky and the labyrinth unit classes. Undifferentiated Plains form the most widespread unit on Titan and are interpreted as aeolian deposits that also appear radiometrically warm (Lopes et al. 2016, Icarus 270). Dunes and lakes are the youngest unit classes on Titan; it is likely that the processes forming them are still active. Characterization and comparison of the properties of the unit classes and the individual features with data from radiometry, ISS, and VIMS provide information on their composition and possible provenance. VIMS analysis shows that compositional variations can also exist within the same class of unit (Solomonidou et al. 2016, Icarus, 270). For example, undifferentiated plains located closer to the equatorial dunes appear to be contaminated by dune materials. The correlations among the data sets not only aid in the interpretation of their origin, but also allow us to infer global distributions within regions not covered by SAR. This is particularly important as SAR data did not provide complete coverage of Titan during the Cassini mission.

B5.3-0020-18 IMPROVED RETRIEVAL OF TITAN SURFACE TOPOGRAPHY FROM THE DELAY-DOPPLER ALGORITHM APPLIED TO CASSINI RADAR ALTIMETER DATA

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During its 13 years of activity the Cassini RADAR altimeter acquired 40 elevation profiles of Titan, Saturn's largest moon. Due to flyby geometry the spacecraft operated at various altitudes, providing broad-scale surface topography measurements. We applied the delay/Doppler algorithm to the radar altimeter data products, adapting it to the specific orbital geometry conditions of the Cassini spacecraft. We present results obtained for the observations of different terrain units, such as dunes, hummocks and mountains. We show that the coherent processing combined with multi-look of Doppler filters, can permit up to tenfold improvement of the along-track resolution and a remarkable radiometric enhancement respect to the standard products.

B5.3-0021-18 TITAN'S INTERIOR STRUCTURE FROM THE COMBINED ANALYSIS OF CASSINI GRAVITY AND TOPOGRAPHIC DATA

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Although Titan is best known for its dense atmosphere and hydrocarbon seas and lakes, it is also an ocean world with a deep water ocean like Europa and Enceladus. One major difference is that this ocean may be sandwiched between the icy crust and a high-pressure ice layer, thus limiting the transfer between the silicate core and the atmosphere. This study uses the recently released shape data [1] to interpret the values of the degree 2 gravity coefficients that have been published [2, 3]. The shape data are transformed into topographic data by using a reference ellipsoid defined by the degree 2 gravity coefficients [2]. The difference between the topography using the reference ellipsoid and the topography relative to an equipotential defined with the higher degree gravity field [3] is equal to 25 m at max, which is less than the uncertainty on the measurements. Titan's long wavelength topography is characterized by polar depressions and elevated equatorial regions that strongly influence interpretations of the gravity data. Several geodynamic models can explain these topographic features: variations of the crustal thickness related to the amount of tidal dissipation inside the crust [4], latitudinal variations of the heat flux at the crust/ocean interface [5], or lateral density variations between the poles and the equatorial regions [6]. The models are explored with different degrees of compensation to investigate the effect of topographic anomalies on the values of the degree 2 gravity coefficients determined from Cassini spacecraft orbit. For each model, the three moments of inertia are computed numerically by discretizing Titan's interior in spherical coordinates and then the degree 2 gravity coefficients are deduced. The simplest model is a fully compensated Pratt model for the polar depressions and fully compensated Airy model for the equatorial topography. However, if the equatorial topography is not compensated because the icy crust is strong enough to prevent compensation, then the degree 2 gravity coefficients can be explained by a 80% compensation Pratt model (or 75% compensation Airy model) for the polar depressions. Although non-unique, the crustal model is bounded by the values of the gravity coefficients and topographic data provided by the Cassini mission. These two models imply very different interior structure. The fully compensated model suggests that Titan's ocean has been in contact with the silicate core in the recent past, providing an environment similar to the terrestrial sea floor.

This work has been performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract to NASA.

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B5.3-0022-18 INSIGHTS ON THE FORMATION OF RAISED RIMS AROUND TITAN'S POLAR BASINS FROM CASSINI NEAR-IR AND MICROWAVE OBSERVATIONS

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We investigate the spectral and microwave properties of the raised rims of five liquid-filled Sharp Edged Depressions (SEDs) [e.g. 1;2;3] in Titan's North pole using both Cassini Visual and Infrared Mapping Spectrometer (VIMS) and RADAR data. The raised rims under investigation have been detected by RADAR stereogrammetry; they are a few hundreds of meters in height, a few kilometers wide, and in some cases, only partially surround the liquid-filled basin. Dedicated methods have been developed to extract their infrared spectra from a high-resolution VIMS cube [4;5] and their 2.2-cm emissivity from RADAR radiometry observations [6;7]. Comparison of the evaluated properties from the SEDs' terrains to that of other Titan regions of interest from all around the globe provide insights into the formation mechanisms of the elevated ramparts around Titan's SEDs. In particular, the emissivity of the considered raised rims is very close to that of the labyrinthic terrains and of the bottom of empty lakes. This suggests that the composition of the raised rims is most likely dominated by organics (rather than water ice). This is supported by the VIMS analyses that show spectral responses close to that of tholinlike materials and is consistent with of the hypothesis of a karst case-hardening post-deflation remnant hypothesis [8]. [1] Hayes, A.G. et al. (2017). Geophysical Research Letters, 44, 11.74511.753; [2] Michaelides, R.J. et al. (2016). Icarus, 270, 57-66; [3] Birch, S.P.D. et al. (2017).

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B5.3-0023-18 TITAN MOLECULAR MINERALS: THE ROLE OF HYDROGEN CYANIDE

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Titan, the largest moon of Saturn, is considered a prebiotic chemical laboratory on a planetary scale. Photochemistry in the atmosphere induced by solar radiation and energy from Saturn's magnetosphere causes a chemical cascade, as N2 and CH4 dissociate and generate organic molecules ranging from simple (ethane, acetylene, HCN) to complex (>10,000 Da). Most of these molecules are transported down to the surface, where they may react and interact as they become integrated into the unique geology of Titan. We have demonstrated in previous work that two common organic molecules on Titan, ethane and benzene, form a stable co-crystalline structure at Titan surface temperatures. This co-crystal represents an exciting new class of compounds for Titan's surface, which would fill the role equivalent to a hydrated mineral in this environment.

The discovery of one Titan organic mineral has led us to search for others. We have recently characterized several possible minerals incorporating acetylene, one of the primary solid photochemical products generated in Titan's atmosphere. These co-crystals - the acetylene series form spontaneously and are stable under Titan surface conditions. The acetylene-ammonia co-crystal, for example, is robust against exposure to pluvial (rain) events of methane, ethane or propane.

We are now investigating the HCN series. Hydrogen cyanide (HCN) may be even more abundant than acetylene on the surface of Titan. Preliminary evidence indicates that HCN associates with ethane and acetylene at 90 K, although the red and blue shifts observed in the Raman (up to 6 cm−1) are not quite as large as the shifts observed for the other co-crystal series involving benzene (up to 12 cm−1) and acetylene (up to 66 cm−1). This may be due to weaker associations between the species. We are exploring interactions of HCN with other hydrocarbons to better elucidate this relationship.

B5.3-0024-18 ON THE CARBON ISOTOPE RATIO IN TITAN'S ATMOSPHERE AND INTERIOR

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To study the evolution of carbon isotopes in Titan's atmosphere, the methane isotope ratio 12C/13C = 89.7 ± 1.0 (Nixon et al. 2012) should be compared with those in the haze precipitating to the surface and in sputtering and ion escape. The former is calculated at 12C/13C

= 88.3 ± 3.0 using the observed carbon isotope ratios in the photochemical products (hydrocarbons, nitriles, and oxides) and their column rates of condensation and polymerization from the photochemical model by Krasnopolsky (2014). Correction for sputtering and ion escape results in 12C/13C = 88.5 ± 3.0 as the final value for the total loss of carbon. If the current loss of methane of 7 kg cm−2 Byr−1 is replenished by outgassing of methane clathrate hydrate

CH4*5.75H2O, then this source should have 12C/13C equal to the above value. It is smaller but within the uncertainties of 12C/13C = 92.4 ± 5.4 in the outer Solar System and 89.4 on the Earth. The difference is even greater for a scenario with injection of methane into Titan's atmosphere and its gradual depletion to the present abundance.

B5.3-0025-18 MACROMOLECULAR ORGANIC COMPOUNDS FROM ENCELADUS

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Saturn's icy moon Enceladus harbors a global subsurface ocean, which is thickest (50 km) below the south polar region. There, through warm fractures in the less than 5 km thick ice crust, jets of vapor and nanometer to micrometer-sized ice grains emerge from the ocean into space. Two mass spectrometers aboard the Cassini spacecraft frequently carried out compositional in situ measurements of material emerging from the subsurface of Enceladus. These measurements were made inside both the plume and the E ring. The Cosmic Dust Analyser (CDA) showed that a large fraction of the ice grains are direct samples of subsurface alkaline ocean water with mild salinity. The CDA also uncovered the first evidence of hydrothermal activity taking place at the interface of the moon's rocky core and its ocean. The detection of molecular hydrogen in the plume by the Ion and Neutral Mass Spectrometer (INMS) provided further support for fluid-rock interactions, most consistent with exothermic serpentinization reactions, similar to certain alkaline hydrothermal systems of Earth's oceans, such as Lost City in the Atlantic Ocean. Because of the relatively low density (2500 kg/m3) of the moon's core it is likely porous and percolated by ocean water. Hydrothermal reactions thus probably take place deep inside the core and are likely powered by tidal dissipation.

Previous CDA and INMS measurements showed that the plume emits organic material of low molecular weight both, in the gas phase and in about 25% of the ice grains, so-called Type 2 grains but complex organics emerging from Enceladus oceans have not been reported before. Here we will present spectra of emitted ice grains containing concentrated, macromolecular organic material with molecular masses above 200u. The data provides key constraints on the macromolecular structure and is suggestive of thin a organic-rich film on top of the oceanic water table. We suggest a large-scale ocean convection mechanism that, together with bubbles of volatile gases, transports these and other materials from the moon's core up to the ocean surface and ultimately, by dispersion from bubble bursting, into space.

B5.3-0026-18 HIGH ENERGY IRRADIATION OF ORGANICS AND ICES: IMPLICATIONS FOR ICY MOONS SUCH AS EUROPA AND ENCELADUS

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The magnetic fields of Saturn and Jupiter intensify the radiation environment and yield high energy electrons which continually bombard the surface of their icy moons Enceladus and Europa. Polycyclic aromatic hydrocarbons (PAHs) are a class of organic molecules which have been identified in comets, meteorites, and interplanetary dust particles (IDPs). It is estimated that 30,000 tons of PAH containing IDPs fall on the Earth each year (Matrajt, et al. 2006). Given PAHs nearly ubiquitous presence within the Solar System and their in-fall onto Earth's surface, it is expected that PAH or aromatic molecules would be part of any organic inventory present within the ices of these moons. Recently we concluded preliminary experiments regarding the processing of solid state PAH thin films and water ice via proton, electron and UV irradiation. As identified by infrared spectroscopy, these experiments produced some very interesting results. This presentation will discuss the experimental results and their implications for the chemistry occurring on these icy bodies.

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B5.3-0027-18 FRACTURES ANALYSIS OF ICY SATELLITE SURFACES

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The analysis of icy satellites surfaces provides hints regarding their interiors, as well as their surface mechanical behavior. Indeed, faults distribution and fault populations on the icy satellite can reveal insights into the evolution of its surface that cannot be gained with other techniques. Statistical characterization of fault-population attributes, such as length and clustering, are fundamental means to explore deformation rates, stress transmission modes, rheology of the medium, and mechanical stratification [e.g. 1,2,3,4,5]. Fractal analysis has been used in terrestrial studies to determine the thickness of the fractured (brittle) crust [e.g., 6,7,2,8]. In the same fashion, on icy satellites we can constrain the depth at which fractures penetrate the brittle ice layer exploring some of the main characteristics of fault populations, such as length and clustering. A previous work [9] has validated the use of this technique on Enceladus fractures estimating the depth of the mechanical discontinuity of the ice shell in five different regions. Such discontinuity is the depth to which fractures penetrate the brittle ice layer above the ductile one [9]. In this work, we analyze the grooves' spatial distribution on the surface of Ganymede to provide an estimate of the thickness of the brittle icy crust. Grooves occupy the majority of light terrains and are organized in systems that crosscut or intersect with each other [10]. They are interpreted as extensional fractures and/or faults, whose origin is still debated. We mapped grooves in well-defined geological units, such as light grooved units, light irregular units and light subdued units, related to tectonic deformation, as reported in the Ganymede geological map provided by [10]. Preliminary results obtained in the area around Harpagia Sulcus (10°S, 40°E) demonstrate i) the prevalence of fractal populations of grooves and ii) a depth to which fracture penetrate the icy crust is about 90 km. These preliminary results will be investigated by extending the analysis also to other regions of Ganymede as well.

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B5.3-0028-18 PRESENT AND FUTURE ACTIVE CENTRES OF ENCELADUS

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Enceladus is the smallest body in the Solar System where volcanic activity is observed. It is concentrated in the South Polar Terrain (SPT) where every second 200 kg is ejecting into space [1, 2, 3, 4, 5, 6]. The loss of matter from the interior should lead to global compression. However, compressive forms are not dominant on Enceladus. [6, 7] proposed tectonic model that explains this paradox.

The loss of the volatiles results in a void and motion to fill the void in statu nascendi as: (i) subsidence of SPT, (ii) flow of the matter in the mantle, (iii) motion of plates towards SPT. If emerging void is being filled by the subsidence of SPT only, then the velocity of subsidence is mmyr-1 [6, 7]. Note that the reduction of the satellite area is not a result of compression but it is a result of the plate sinking.

[7] presents experimental model of SPT subsidence in viscoelastic material. He found that contrary to expectations, the 'kinks' (formed above vertices of plate) appear to be stable features.

We improve numerical model of [7] of suggested processes. The results indicate the subsidence rate of 0.04 mmyr-1 for Newtonian rheology. For non-Newtonian rheology the rate could be lower. If thermal convection is included the results are more complicated, the adjacent plates to move into or out of the SPT.

There are some traces that could be attributed to past active centers similar to STP. Moreover, the ovoid-shaped depression down to 2 km deep, of size 200×140 km with the center at 200E, 15S is a good candidate for the future center of activity [6, 7]. The depression could indicate the partial melting of the mantle. It could lead to an increase of heating and formation of the center of activity. More realistic calculations of distribution of tidal heating are necessary to achieve better understanding of the present and future activity of Enceladus.

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B5.3-0029-18 FIRST TECTONIC STRESS MAP ACROSS ENCELADUS' SPT AND POSSIBLE DYNAMIC CAUSES

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Enceladus is a small moon of Saturn (radius 250 km), distinguished by its uniquely active south pole. The moon's geological activity is expressed as regularly erupting plumes sourced from a series of parallel "tiger-stripe" fractures (TSF) (Porco et al., 2006). The cyclic nature of these eruptions are attributed to diurnal variations of tidal stress (Hurford et al., 2007). There is, however, a mismatch in timing between Cassini's observations of peak eruption and what is predicted by the theory of tidally modulated cracks (Nimmo et al., 2014). Existing models have attempted to reconcile the plume timing discrepancy by invoking stress relaxation in a viscoelastic ice sell (Běhounková et al., 2015). However, such an approach assumes the stress in the ice shell to be entirely induced by tidal stress, neglecting the role tectonically induced stress play in order to support the high (>1 km) topographic relief around the moon's south pole (Schenk and McKinnon, 2009). We propose to address this by relaxing the assumption of a tectonic stress-free ice shell and offering an analytical tensor analysis decomposing tidal and tectonic stresses in the ice shell. We thus investigate the total stress as a result of three sources: tidal stress from a bulged figure, stress induced by physical libration (Hurford et al., 2009), and tectonic stress. With the aforementioned framework, we derive the magnitude and direction of tectonic stress at numerous points along the active TSFs, resulting in a comprehensive tectonic stress map of Enceladus' South Polar Terrain (SPT). We find tectonically derived stresses to be non-trivial; while these results are perhaps not surprising, the need for a more comprehensive plume eruption model, one that includes both tidal and tectonic stresses in its mathematical framework, is evident. We posit that perhaps the fundamental question of eruption timing may lie in cultivating this understanding.

B5.3-0030-18 THE INTERIOR OF ENCELADUS JUST AFTER CASSINI

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While the observation of a large-scale plume emitted by Enceladus occurred early after the insertion of the Cassini spacecraft around Saturn, a coherent view on the interior processes that power and feed this activity started emerging only in the latest year of the mission. Thanks to a flexible payload as well as multiple flybys during the extended mission, analyses of Enceladus data (composition of materials originating from the moon's interior, geophysical measurements and long series of surface images) composed a view where a global salty ocean is present underneath an ice crust of very uneven thickness (20-25 km in average, less than 5 km beneath the south pole, more than 30 km in some equatorial regions). Density of the rock core implies a significant (water-filled) porosity. Furthermore, several independent chemical clues indicate that high-temperature (>363 K) hydrothermal processes probably occur at present, deep in the moon.

In this presentation, we show that tidal deformation within a rock core filled with interstitial liquid water can produce a sufficient amount of heat to enable the persistence of a global ocean, for at least tens of Myr. Thermal convection of interstitial water within the tidally heated core leads to strongly focused hot upwellings, especially beneath the poles. Modeled temperatures agree with the range inferred from compositional measurements by Cassini that indicate waterrock interaction and might be detected in the gravity data. Powerful hotspots (several GW) are thus predicted at the seafloor. While ocean dynamics partly filter this strongly heterogeneous heat flux at the seafloor, our models demonstrate that heat supply to the base of the ice shell is expected to be largest in regions coinciding with the lowest ice thickness - the transport time of organic products by ocean thermal vents would match the constraints derived from Cassini measurements (typically a few months).

B5.3-0031-18 JUICE: A EUROPEAN MISSION TO JUPITER AND ITS ICY MOONS

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JUICE - JUpiter ICy moons Explorer - is the first large mission in the ESA Cosmic Vision programme. Due to launch in May 2022 and arrival at Jupiter in October 2029, it will make detailed observations of the Jovian system, with a special focus on the planet itself, its giant magnetosphere, and the three icy moons: Ganymede, Callisto and Europa. The current mission baseline assumes a Jupiter tour of almost three years including two close flybys of Europa, fifteen flybys of Ganymede, and twelve flybys of Callisto, together with a high inclination phase of six months in order to characterize Jupiter high latitudes. In August 2032, JUICE will then orbit Ganymede for at least ten months, down to an altitude of 500km. The first goal of JUICE is to to characterize the conditions that might have led to the emergence of habitable environments among the Jovian satellites. Ganymede is a high-priority target as it provides a unique laboratory for analyzing the nature, evolution and habitability of icy worlds, including the characteristics of subsurface oceans, and its unique magnetosphere interaction with the Jovian magnetodisc. For Europa, the focus will be on recently active zones, while Callisto will be explored as a witness of the early Solar System. JUICE will also investigate the Jupiter system as an archetype of gas giants. The circulation, meteorology, chemistry and structure of the Jovian atmosphere will be studied from the cloud tops to the thermosphere and ionosphere. JUICE will also study the properties of the magnetodisc, and will analyse the coupling processes within the magnetosphere, ionosphere and thermosphere. The payload consists of 10 instruments plus a ground-based experiment (PRIDE) to better constrain the S/C position. A remote sensing package includes imaging (JANUS) and spectral-imaging capabilities from the UV to the sub-mm wavelengths (UVS, MAJIS, SWI). A geophysical package consists of a laser altimeter (GALA) and a radar sounder (RIME) for exploring the moons, and a radio science experiment (3GM) to sound the atmospheres and to determine the gravity fields. The in-situ package comprises a suite to study plasma and neutral gas environments (PEP) with remote sensing capabilities via energetic neutrals, a magnetometer (J-MAG) and a radio and plasma wave instrument (RPWI).

B5.3-0032-18 ADDRESSING THE HABITABILITY OF EUROPA WITH THE EUROPA CLIPPER MISSION

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The ice-covered world Europa, one of the four large Galilean satellites, may be a habitable world. Europa is about the same size as Earth's Moon and is mostly rock, with an outer icerich shell that is quite dynamic. Its young, bright, icy landscape is crisscrossed by a network of cracks and ridges, interrupted by smooth bands, disrupted chaotic terrain, and exhibits few large craters. Several lines of scientific evidence, which include observations of gravity and induced magnetic fields as well as results from thermal modeling of the moon's interior, point to the conclusion that Europa likely has a global ocean of water under the ice, maintained in liquid form by tidal flexing and heating as the moon moves in its eccentric orbit about Jupiter. The orbital eccentricity is maintained by gravitational resonances with the other Galilean moons and is likely long-lived. While the presence of the ocean is compelling, it is unknown whether Europa is for certain habitable. Thus, investigation of Europa is a top priority for planetary exploration.

The science goal of NASA's Europa Clipper mission is: Explore Europa to investigate its habitability. The mission's three objectives are focused on Europa's ice shell and ocean, composition, and geology. To achieve the mission's science goal and objectives, the spacecraft will conduct more than 40 flybys of Europa with closest approach altitudes in the range of 25-100 km, with a capable suite of nine remote sensing and in situ instruments plus gravity science. During the time period near closest approach, the remote sensing instruments are in a nadir-looking orientation, the fields of view of the particle sensors encompass the Keplerian ram direction, and supplemental antennas enable gravity science. In this configuration, the entire payload can collect data simultaneously during the flybys. The anticipated observations will facilitate the search for subsurface water, chemistry compatible with habitability, and active geological processes. In studying Europa in depth, the Europa Clipper mission, currently in Phase B, will enable a leap in scientific understanding of ocean worlds and their potential habitability.

B5.3-0033-18 THE EUROPA LANDER MISSION CONCEPT AND SCIENCE GOALS OF THE 2016 EUROPA LANDER SCIENCE DEFINITION TEAM REPORT

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In June of 2016 NASA convened a 21-person team of scientists to establish the science goals, objectives, investigations, measurement requirements, and model payload of a Europa lander mission concept. The Europa Lander Science Definition Team (SDT), following a charter from NASA HQ, refined these requirements into a viable Europa Lander mission concept, and published the Europa Lander Study 2016 report (Europa Lander, 2016). Since the completion of the SDT report, the Europa Lander mission concept team at JPL has refined the mission concept through a Mission Concept Review (MCR), and subsequently through the advice and oversight of an external advisory board. This board was active during the Summer and Fall of 2017, and a final report was presented to NASA HQ in the late Fall of 2017. The Europa Lander mission concept team is currently addressing guidance from NASA HQ in terms of technologies and mission architecture. The science of the mission concept has remained largely constant with respect to the 2016 SDT Report.

Europa Lander SDT Science Goals The NASA HQ Europa Lander SDT Charter goals, in priority order, were as follows: 1. Search for evidence of life on Europa. 2. Assess the habitability of Europa via in situ techniques uniquely available to a lander mission. 3. Characterize surface and subsurface properties at the scale of the lander to support future exploration of Europa. Within Goal 1, the SDT developed four Objectives for seeking signs of life (i.e., biosignatures). These include the need to: a) detect and characterize any o ganic indicators of past or present life, b) identify and characterize morphological, textural, and other indicators of life, c) detect and characterize any inorganic indicators of past or present life, and d) determine the provenance of Lander-sampled material. Within the Goal 1 investigations and measurement requirements there are more than seven distinct and complementary approaches for detecting potential biosignatures within material sampled from Europa's surface and near-subsurface. Goal 2 focuses on Europa's habitability and ensures that even in the absence of the detection of any potential biosignatures, significant ocean world science is still achieved. The objectives within Goal 2 are to: a) characterize the non-ice composition of Europa's near-surface material and determine whether there are indicators of chemical disequilibria, and b) determine the proximity to liquid water and recently erupted materials at the lander's location. Goal 3 ensures that the landing site region is quantitatively characterized in the context needed for

Goals 1 and 2, and that key measurements about Europa's ice shell are made to enable future exploration. The objectives for Goal 3 include the need to: a) observe the properties of surface materials and sub-meter-scale landing hazards at the landing site, including the sampled area (connecting local properties with those seen from precursor Europa flyby remote sensing), and b) characterize dynamic processes on Europa's surface and ice shell over the mission duration to understand exogenous and endogenous effects on the physiochemical properties of surface and shallow sub-surface materials. The Europa Lander mission concept is capable of achieving a suite of measurements such that if potential biosignatures are present on Europa's surface they could be detected at levels comparable to those found in benchmark environments on Earth, and, further, that even if no potential biosignatures are detected, the science return of the mission will significantly advance our fundamental understanding of Europa's chemistry, geology, geophysics, and habitability.

References: Europa Lander Study 2016 Report: Europa Lander Mission. JPL D-97667. https://solarsystem.nasa.gov/docs/EuropaLanderSDTReport2016.pdf

B5.3-0034-18 CURRENT AND FUTURE EXPLORATION OF THE HABITABILITY POTENTIAL OF ICY MOONS AROUND GIANT PLANETS

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Recent studies have demonstrated the habitability potential of the natural satellites of gas giants, which causes our thinking of the habitable zone to extend to the outskirts of the solar system. Several satellites around giant planets, Jupiter and Saturn in particular, show evidence of their harboring liquid water underneath the surface, organic chemistry in their atmospheres or exospheres, as well as energy sources. Measurements from the ground but also by the Voyager, Galileo and the Cassini spacecraft revealed the interest of these satellites in this context, and our understanding of habitability in the solar system and beyond can be greatly enhanced by investigating several of these bodies.

Indeed, several of the moons show promising conditions for habitability and the development and/or maintenance of life. Europa, Callisto and Ganymede are hiding, under their icy crust, undersurface liquid water oceans which, in the case of Europa, may be in direct contact with a silicate mantle floor and kept warm by tidally generated heat. Titan and Enceladus, Saturn's satellites, were found by the Cassini-Huygens mission to possess active organic chemistry with seasonal variations in their atmospheres, unique geological features and internal liquid water oceans. As revealed by Cassini, the liquid hydrocarbon lakes currently distributed mainly at polar latitudes on Titan are ideal isolated environments to look for biomarkers.

If the silicate mantles of Europa and Ganymede and the liquid sources of Titan and Enceladus are geologically active as on Earth, giving rise to the equivalent of hydrothermal systems, the simultaneous presence of water, geodynamic interactions, chemical energy sources and a diversity of key chemical elements may fulfil the basic conditions for habitability. These would be investigated with future space missions.

Indeed, after the discoveries by Cassini-Huygens at Saturn and Galileo at Jupiter, such potential habitats will be investigated with appropriate designed space missions in the future, like ESA's L1 JUICE and NASA's Europa Clipper mission. I will review our current knowledge of the habitable conditions around these moons and discuss future exploration, with a focus on the JUICE mission.

B5.3-0035-18 LABORATORY ANALOGUES FOR THE SURFACES OF JUPITER'S ICY MOONS

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The surfaces of Jupiter's icy moons are continually irradiated by charged particles from the Jovian plasma environment. This irradiation triggers chemical reactions in the surface ice and also acts as an atmospheric release process. Remote observations, theoretical modelling, and laboratory experiments must be combined to understand this plasma-ice interaction.

Over the last years, we experimented with a wide variety of water ice samples, ranging from dense ice films (100 nm) on microbalances to thick (1 cm) and porous ice regolith. We subjected these ice samples to electron and ion irradiation and quantified the sputtering yields and other loss processes. Now we shift our attention to studying the chemical and physical alterations in ice samples upon long-term irradiation.

In this presentation, we will present first results of our recent and ongoing experimental work: We irradiate thick porous samples of water ice with an electron beam at energies representative of the Jovian plasma and monitor the sample with a camera in the visible and near-infrared spectral range.

B5.3-0036-18 COUPLED INTERIOR STRUCTURE AND EXTERIOR PLASMA MODELS OF EUROPA

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In the search for life elsewhere, Europa may be the top candidate. Remote sensing data suggest that beneath its icy shell lies a liquid water ocean, in contact with a rocky silicate mantle. Magnetic field measurements from the Galileo mission provide a strong confirmation that Europa has a subsurface ocean; an induced magnetic field is observed that implies a conducting layer consistent with salty water. However, Europa is immersed in a complex plasma environment that reacts to—and generates—its own magnetic fields, complicating any and all attempts to model Europa's magnetic induction. Past studies of Europa's ocean structure have applied simplified models for Europa's interior, or incomplete models of the surrounding plasma environment.

In this work, we simulate Europa's magnetic interactions with coupled models for both the interior and exterior, to better understand how ocean structure affects Europa's magnetic induction signature. We apply a 1D thermodynamic model for the interior of Europa, generated by PlanetProfile, to obtain realistic geophysical parameters such as electrical conductivity. These parameters form inputs to 3D global multifluid simulations of Europa's induction and plasma environment. The resulting coupled model has strong explanatory power, through self-consistent modeling of plasma behavior over many scale ranges, flexible representation of interior conducting layers, and more accurate accounting of planetary and upstream plasma conditions.

A detailed description of our coupled model, initial results, and plans for its use will be presented.

B5.3-0037-18 UNDERSTANDING EUROPA'S SURFACE TEXTURE FROM REMOTE SENSING PHOTOPOLARIMETRY

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We use a Goniometric Photopolarimeter (GPP) to measure reflectance and polarization phase curves of the light reflected from particulate materials that simulate planetary regoliths. We compare these laboratory results to astronomical remote sensing observations in an effort to understand the chemical and textural state of an object's surface. Our GPP methodology employs the Helmholtz Reciprocity Principle (1, 2): the incident light is linearly polarized, and the intensity of the reflected component is measured. With this technique, the light encounters fewer optical surfaces, improving signal-to-noise. The Helmholtz Reciprocity Principle holds that these lab measurements are physically equivalent to the astronomical measurements. Here we present our new and improved reflectance and polarization phase curves of highly reflective, fine-grained, media that simulate the regolith of Jupiter's satellite Europa. We previously reported that these materials exhibit an increase in circular polarization ratio with decreasing phase angle; this suggests coherent backscattering (CB) of photons in the medium (3). Our new laboratory data exhibit reflectance and polarization phase curves that are remarkably similar to published astronomical results (4), and also to measurements reported from other GPP laboratories; e.g., Shkuratov et al. report that the polarization properties of these particulate media are also consistent with the CB enhancement process (5). The close match between our measurements (fine-grained and loosely packed, with void space exceeding 90%) and reported photopolarimetric measurements of Europa indicate that Europa's regolith may be similarly fine-grained and highly porous. We suggest that those who are developing lander vehicle concepts for Europa's surface might consider this evidence in their design. Furthermore, future spacecraft missions to the Jovian system will enhance science return by incorporating angular scattering measurements of the reflectance and polarization of the surface (6). This work supported by NASA's Cassini Science Office

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B5.3-0038-18 A COMPREHENSIVE PICTURE OF CALLISTO'S MAGNETIC ENVIRONMENT DURING THE GALILEO ERA: IMPLICATIONS FOR JUICE

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We apply data analysis techniques and hybrid modeling to study Callisto's interaction with Jupiter's magnetosphere. Magnetometer data from the C3 and C9 Galileo flybys had been explained with a pure induction model, as the plasma interaction was weak. We expand this analysis to include the remaining five flybys (C10, C21, C22, C23, C30) where the plasma interaction was non-negligible. We therefore consider contributions to Callisto's magnetic environment generated by induction as well as the plasma interaction. We have identified a quasidipolar "core region" near Callisto's wakeside surface, dominated by induction and partially shielded from the plasma interaction. Outside of this region, Callisto's magnetic environment is characterized by field line draping. Future flybys during the upcoming JUICE mission may sample the wakeside "core region" to better constrain the conductivity, thickness, and depth of Callisto's subsurface ocean. Our analysis also shows that even during a single flyby, various non-stationarities in the upstream environment may be present near Callisto, which may partially obscure the magnetic signature of the moon's subsurface ocean. Overall, our study provides a complete three-dimensional picture of Callisto's magnetic environment during the Galileo era, based on all available magnetometer data from the Galileo flybys. We apply our understanding to the future JUICE flybys of Callisto to determine which encounters will be best to identify Callisto's inductive response in magnetometer data.

B5.3-0039-18 INVESTIGATING EUROPA'S PLASMA ENVIRONMENT FROM RADAR SOUNDING

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Investigation of Europa's icy crust from the ocean to its surface and atmosphere is a programmatic goal for the Europa Space Agency (ESA) and the National Aeronautics and Space Administration (NASA), achieved through the future JUpiter ICy moons Explorer (JUICE) and Europa Clipper missions, respectively. The ability to directly probe the subsurface makes radar sounders key instruments of those two missions for ice-ocean detection down to down to several to tens of kilometers deep, sampling the macro-structure and composition of the ice crust. However, radar sounder performance can be degraded by planetary ionospheres along the signal propagation path, affecting the nominal radar vertical resolution and signal-to-noise ratio. Typical vertical profiles of Europa's ionosphere, as measured by Galileo by occultation, can impact the 9-MHz channel of the Radar for Icy Moons Exploration

(RIME, onboard JUICE) and the Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON, onboard Europa Clipper) investigations. We review the current state of knowledge of the Europan plasma environment, its effects on radio wave propagation, and its impact on the performance and design of future radar sounders for the exploration of Europa's ice crust. The severity of these impacts decrease with increasing center frequency and increase with altitude, latitude, and bandwidth. We also explain strategies to correct these impacts based on the extensive heritage from the Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) and the Shallow Radar (SHARAD) at Mars. Ionosphere correction will be a part of REASON's data processing, providing a Total Electron Content (TEC) data-product for characterization of the Europan plasma environment. Observations from the Hubble Space Telescope reported transient ultraviolet emissions from Europa's exosphere consistent with 200-km high plumes of water vapor venting upward materials from the sub-surface. Plume activity adds neutrals in the exosphere that can in turn be ionized by the incident Jovian magnetospheric flow, creating a plume-induced ionosphere as shown at Enceladus with the Cassini Spacecraft. TEC measured by REASON will address Europa Clipper's plume-search objectives by detecting localized plume-induced plasma-clouds under the spacecraft.

B5.3-0041-18 CANYONS ON TITAN: NEW INSIGHTS BY THE CASSINI RADAR ALTIMETER

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The Cassini radar altimeter observed for the first time features similar to the liquid filled canyons already detected at Vid Flumina during the flyby T91. Herein, we present the analysis of data acquired during the fly-bys T49, and T108, and then processed to improve the radar resolution. We show that the altimeter detected liquid filled canyons, which can be seen in SAR images to connect to Ontario Lacus (T49) and Punga Mare (T108). We retrieved a topographic profile over these features, and performed quantitative measurements of backscattering behavior, showing that they are indeed liquid filled. Another tentative feature was observed in T126, where it too resembles a canyon-like feature. Further quantitative work is underway to more fully understand this putative feature.

B5.3-0042-18 GLOBAL GEOMORPHOLOGY MAP OF TITAN: A LOOK AT THE NORTH AND SOUTH POLES

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We carried out detailed geomorphology mapping of Titan's north and south poles as part of our global mapping effort. We used radar data collected by Cassini's Synthetic Aperture Radar (SAR) as our basemap, supplemented by images from VIMS, ISS, SARtopo, and microwave emissivity datasets. We mapped at a scale of 1:800,000 in all areas of the poles covered by SAR swaths, taking into consideration the 300 m/pixel resolution of the swaths. We extend our terrain classification from previous mid-latitude mapping efforts (Malaska et al. 2016) to the poles and find that the definitions of our mapping units remain applicable. The terrain classes relevant to the poles are Basin and Lakes, Hummocky, Labyrinth, and Plains. In both the north and south poles, the Plains units dominate by area. This is also true of the mid-latitude regions (Lopes et al., 2016). However, the Basin and Lake units are the second most dominant terrain type in the north pole, while the Labyrinth units are the second most dominant unit in the south. We find our mapping of the polar regions correlate well with previous polar mapping efforts, including consistency between analogous mapping classifications (Birch et al., 2017). Plains unit designated "scalloped plains" (Malaska et al., 2016) and "dark irregular plains" (Hayes et al., 2008) are prominently featured between the 50°S and 60°S latitudes of Titan. We also note a higher occurrence of fluvial channels and alluvial fans starting at this latitude zone and extending poleward. We suggest that these features indicate the transition zone between mid-latitude/equatorial regions and the poles. The detailed mapping of Titan's poles presents a significant step towards the end goal of a global geomorphology map of Titan, offering a more comprehensive analysis of global geologic trends and stratigraphic relationships.

B5.3-0043-18 RETURNING TO TITAN: ASSESSING TITAN'S TRANSMISSION FOR FUTURE MISSIONS

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We present in this work an analysis of the transmission of Titan's atmosphere as a function of altitude modelled using radiative transfer. We find that unless close to the surface the spectral shape of Titan's atmosphere changes very little.

Despite a decade's worth of observations and discoveries with Cassini, the composition of Titan's surface still remains elusive. This is because there are only a few narrow "windows" that are able to see through Titan's thick atmosphere to the surface, due to methane absorption and scattering off of Titan's complex hazes. Despite these limitations, there are still some constraints for Titan's surface composition, suggesting complex hydrocarbons, and CO¬2 and H2O ices, although the limited spectral coverage makes species identification difficult. An increased range in the spectral regions sensitive to the surface would not only vastly improve our knowledge of composition, but would inform studies of surface processes and photochemical production in the atmosphere (and subsequent deposition onto the surface). Further, detailed studies of the surface would constrain astrobiologically relevant chemistry in the atmosphere and on the surface (e.g. water-organic interactions).

We model Titan's atmosphere using the radiative transfer code, PyDISORT. This code uses profiles measured by the Huygens probe to simulate Titan's atmosphere and contains contributions from multiple scattering off of hazes, collision-induced absorptions, and variable compositions with altitude. To model Titan's methane

absorption, we use the k-coefficients derived from laboratory measurements and direct observations of Titan's atmosphere. This allows for the most complete spectral coverage to even shorter wavelengths where current absorption databases are incomplete. The code permits any number of species in the atmosphere, but for this work we remain limited to methane only.

To best align with potential future missions to Titan, we model the transmission of Titan's atmosphere at three different characteristic altitudes: from orbit, a balloon, or for a lander/aircraft, at 1500 km, 10 km, and 10 m respectively. We find significant broadening in the spectral windows with decreasing altitude, but only at altitudes less than 10 km. This is a result of the increased atmospheric density and methane abundance close to the surface. However, because incident solar radiation is absorbed quickly in Titan's upper atmosphere, an onboard lamp is required to access these additional spectral regions. However, even a modest lamp, comparable to a common 100-W incandescent lamp, is sufficient to provide an observable signal over all the broadened spectral regions at a distance of 10m, thus greatly increasing the spectral regions accessible to future surface missions.

B5.3-0044-18 TITAN LAKES SIMULATION SYSTEM: AN EXPERIMENTAL PLATFORM FOR CHEMICAL AND SPECTRAL CHARACTERIZATION OF TITAN'S HYDROCARBONS LAKES

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The dense atmosphere, rich organic chemistry and surfaces of liquid hydrocarbons make Titan a particularly intriguing object among the ocean worlds. Accordingly, Titan is a prime destination for future missions aiming to assess the habitability of icy moons. Liquid methane and ethane form liquid deposits on the surface of Titan, detected and mapped by RADAR and VIMS instruments on Cassini. Our knowledge of their composition relies mainly on thermodynamic modeling and assumptions based on Cassini observations. Several thermodynamic models have been used to calculate the composition of lakes, and their results on even the major lake components (methane, ethane, propane and nitrogen) exhibit large discrepancies. The Titan Lakes Simulation System (TiLSS) is a cryogenic vacuum system designed and developed at JPL to produce and characterize liquid hydrocarbons in equilibrium with the gas phase. The setup consists of a large "bell jar" high vacuum chamber (10-6 torr) that contains a stainless steel Pressure Vessel. This Pressure Vessel plays the role of condenser for hydrocarbons. Temperatures relevant to Titan surface are reproduced using a closed-cycle helium cryostat and liquid nitrogen flowing through a cooling plate. Feedthroughs in the top flange of the pressure vessel allow the injection of gaseous N2 to pressurize the chamber to 1.5 bar and to introduce hydrocarbons into the condenser. To analyze the chemical composition of liquid hydrocarbons, a solenoid valve allows for sampling the liquid and sending it to a SRI Gas Chromatograph (GC). A separate line allows to measure the composition of the gas in the headspace with the SRI GC as well. Optical fiber probes were installed inside the

Pressure Vessel, permitting spectral measurements of the liquid in the infrared wavelength. We accomplished preliminary studies of condensed pure CH_4, pure C_2H_6 and 1:1 CH_4:C_2H_6 mixture, all under 1.5 bar of N_2. This work shows the higher solubility of N_2 in liquefied methane compared to ethane. The CH_4:C_2H_6 mixture experiment shows clearly the difference between the liquid and gas composition at 92 K and its evolution as the temperature increases up to 103K. Infrared spectra were collected for methane and ethane pure liquids. Combining Infrared and GC measurements on the same samples will allow the calibration of the optical fiber probe for quantitative measurements. The potential of this new system to enhance the science and technology related to investigating Titan lakes will be discussed in this presentation. Acknowledgements: This work has been conducted at the Jet Propulsion Laboratory, California Institute of Technology, under contract to NASA.

B5.3-0045-18 EXPERIMENTAL CHARACTERIZATION OF FINE-GRAINED WATER ICE PARTICLES: EVOLUTION OF PHOTOMETRIC AND POLARIMETRIC PHASE CURVES DUE TO GRAIN SINTERING. APPLICATIONS TO PLUME DEPOSITIONS ON ICY SATELLITES

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The discovery of cryovolcanism on Enceladus [1] and recent potential findings on Europa [2,3] lead to questions about the nature and the age of plume deposits under the harsh conditions in the outer Solar System. The composition, structure and surface deposition rates of the plume material are major questions. The depositions rate defines the surface age and corresponding timescales for morphological processes such thermal sintering or space weathering.

To characterize potential plume deposits at the surface of icy satellites remote sensing observations are necessary to achieve sufficient spatial resolution compared to ground-based observations. To make the transition from observation data to physical interpretation, the study of well characterized materials in the laboratory is an appropriate approach.

The application of standardized and reproducible sample production methods and protocols is key when using laboratory analogues to interpret remote sensing data. The Laboratory for Outflow Studies of Sublimating icy materials (LOSSy) has been developed for this purpose at the University of Bern since 2010. We are able produce three different types of spherical water ice particles with different grain size distributions in the micrometer size range.

We have previously shown in laboratory experiments that morphological changes by grain sintering have a substantial impact on the light scattering properties of granular water ice surfaces in the 450 to 1064nm spectral range at phase angles from

0 to 140° [4]. The opposition effect is reduced as particle shapes evolve from spherical to more irregular, further sintered particles tend to be more scattering in the forward direction.

More recently, we measured the polarimetric phase curves of the same water ice particles at 530 nm It has been shown that the degree of linear polarization as a function of phase angle is very sensitive to properties such as particle shape, grain size and frost deposition.

We will present a selection of these recent laboratory measurements of photometric and polarimetric phase curves of fresh and sintered ice particles and we will show how this dataset can help to characterize the surface activity/ages of icy satellites.

References: [1] Porco et al., 2006, Sci 311-5766. [3] Jost et al., 2016, Icarus 264., [2] Sparks et al., 2016, ApJ 829-2. [3] Sparks et al., 2017, ApJ 839-2. [4] Jost et al., 2016, Icarus 264.

B5.3-0046-18 ENCELADUS' BRILLIANT SURFACE: RATIONALIZING CASSINI RADAR AND OPTICAL REMOTE SENSING OBSERVATIONS

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The fresh, clean ice that dominates Enceladus' surface makes it the most reflective surface of any Solar System body across a broad range of wavelengths, from visible to microwave. Fine-grained micron to tens of micron particles resulting from plume or E-ring deposition dominate optical wavelengths, enabling enhanced geometric albedo due to coherent backscatter. However, high albedo at centimetric radar wavelengths suggests scattering from characteristic spatial scales of millimetric or greater. To date, no single model of surface material structure has been proposed that can explain all the observed phenomena. We propose that sintering of fine particles during past periods of low or zero cryovolcanic activity may create subsurface layers that enhance radar backscatter sufficiently to explain the observations. The thickness of the upper, unsintered layer is likely at least 1-2 cm, and probably well under a meter. More modeling and laboratory work is required to test the validity of our assertion that sintering during quiescent periods of plume activity is responsible for the enhanced radar backscatter.

B5.3-0047-18 EXPLORATION OF PLUTO WITH A NEW-FRONTIERS-CLASS LANDER OR ORBITER MISSION

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With water-ice mountains, expansive glaciers, possible cryovolcanism, and an extended Nitrogen atmosphere, Pluto is a dynamic world shrouded in mystery. Surface features aligned with Pluto's tidal axis suggest that it has a hidden subsurface ocean of liquid water. Pluto could be the most distant "Ocean World" in our solar system. The best way to unravel the mysteries of Pluto is to get as close as possible with a new mission to explore the surface and atmosphere.

A low-cost, New-Frontiers-class Pluto lander or orbiter mission with a launch in 2029, Jupiter gravity assist in 2030, and arrival at Pluto in 2040 is possible. The next opportunity for a similar mission will not be possible until a 2042 launch when Jupiter is again positioned for a gravity assist.

So how can we land on or orbit Pluto without several hundreds of millions of dollars in nuclear power sources, a next generation launch vehicle, or a massive propulsion system? One way is to launch a probe on a trajectory similar to the Jupiter flyby trajectory of New Horizons, target it for entry at Pluto at 14 km/s, and deploy a large inflatable drag device prior to entry at an altitude of 1600 km. The low density Pluto atmosphere has a scale height of 60 km, nearly 8 times larger than at Earth, enabling atmospheric drag to slowly dissipate the 50 gigajoules of kinetic energy of entry.

Only one Multi-Mission Radioisotope Thermoelectric Generator (MMRTG), currently in production by NASA, is needed to power onboard spacecraft systems. Depending on the trajectory and flight path angle, the probe can either descend to the surface and deliver a 200-kg landerhopper or insert an orbiter via aerocapture. We deem this architecture Entrycraft.

The preliminary results of a NASA Innovative Advanced Concepts (NIAC) study will be presented including the results of the interplanetary and approach mission design; structural, aeroelastic, aerothermodynamic, and thermal modeling; aerodecelerator and lander/hopper system design; and possible orbiter mission design efforts.

B5.3-0048-18 MAPPING OF SURFACE OF ENCELADUS THROUGH A ROBOTIC VEHICLE

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The scarves for the satisfactory settlement with all knowledge and experience in terms of life made human's to reach beyond the earth's orbit and the idea with advancement made in technology results proves it true creating several milestones of innovation lead by great ideas. These remarkable milestones give a glimpse of every innovation and brilliant approaches have done so far. In the present world, the idea for reaching moon, planets or stars is the current need for the advancement of human civilization. In fact, various studies have been done even for the terrestrial bodies some light years away, and of Enceladus by Cassini. For every revolutionary idea, all we need is to remember and learn from the past experience, applying it to present scenario keeping in mind for future outcomes and every possibility that can be think of. This approach of study Enceladus is all about to search for the hydra-characteristics on the moon of ring planet, Saturn, of our solar system, believing to have a rough center blended with water ice and a solidified mantle. In addition of the research and developing with the goals of safety, affordability, and sustainability, the proposed aerial rover's goal is ambitious including the mapping and collection of samples from the icy surface that a future mission could potentially give deep information and from that point, it will develop into the most capable dispatch unmanned vehicle at any point flown by means of a developmental approach that will give building pieces to future space investigation on Enceladus. Enceladus is a to a great extent frigid world with some level of its mass being silicates. Depending on the instrument, the target material can include things like icy plume materials, the cause of volcanic actions. It recommends a few insights for the fluid water sea under the surface. From studies, Enceladus is believed to be warmed from inside by either radioactive warming or tidal flexing as Saturn's huge gravity pulls on the moon. Likewise, with Europa at Jupiter, researchers speculate that Enceladus could be a tenable world for a few types of life. There is no confirmation of life there, however, future missions could test forever signs.

B5.3-0049-18 AN ARCHITECTURE FOR ACCESSING EUROPA'S OCEAN

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The icy moon oceans beckon with ingredients that potentially may harbor extant life. Beginning with the Galileo and Cassini missions, measurements have revealed the presence of global oceans under the icy crust of several moons of Jupiter and Saturn. Among those moons, Europa and Enceladus have their ocean in contact with the rocky core, providing an environment similar to the conditions existing on the terrestrial sea-floor where life has developed at hydrothermal vents. Accessing these oceans presents considerable difficulty due to a number of issues including the depth and composition of the icy crust, the time needed to travel through the crust, the power needed to propel a probe, communication of scientific and engineering data though the ice and back to earth, entry and mobility in the ocean and autonomous operations for the life of the mission.

A detailed trade space study was conducted to develop a technology architecture defining a system that would access an icy moon's ocean. To specifically bound the architecture, Jupiter's moon Europa was chosen as the target body. The current understanding of the scientific properties of the ice crust and ocean was used to guide the development. A strawman scientific payload was devised to further develop a baseline set of requirements. Beginning with a launch and trajectory that can bring a system to Europa's orbit, a complete trade space was developed outlining the engineering systems needed to access the ocean. The launch system and trajectory provided a bound for the amount of mass that would be available to Europa's surface. The architecture was divided into specific phases for i) deorbit, descent and landing, ii) surface operations, iii) ice descent and iv) ocean access. The needed functions for each phase were then identified with potential options for each sub-system evaluated. The technical maturity of each of these sub-systems was assessed for systems that could be developed to a maturity ready for a preliminary design in 5-10 years. Integrated system parameters on power, communication capacity, and mass were developed to further define the overall system. To constrain the design, a total time in the ice, from the ice crust surface to accessing the ocean was limited to two years, and 10Km of ice was baselined with a temperature profile through the ice estimated from the scientific literature.

The results of this architecture will be presented in the paper. A complete system has been defined for a system that can access the ocean after two years of travel through the baseline 10Km of ice. Models with a range of fidelity are being developed to bring additional prediction to the effort. A description of testbeds that can validate the models as well as provide experimental validation of subsystems will be described. The trade space and key technology needs will be reported.

B5.3-0050-18 UNDER-ICE COMMUNICATION SYSTEM FOR EUROPA EXPLORATION MISSION

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Jupiter's moon Europa is one of the best site in our solar system to explore the habitable zone beyond earth. Some ideas came in the past years for the exploration of this Jovian moon like the cryobot, VALKYRI etc. But for the exploration purpose there are many problems such as effective drilling technology for penetrating such deep ice crust and the development of smart instruments that will work even in such cold environment. Besides that communication from the bottom sea to the top surface lander is also a major problem. In this work a concept about the communication system between the ocean and surface of the moon is demonstrated. Using wireless Ice embedded transceivers for the complete communication link would involve much complexity, effect of radiation, low data transfer due to large number of nodes and interference. As expected the surface temperature of Europa is the order of -170C while the sub surface temperature at ice and ocean link is nearly -0C. The thermal gradient throughout enables the use of this heat power as the primary power source of the embedded transceivers. A number of pairs of transceivers spread into the ice which will offer various advantages as compared to fully wireless link, in each pair one transceiver is connected to other with a one kilometer long conductor wire. Space diversity and Multi Input Multi Output can be used to boost the data rate and reduces the total wireless nodes and hops required to half saving power on individual node. The proposed system is as - Both faces of the transceiver nearer to the lander acts as the cold side of the Thermo Electric Generator (TEGs) whereas both the faces of transceiver near the ocean acts as the hot side creating two virtual TEG's whose power can be shared mutually among the transceivers depending on the requirement. The effective wireless channel path is reduced is the limiting factor of the overall achieved data rate. This also addresses the problem of deploying more sensor nodes towards the ocean surface due to diminishing permeability offered by ice and mitigate the signal attenuation problem. The wired link on the other hand will have no problem regarding to this.

B5.3-0051-18 THE JUICE MISSION AND THE FUTURE EXPLORATION OF THE ICY GALILEAN SATELLITES: COMPLEMENTARITIES AND SYNERGIES IN VISIBLE AND NEAR-INFRARED REMOTE SENSING

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The Jupiter Icy Moons Explorer (JUICE) mission, whose launch is currently scheduled in 2022, is the first ESA-led mission devoted to explore the Jupiter system with an emphasis on the icy Galilean satellites Europa, Ganymede and Callisto. JUICE will indeed be the first spacecraft ever to enter orbit around an icy satellite, Ganymede, allowing an unprecedented analysis of its surface, interior and tenuous atmosphere. Among the remote sensing instruments onboard JUICE are a multispectral camera (JANUS) equipped with 13 filters covering the spectral range 0.34-1.08 µm, and an imaging spectrometer (MAJIS) whose sensitivity covers the overall spectral range 0.5-5.54 µm.

Once in orbit around Ganymede at 5000-km altitude (GCO-5000 phase), JANUS is committed to achieve global coverage in 4 filters at a resolution better than 400 m/px, but it can reach the maximum achievable resolution of 75 m/px where necessary. In this phase, MAJIS shall achieve global coverage at spatial resolution between 2 and 5 km/px.

In the following orbital phase carried out at 500-km altitude (GCO-500 phase), the actual color coverage will depend on the available data volume, but in principle it may be planned to observe specific regions of interest at the maximum achievable spatial resolution with both JANUS (7.5 m/px), also using contiguous color filters, and MAJIS (75 m/px).

The joint analysis of multispectral and hyperspectral datasets of past or ongoing planetary space missions permitted to achieve better scientific results than those obtainable from the individual analysis of these two kind of datasets. For instance, the correlation between the photointerpretation obtained at a high spatial resolution and the identification of spectrally homogeneous regions at lower spatial resolution, in principle would allow an extrapolation of hyperspectral data at spatial resolutions inaccessible to MAJIS in the spectral region 0.5-1.0 µm where JANUS and MAJIS overlap each other.

Here we describe the main complementarities and synergies that could be planned in the future, regarding the exploration of the icy Galilean satellites - most notably Ganymede - thanks to the combination of JANUS and MAJIS data. Moreover, we suggest further synergies potentially achievable through the integration of data sets from additional instruments. In doing this, we take into account the operational constraints imposed by the technical characteristics of the spacecraft during the different phases of the JUICE mission.

B5.3-0052-18 INVESTIGATING EUROPA'S GEOLOGY, ICE SHELL, AND POTENTIAL FOR CURRENT ACTIVITY WITH THE EUROPA IMAGING SYSTEM (EIS)

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Europa Clipper's Europa Imaging System (EIS) consists of narrow-angle and wide-angle cameras (NAC and WAC) designed to transform our understanding of Europa through global coverage, topographic and color mapping and unprecedented sub-meter-scale imaging. To investigate Europa's geology, composition, ice shell and ocean, and habitability, EIS will:

Constrain the formation processes of surface features by characterizing endogenic geologic structures, surface units, global cross-cutting relationships, and relationships to Europa's subsurface structure and potential near-surface water (e.g., Schmidt et al. 2015);

Search for evidence of recent or current activity, including potential erupting plumes (Sparks et al. 2017; Roth et al. 2014);

Characterize the ice shell by constraining its thickness and correlating surface features with subsurface structures detected by ice penetrating radar (Schroeder et al. 2016);

Characterize scientifically compelling landing sites and hazards by determining the nature of the surface at scales relevant to a potential lander (Hand et al. 2017).

EIS will provide comprehensive data sets, including cartographic and geologic mapping, regional and high-resolution digital topography, GIS products, color and photometric data products, a database of plume-search observations, and a geodetic control network tied to radar altimetry

The NAC will achieve 0.5-m pixel scale over a 2-km-wide swath from 50-km alt. A 2-axis gimbal enables independent targeting, allowing very high-resolution stereo imaging to generate DTMs with 8-m spatial scale and 1-m vertical precision over a 4-km swath from 100-km alt. The gimbal also makes near-global (>90%) mapping possible at 100-m pixel scale (to date, only 14% of Europa has been imaged at 500 m/pixel), as well as regional stereo imaging. With 10-km pixel scale at 1E6 km range, the NAC can take advantage of good illumination geometry to search for forward scattering by potential plumes even when distant from Europa.

The WAC is designed to acquire pushbroom stereo swaths along flyby ground-tracks. From 50-km altitude, the WAC achieves 11-m pixel scale over a 44-km-wide swath, generating DTMs with 32-m spatial scale and 4-m vertical precision. WAC and NAC data also support characterization of surface clutter for interpretation of radar sounding.

The cameras have identical rapid-readout, radiation-hard 4k x 2k CMOS detectors (Janesick et al. 2014) that image in both pushbroom and framing modes. Color pushbroom observations using six broadband filters (370-1050 nm) will map surface units to correlate with geologic structures and compositional units (Blaney et al. 2017). The rad-hard data processing unit (DPU) uses real-time processing for pushbroom imaging, including WAC 3-line stereo, digital TDI, and data to measure and correct pointing jitter, taking full advantage of the rapid, randomaccess readout of the CMOS arrays.

B5.3-0053-18 EXPLORING THE HABITABILITY OF OCEAN WORLDS THROUGH IMPACT IONIZATION OF ICY MATERIAL - DEVELOPMENT OF AN ICY DUST ACCELERATOR

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The astrobiological relevance of the Ocean Worlds - Enceladus and Europa in particular - is outstanding, as they possess liquid oceans that are in contact with a rocky core, where hydrothermal activity is assumed. Similar environments on Earth have been discovered to harbor unique and complex living ecosystems. There are natural processes that deliver samples of the surface ice and subsurface liquid ocean from these bodies to altitudes, where they become available for in situ detection and analysis using mass spectrometry techniques after the impact ionization of the icy dust particles. This detection method is demonstrated to provide outstanding sensitivity to organic and inorganic compounds solvated in the water ice and thus is a promising tool that is yet to be fully exploited. As of today, there are no existing laboratory capabilities for accelerating icy dust particles to typical velocities encountered in space (approx. 4 km/s). A design of a new facility has been completed that exploits a commercial electrospray source and a linear accelerator configuration to produce small, highly charged icy dust particle, and accelerate them to relevant velocities. Such capability is needed for high-fidelity studies of the impact ionization process of micronand submicron-sized particles, as it would help to lay the foundations of the detectability of diverse biomarker molecules through impact ionization. Of particular interest is the investigation of the detectability of organic molecules embedded in icy grains, and the constraints on the sensitivity posed by absolute and relative concentrations, ionization efficiencies, and the effects of the geochemical environment, e.g. salt concentrations, and pH values.

B5.3-0054-18 NASA'S EUROPA CLIPPER MISSION ULTRAVIOLET SPECTROGRAPH (EUROPAUVS)

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NASA's Europa multi-flyby mission is designed to provide a diversity of measurements suited to enrich our understanding of the potential habitability of this intriguing ocean world. The Europa Clipper mission's Ultraviolet Spectrograph, Europa-UVS, is largely based on the JunoUVS instrument, currently in orbit at Jupiter. Its design is even more similar to the Jupiter Icy Moons Explorer UVS (JUICE-UVS), which leads Europa-UVS in its development and delivery schedule by 18 months. The science objectives of Europa-UVS are to: 1) Determine the composition chemistry, source sinks, and structure variability of Europa's atmosphere, from equator to pole; 2) Search for and characterize active plumes in terms of global distribution, structure, composition, and variability; 3) Explore the surface composition microphysics and their relation to endogenic exogenic processes; and 4) Investigate how energy and mass flow in the Europa atmosphere, neutral cloud and plasma torus. Europa-UVS observes photons in the 55-210 nm wavelength range, at moderate spectral and spatial resolution along a 7.5° slit. Three distinct apertures send light to the off-axis telescope mirror feeding the long-slit imaging spectrograph: i) a main entrance airglow port is used for most observations (e.g., airglow, aurora, surface mapping, and stellar occultations); ii) a high-spatial-resolution port consists of a small hole in an additional aperture door, and is used for detailed observations of bright targets; and iii) a separate solar port allows for solar occultations, viewing at a 40° offset from the nominal payload boresight. Programmable acquisitions with customized detector array binning and windowing capabilities allow for observational flexibility and optimal science data management. Both photon event time-tagging (pixel list mode) and spectral imaging (histogram mode) acquisition types take advantage of this data volume optimization capability. As on Juno-UVS, the effects of penetrating electron radiation on electronic parts and data quality are mitigated through contiguous shielding, management of high-voltage settings, and careful use of radiation-hardened parts. Additional mitigation of radiation effects on UVS science measurement quality is provided by implementing microchannel

plates with ALD coatings (to eliminate gain-sag), borosilicate glass substrates (to decrease sensitivity to energetic particles and secondaries), and large global count rate limits and filtering of pulse height amplitudes (to process noise events). Europa-UVS passed its preliminary design review (PDR) milestone in November 2017. We present the current investigation details regarding the science we plan to address, the salient details of the instrument, and the basic concept of operations.

B5.3-0055-18 REASON FOR EUROPA

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The science goal of the NASA's Europa Clipper mission is to "explore Europa to investigate its habitability". One of the primary instruments selected for the scientific payload is a multifrequency, multi-channel ice penetrating radar system. This "Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON)" could revolutionize our understanding of Europa's ice shell by providing the first direct measurements of its surface character and subsurface structure. REASON will address key questions regarding Europa's habitability, including the existence of any liquid water, through the innovative use of radar sounding, altimetry, reflectometry, and plasma analyses. These investigations require a dual-frequency radar (HF and VHF frequencies) instrument with simultaneous shallow and full-depth sounding that is designed for performance robustness (in particular against subsurface volume scattering, ionospheric distortion, and Jovian noise emissions) in the challenging environment of Europa. The flyby-centric mission configuration is an opportunity to collect and transmit minimally processed data back to Earth and exploit advanced processing approaches developed for terrestrial airborne data sets. The observation and characterization of subsurface features beneath Europa's chaotic surface requires discriminating abundant surface clutter from a relatively weak subsurface signal. Finally, the mission plan also includes using REASON as a nadir altimeter capable of measuring tides to test ice shell and ocean hypotheses as well as assessing roughness across the surface statistically to identify potential follow-on landing sites. We will present a variety of measurement concepts for addressing these challenges.

B5.3-0056-18 MAPX-PIXE: A FULL FIELD MICRO X-RAY FLUORESCENCE IMAGER FOR ASTROBIOLOGY APPLICATIONS ON OCEAN WORLDS

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Introduction: Investigations of Ocean Worlds and other icy bodies as potential habitats for life require a knowledge of the mineralogy and elemental chemistry at the surface [1]. APXS, currently deployed on MSL, obtains compositional information from X-ray fluo-rescence (XRF) spectra with a spot size 1.6 cm in di-ameter [2]. However, the information on bulk samples leaves out spatial information which can reveal traces of physical, chemical, and biological processes. The Mapping X-ray Fluorescence Spectrometer (MapX) employs XRF at the micrometer scale (XRF) to ob-tain such information [3]. MapX-PIXE has been de-signed for use with radioisotope sources that will emit both and radiation. The radiation will induce XRF from heavy elements, while particles will be able to induce XRF from lighter elements via particle induced X-ray emission (PIXE). Thus, MapX-PIXE will be ca-pable of imaging both heavy elements for mineralogi-cal characterization and light elements for possible identification of biological material. MapX Prototypes to Date: MapX is a full-field XRF imager which employs a CCD detector operated in single photon counting mode. The number of elec-tron hole pairs created by an incident photon is energy dependent, and by summing multiple frames it is pos-sible to produce XRF spectra for each pixel of the CCD. The same technology is employed in the CheMin instrument on MSL, which provides qualitative bulk compositional information as well as spatially-resolved diffraction information for mineral identifica-tion. MapX combines this CCD with a micro-pore op-tic (MPO) which focuses X-rays 1:1 onto the CCD. The resulting instrument is capable of producing XRF maps with a resolution of 100 m. Data is currently being collected using two prototypes employing X-ray tube sources, MapX-II and MapX-III, which are at TRL3 and TRL4 respectively. The MPO/CCD geometry has significant ad-vantages over other XRF systems. MapX has no moving parts. Further, the MPO provides a greater depth of field than instruments which employ poly-capillary optics. MapX has a measured depth of field of approximately 10 mm, which means that rough, unprepared surfaces can be imaged with minimal loss of resolution. Employing Radioisotope Sources: So far, MapX has been developed with X-ray tube sources which efficiently excite elements heavier than Ne. Using fun-damental parameters methods it is possible to calculate the overall composition in terms of weight percent for heavy elements without directly measuring the light elements. However, detecting life or its precursors on Ocean Worlds will require the detection and mapping of C and N on the surface. To this end, MapX-PIXE will employ 244Cm which emits 14 keV and 18 keV -rays as well as 5.8 MeV -particles [4]. The -rays effi-ciently excite heavy elements (20

< Z < 30) similarly to X-ray tubes, while -particles excite lighter elements (6 < Z < 19) via PIXE. GEANT4 simulations show the increased signal from light elements when using 244Cm compared to X-ray tubes [5]. A 244Cm equipped MapX-PIXE instrument will be smaller, less complex and more robust than an X-ray tube based instrument. Radioisotope-based XRF instruments have been em-ployed on the MER and MSL rovers, demonstrating their feasibility in flight [2]. Applications to Ocean Worlds: MapX-PIXE will be well suited to answer a range of scientific questions on Ocean Worlds. Designed to be included in the in-strument vault of a Europa lander, it will be able to map and quantitatively analyze as-received ice frag-ments. It will be able to determine the ion content of the ice at the surface as well as quantify the amount of dissolved C and N. As water ice freezes, ions are pushed to grain boundaries forming brine channels. These channels create patterns at scales MapX will be well suited for, and will inform the provenance of sur-face ice as well as any surface weathering processes. For Ocean Worlds such as Europa, the surface is expected to contain micro-meteorites which have “gardened” the surface to a depth of 2 cm [6]. This rough material can be imaged without sample preparation, and MapX will be able to characterize embedded meteorites in the immediate sub-surface. While -particles will only induce emission at the surface, the 14 and 18 keV -rays are expected to penetrate to a depth of 3.5 and 6.5 mm respectively with only 50% loss of intensity. This will render elements heavier than Fe detectable at depths ranging from 1 to 2 mm in the ice based on the energy of the XRF lines. Data Processing: The full x, y, energy data cube produced by MapX and MapX-PIXE will be too large to send back from space; algorithms are in develop-ment to automate the selection of regions of interest (ROI). The XRF spectra from these autonomously selected ROIs can be sent back in addition to element maps. The summed spectra will be processed on the ground for element quantification which will then be used to constrain possible minerals present in the ana-lyzed material based on the RRUFF database [7]. References: [1] Blake, D.F. et al. (2017) AbSciCon 2017, 3074. [2] Rieder, R., R. et al. (2003)

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B5.3-0057-18 EXPECTED PRECISION OF EUROPA CLIPPER GRAVITY MEASUREMENTS

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The primary gravity science objective of NASA’s Clipper mission to Europa is to confirm the presence or absence of a global subsurface ocean beneath Europa’s Icy crust. Gravity field measurements obtained with a radio science investigation can reveal much about Europa’s interior structure. Here, we conduct extensive simulations of the radio science measurements with the anticipated spacecraft trajectory and attitude (17F12v2) and assets on the spacecraft and the ground, including antenna orientations and beam patterns, transmitter characteristics, and receiver noise figures. In addition to two-way Doppler measurements, we also include radar altimeter crossover range measurements. We concentrate on 2 hour intervals centered on the closest approach of each of the 46 flybys. Our covariance analyses reveal the precision with which the tidal Love number k2, second-degree gravity coefficients $\bar{C}20$ and $\bar{C}22$, and higherorder gravity coefficients can be determined. The results depend on the Deep Space Network (DSN) assets that are deployed to track the spacecraft. We find that some DSN allocations are sufficient to conclusively confirm the presence or absence of a global ocean. Given adequate crossover range performance, it is also possible to evaluate whether the ice shell is hydrostatic.

B5.3-0058-18 RADIATION-HARD ELECTRON MONITOR FOR JUICE SPACE MISSION

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Radiation Hard Electron Monitor (RADEM) is a particle measurement monitor dedicated to a Jupiter Icy Moons Explorer (JUICE) space mission. Its purpose as a part of a JUICE environmental monitor system is to provide a handful of important information about Jupiter radiation belts such as particle fluxes with their energy ranges, incoming particle discrimination and directionality. Those properties would be of a great importance due to the lack of sufficient and precise measurements so far.

RADEM consists of three independent detector systems: Proton and Heavy Ion Stack Detector (P&HID), Electron Stack Detector (ED) and Electron Directionality Detector (DD). Each of them has a dedicated, radiation-hard IDE3466 ASIC responsible for readout, signal conversion and communication with spacecraft. ED is build out of eight silicon detectors, separated by different absorbers, in a way to cover the energy range from 0.1 to 40 MeV. Combined with DD, which is a pixelated silicon detector placed under directional collimator, RADEM is optimized to detect electrons within wide energy range and determine their incoming direction in nearly 2π. Beside that, P&HID will provide additional information concerning proton spectra in a range within 5 and 250 MeV as well as heavy ion discrimination for particle fluxes even up to 109/cm^2/s. The whole instrument inclusive all three detector heads, their PCBs and ASICs, outer shielding and connectors is designed in a way to fulfill JUICE mission requirements, that is for example a total mass below 1 kg and a power on a level of 1 W.

Current status of RADEM project is Engineering Model development. Its purpose is to test all important functionalities of the device with assumption, that this model will be as close to the final Flight Model as possible. During this phase the detection capabilities as well as the data collection and processing will be tested with a usage of various measures such as proton and electron beams.

B5.3-0059-18 CRYOGENIC SAMPLE ACQUISITION AND DELIVERY SYSTEM (CRYOSADS) FOR TITAN AND EUROPA

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We present a novel design of a surface sample acquisition and delivery system for Ocean Worlds, with emphasis on Titan and Europa. The near-term missions that could take advantage of this system, called Cryogenic Sample Acquisition and Delivery System (CryoSADS), are the Applied Physics Lab's Dragonfly relocatable Titan lander (currently undergoing a New Frontiers Phase A study) and Europa Lander (NASA Flagship mission). CryoSADS is funded under NASA's COLDTech program and it will reach TRL 6 in 2019.

To date, a limited number of sampling systems have been developed for Europa and Titan. The optimal system would need to deal with a range of Europa's cryogenic materials: ice and salty ice, and Titan's cryogenic materials: ice, organic solids and liquids, and mixtures thereof. The other environmental constrains include hard vacuum, cryogenic temperature and significant radiation on Europa, and 1.5 bar atmospheric pressure and cryogenic temperature on Titan. In essence, apart from different atmospheric pressure and radiation levels, the two bodies are similar with respect to temperature and gravity.

Most science instruments such as GC/MS, Raman, LDMS require subsurface samples in powdered form. For Europa, these samples should come from greater depths (depths where radiation alteration is minimal) while for Titan, there are no radiation effects and near surface samples may suffice. The design of CryoSADS is such, that it will be able to reach samples in the 10-20 cm range. Greater depths are possible with the addition of a longer drill bit. The baseline sample volume is 1 cc per each centimeter of depth.

CryoSADS consists of a deployment system, rotary-percussive drill with powder sample acquisition and capture bit, and pneumatic sample transfer and drop-off system. The Weight on Bit will be limited to <40 N because of the low gravity and low spacecraft mass. To enable penetration into cryogenic material with such a low bit-ground contact pressure, the hammer system will deliver 2 J/blow at 20 Hz. To minimize reaction forces and vibration into the lander, the drill will be mounted on vibration isolator.

The pneumatic approach allows extremely fast sample transfer to an instrument, with minimal heating of the sample itself. The gas options include compressed gas from a dedicated tank for Europa's probe and a suction blower for Titan's probe. In essence, the difference between the two options is how the deltaP across the pneumatic system is being generated. On Europa the sample is 'blown' into an instrument by compressed air ("air gun" approach) while on Titan the sample is 'sucked' because of lower pressure generated by a blower ("vacuum cleaner" approach). To enable pneumatic transfer, the drill bit is a combination of a coring bit and a full faced bit. The coring cutters ensure a hole can be started even on a steep incline while the full faced cutter ensures generation of cuttings rather than a core.

CryoSADS is currently undergoing breadboarding and testing in Titan and Europa relevant materials. The test results will drive the final CryoSADS design and architecture. The fabrication of CryoSADS will be performed in the summer of 2018, and end to end tests will continue into 2019. CryoSADS will also undergo vibration and vacuum thermal tests to reach TRL6.

B5.3-0060-18 LABORATORY STUDIES WITH COSMORBITRAP IN THE CONTEXT OF FUTURE SPACE MISSIONS TO ICY WORLDS

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Today, a number of community-driven space mission concepts have been dedicated to the exploration of icy worlds, particularly those orbiting the Giant planets Jupiter and Saturn. The investigation of such environments and their chemistry, including the dense atmosphere of Titan, the possible sub-surface ocean of Europa, or the plumes of Enceladus, is among the highest priority objectives of new space missions. Mass spectrometers are among the key instruments that will be embarked for the in situ characterization of those environments, but require a new generation offering, for example, higher mass resolution than currently available.

A new mass analyzer based on the OrbitrapT M technology (extensively used in ground-based laboratories) is currently being developed, as a part a future development of more capable space mass spectrometers. The analytical cell is an ion trap (1) and its main assets are the high mass resolution combined with the design and the size of the analyzer (40 mm in diameter, 60 mm long). The Research and Development project is called Cosmorbitrap (2). This kind of instrument in space would provide us a very deep analysis capability of the chemical compositions of these moons.

This work aims at evaluating the analytical performance of a prototype of the Cosmorbitrap with respect to the detection of organic molecules in a variety of Titan and Europa analog samples. Lab-produced tholins, analogs of Titan aerosols (synthesized with the PAMPRE experiment (3)), have been analyzed in addition to dilute aqueous amino acid mixtures. In the context of a future space mission, these measurements demonstrate the capability of the Cosmorbitrap mass analyzer to identify and study a wide range of compounds (pure and complex organics, inorganics, and biosignatures) with ultrahigh mass accuracy (less than 5 ppm with internal calibration, Indium in our experiments) and resolving powers (more than 100 000 at m/z 136 and 80 000 at m/z 431). Work on the accuracy of the measurements of isotopic ratios is ongoing.

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B5.3-0061-18 SYLPH: BIOSIGNATURE DETECTION PROBE FOR POTENTIAL EUROPA PLUMES

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A concept is described for a biosignature-detection enhancement for the ocean-worlds flagship mission Europa Clipper. The investigation would use two instruments on the Clipper payload (MASPEX gas mass spectrometer and SUDA impact ionization mass spectrometer), plus a small, dual-channel version of SUDA deployed on a free-flying probe called Sylph. Together this instrument suite would directly sample the chemistry of plumes that Clipper may discover. Cassini measurements at Enceladus prove that these instruments can exquisitely measure the composition of ice grains, dust, and gas in a plume, profiling the habitability of the source water reservoir, and even detecting biomolecules. Sylph is a single-purpose probe designed to enable this investigation by performing the one critical measurement that Clipper itself cannot make: in situ, hypervelocity impact-ionization mass spectrometry of large ice grains. At Enceladus such large grains are known to be frozen ocean spray; at Europa, they would fall out of a plume 20km below the reach of Clipper. Sylph is a rad-hard, terrain-guided AutoNav freeflyer. Its small size (45kg, about the size of a home propane tank), simple instrument, and modularity allow it to be brutally sterilized during assembly, to meet anticipated Category IV planetary protection requirements. Target-initialized and deployed from a shielded, biobarrier hangar eight hours before a Clipper plume fly-through, Sylph drops down to 2-5 km altitude, skimming along the moon's surface to make a 3-second pass through the densest part of the plume. Cation and anion mass spectra, and AutoNav images, are relayed to Clipper within 30 minutes; the sterile probe eventually impacts Europa. With grain and gas mass spectra, the Clipper science team can quantify habitability of Europa plume water reservoirs. The first Sylph unit would cost about $85M; copies would cost less, and Clipper could carry two or three. The Sylph concept extends Cassini's demonstration of hypervelocity ice-grain spectrometry, and demonstrates cost-effective planetary protection for in situ exploration of ocean worlds in the outer solar system.

B5.3-0062-18 ZEOLITE-LOADED AEROGEL GETTERS AS A PRIMARY VACUUM SORPTION PUMP IN PLANETARY INSTRUMENTS

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Zeolite-loaded aerogel (ZLA) getters were devised, developed and produced for maintaining vacuum in the CNES seismometer instrument (SEIS) on the NASA InSight mission to Mars. The ZLA are very light compound materials (typically 0.1 g/cm3) with tunable density and very high surface area (>500 m2/g), when loaded with zeolite of choice. These materials are capable of maintaining medium vacuum (<10−3 mbar) for extended periods of time (months to years at room temperature) without any maintenance or consumption of power. The outgassing constituents of a typical vacuum system are vastly dominated by water, for which adsorption on zeolites is extremely efficient when properly conditioned. Ion exchange (Na+, Ca+, Mg+, Pd+, etc.) of the zeolites, prior to incorporation into the ZLA, can be used to further enhance the adsorption of non-dominant species, such as CO2, organic volatiles and, potentially, hydrogen.

The ZLA are prepared using a modified two-step silica aerogel process, and are loaded with fumed silica and zeolite particles in the liquid aerogel precursor. The precursor composition was chosen such that the zeolite particles stay homogeneously dispersed during the gelation process. The aerogel precursor with the dispersed zeolite particles forms a wet gel, locking the zeolite particles into the silica network formed. The material is then dried supercritically to produce a rigid silica network and to minimize shrinkage. The ZLA can be cast in practically any shape while in the liquid state, thus minimizing special engineering efforts. For particle-sensitive applications, the ZLA can be isolated by sub-micron filters without noticeably affecting the adsorption rate. The open pore network of the primarily mesoporous silica aerogel matrix, in which the zeolite particles are dispersed, provides excellent molecular conductance to the zeolite particles. This dramatically increases the effectiveness of the zeolite adsorption in comparison with their standard pellet form applications.

The ZLA getters are especially suitable for planetary instruments operating in extremely cold planetary environments, such as Europa, Enceladus, Titan, as well as Mars. The effectiveness of the getters at such conditions increases by several orders of magnitude due to the lowtemperature dependence of the adsorbance. It appears feasible that ZLA getters may be suitable to maintain even high vacuum (<10−6 mbar) for many years without any maintenance or power consumption. The low mass, 0.1-1 g per liter volume, and no detectable organics outgassing is particularly beneficial for optical instruments.

B5.3-0063-18 EFUN: THE PLUME SAMPLING SYSTEM FOR ENCELADUS

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Missions to Enceladus that seek to determine the habitability of its icy ocean and search for extant life must acquire a pristine sample of the Enceladus ocean water. This can either be accomplished via a lander or flythroughs of the plumes. From the mission and flight system design perspective, flythroughs incur less risk and cost, and the planetary protection requirements are easier to meet. One of the key challenges for these missions is to avoid ambiguity of results in the search for life. Therefore, the system must collect a large enough sample to enable analysis by several independent techniques. In addition, the sample collection process must not alter or contaminate the sample. The reliability of the collector after a long cruise time, its cleanliness, and low mass are also key concerns.

Maturation of the Enceladus Funnel (or EFun) sample collection mechanism is funded under the NASA COLDTech program. EFun's goal is to obtain a pristine sample of the ocean water via multiple flythroughs of the Enceladus icy plumes. The requirements for the sample collector include a large area to acquire as much sample as possible while ensuring that it is efficiently transferred into a very small holding volume. It must preserve the sample in its pristine ice form until the instruments are ready to perform analysis and then efficiently transfer the sample to the downstream instruments. EFun is the enabling technology for a suite of analytical instruments that determine the biological content of the Enceladus plume and determine Enceladus' habitability.

EFun collector development to date includes the verification of high-velocity (km/sec) ice particle capture using collector prototypes at the Ames Vertical Gun Range (AVGR), for range of particle sizes expected in the Enceladus plumes. It also includes measurements of capture efficiency and organics' alteration through collision with the collector walls. Methods for strict contamination control of the collecting surfaces are developed and tested. They involve cleaning protocols to minimize cross contamination in the AVGR shooting chamber environment, microbial reduction, and NASA approved bioburden monitoring practices. Multiple trades and a detailed design of the transfer and expulsion mechanisms are completed. The prototypes of those mechanisms are currently in test, and are on track to reach the expected level of maturity by the end of the COLDTech project.

B5.3-0064-18 CONTAMINATION MANAGEMENT OF SAMPLE COLLECTION DEVICES FOR LIFE DETECTION ON ICY WORLD PLUME FLY-THROUGH MISSIONS

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Life detection missions to the Ocean Worlds Jupiter and Saturn, such as Europa and Enceladus, will collect ice samples by either landing on the surface, or flying through the moon plumes using sample collection devices. Ice particles plumes, ejected into space from the underlying ocean, have been mapped on Enceladus [1-2] and, most recently, detected on Europa [3]. A key issue for highly sensitive life-detection instruments for sample analysis (e.g., capillary electrophoresis with laser-induced fluorescence, gas chromatography-mass spectrometry, and antibody microarray chips) is how to determine that a positive signal of life in a sample is intrinsic to the planetary body and not a result of exogenous contamination from Earth. Contamination management methods involve the use of blank control samples to calibrate the instrument against biomarker contamination just prior to receiving samples. However, in space or planetary surface environments, it is difficult or impossible to run blanks that fully sample the collection-and-handling devices, limiting the efficacy of this contamination management tool. In addition, the instrument detection sensitivity for target organics must be adequate for the lower limit of the anticipated concentration range of cellular and organic biomarkers in the target Ocean World, which can be very low, e.g., less than 80-120 cells/mL, in the range of the lowest values detected in the Antarctic subglacial Lake Vostok ice counterpart [4]. In this context, NASA Ames Research Center (ARC) has been simulating plume fly-throughs of prototype collectors of ice particles as well as surface ice sampling. During these impact tests at ARC's Vertical Gun Range (AVGR), basic ancillary experiments involve measurement of microbial and biomarker survival, and simultaneous management/monitoring of contamination levels of the prototype collectors and the AVGR chamber using NASA-approved practices [5]. The objective was to evaluate cleaning and microbial reduction techniques. These involved an ultrasensitive adenosine 5 triphosphate (ATP) luminometry assay (limit of detection: 0.2×10-15 moles (femtomoles, or fmol) for pre-screening of collector surfaces, which is below the threshold cleanliness limit of 2.3×1011 mmol ATP/ 25 cm^2 (0.9 fmol/cm^2) [6], and bioburden monitoring. The ATP does not survive cellular death and is a proxy for recent biological activity being used for bioburden monitoring in spacecraft [5] and cross-contamination during field trials. Furthermore, we used protocols that enabled mitigation of false negatives (kinetic-inhibited) and false positives (by reaction enhancement) in salt-rich samples. During sampling of the target sea ice (< 2 to 0.3 fmol ATP/100 µL) and on collector surfaces (< 0.2 to < 0.9 fmol/cm^2), contamination levels were negligible and did not affect scientific evaluation of biomarker survival upon impact in natural and synthetic seawater experiments (e.g., 5×103 fmol ATP/100 µL). These results are preliminary as test data are still being analyzed.

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Venkateswaran (2016) AMB Expr. 6:113.

B5.3-0065-18 ASK ASTROBIOLOGY SEARCH KIT FOR EUROPA

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Introduction:. Astrobiology Search Kit (ASK) instrument is a field portable spectrometer that: 1) Searches for evidence of biomarkers common to life on Earth; and 2) Assesses the habitability of the surface material (liquid, ice, soil) by measuring chemical constituents and mineralogy. The scientific basis of the instrument is wet chemistry combined with spectroscopy. Specifically, transmission, reflectance and organic (biological and geochemical) native fluorescence. For the geochemical assessment, we use wet-chemistry protocols that are well established and proven assays. ASK uses both contact ad non-contact methods. The contact method is similar to current techniques in environmental assays and medical diagnostics. These methods are indicative of specific lipids and proteins, common to most organisms on Earth. The non-contact method is spectroscopyfluorescence, transmission, and reflectance. We search for extant life,a nd the chemistry surrounding those biomolecules. Employing multiple techniques allows for redundancy within the same sampleessential to life detection verification. The ASK instrument is relevant to several potential near-term missions. We compare the ASK instrument capability to the mission goals/objectives of the Europa Lander directed mission. Science Goal:

1. Search for evidence of biomarkers and /or life, especially extant life. On Earth, all organisms that we know of have similar biochemistrythey use the same 20 amino acids, have nucleic acids (DNA or RNA), use the TCA Krebs cycle for energy and rely on Carbon, Hydrogen, Nitrogen, Oxygen, Phosphate, and Sulfur elements (CHNOPS). Due to these commonalities of life on Earth, our life detection instrument suite aims to detect aspects of each of these. The ASK instrument utilizes complementary biomolecule (life detection) methods using spectroscopy (including fluorescence) and biochemical assays based on enzymatic reactions in the Krebs cycle to gain an understanding of the biological mileau of the sample. The biomarker assay employs dry chemistries, transmission and fluorescence spectroscopy. The core detection technology utilizes the Patent Pending (US 2017/0038357-A1) Retego Labs advanced spectrometer. We have a complement of wet chemistry and fluorescence assays to detect universal compounds (DNA, RNA, NADH, and ATP for instance) and unique compounds to a specific extant life process such as (F420) in methanogens. The biomarker assays provide an insight into the diversity and evolution of microbial life providing a glance into the microbiome of the planetary body. Science Goal 2: Asses the habitability (particularly through quantitative compositional measurements) of Europa via in situ techniques uniquely available to a landed mission. Our search for extant life on Ocean Worlds begins with assessing the habitability by determining the basic chemistry of the sub-surface brine. The Retego Labs Advanced Spectrometer is designed for chemistry assays in brine produced water from the oil and gas industry. The brine water from these fields ranges from low to near saturation. Retego Labs designed a method using dry chemical assays combined with fluorescence to measure the desired constituents within the brine. These assays are specifically designed for brine environments, have more than a four year shelf-life and require no additional liquid reagents. The size of the ASK instrument is in the 1U range and could be a payload on a mission ranging from an interplanetary cubesat size to a New Frontiers Icy moons mission.

B5.3-0066-18 ADVANCED SPATIAL METHODS OF LOW COST MISSION DESIGN FOR JOVIAN MOONS EXPLORATION

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Spatial mission design of low-cost Delta V gravity assists tours for the Jovian moons exploration is considered, taking radiation hazard into account. The future space missions—the Laplace-P project of Roskosmos with the possible cooperation with the ESA's JUICE project which involves a landing on one of Jovian moons must be very refined. This is caused by a fact that the necessary cruise, flyby, and landing on the Jovian moon imply multiple reductions in the approach velocity of the spacecraft (SC), which, in view of contemporary restrictions for propellant consumption, can be ensured only by using of gravity assist maneuvers (GAMs) near Jovian moons. For these projects the execution of limitations on a mission duration, minimization of the level of total ionizing dose (TID) of radiation, and the delta V budget are required. The urgency of the creating a regular procedure for the construction of optimal scenarios or schedules of flybys of the appropriate celestial bodies and the development of conditions for executing of these schedules becomes evident. Advanced of the 3D construction methodology for such scenarios taking into account the spatial model of the Jovian radiation is descripted. The reduction of the SC's asymptotic velocity relative the satellite for the moon's capture is impossible. A valid reason is in the invariance of the Jacobi integral and the Tisserand parameter in the restricted three-body problem model (R3BP). Formalized spatial beam's algorithm of multibody GAMs used the refined ephemeris model has been implemented. Advanced modifications of the spatial Tisserand-Poincare graph for this purpose are introduced taking into account the 3D Divine/GIRE model of the Jovian radiation. Tisserand parameters of SC in several local R3BP for this purpose are used. The Multi-Tisserand graphs based on them are built. It is shown that the "cross" gravity assists at the early stage of SC's orbital energy reduction for TID-comfortable tours are required. As a result, a reasonable increase in the duration of the mission for Jovian moons exploration can be exchanged on a sharp decline TID and "comfortable" spatial 3D tours can be found in the Jovian system: less than 65 Krad for standard SC protection 8 mm Al.

B5.4-0001-18 RADIO OBSERVATIONS OF THE DEEP TROPOSPHERE OF URANUS: COMPARING GASAND ICE-GIANT PLANETS

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Ground-based radio observations of the giant planets at wavelengths from 1 millimeter to 1 meter probe the atmospheres from pressures near 0.1 bar (the tropopause) to pressures of 100's of bars or more. Our main focus in this talk will be disk-averaged quantities to highlight average composition, cloud formation and chemistry in Uranus' atmosphere, and how it compares to the gas giant planets. Planetary formation models for Uranus and the observed CH_4 abundance suggest the bulk abundances of both NH_3 and H_2S on the planet should be 50 to 100x solar, and that the NH_3 mixing ratio should be greater than the H_2S mixing ratio. As expected from previous works (e.g. Gulkis et al. Icarus 1978; de Pater and Massie Icarus 1985) we find that Uranus' atmosphere at pressures less than 20 bars has very little ammonia in it (on the order of 1 part per million, which is 1% of a solar abundance). Cloud formation in the deep troposphere (at pressures much higher than a pure NH_3 cloud would form) has been suspected of removing NH_3 from the atmosphere, but quantitative models do not achieve that level of depletion. Our new inverse modeling analysis finds NH_3 is only modestly depleted relative to solar (0.2 to 0.6x solar) between 20 and 50 bars pressure, while H_2S is moderately enhanced relative to solar in this region (1 to 2x solar). Equilibrium models indicate this region is bounded by an NH_4SH cloud on the low pressure side and a liquid water cloud on the high pressure side. In this region, the absolute abundance of H_2S molecules is greater than the abundance of NH_3. The radio data also suggest the presence of an upper tropospheric absorber such as PH_3 at 3x solar (or H_2S if its mixing ratio is allowed to increase with altitude), and the data suggest that the deep atmospheric H_2O abundance is >3x solar.

To explain the discrepancy between the high NH_3 and H_2S abundances in ice giant formation models and the low observed values, chemistry and dynamics can be invoked. We speculate that the presence of a high pressure water ocean in the deep interior of ice giant planets could account for much of the depletion of NH_3 and H_2S, if the solubility of those species under ocean conditions is high. (We do not know the state of the ocean, e.g. if it is ionic or not, nor do we know the thermodynamic properties of the H2O, NH3, H2S system under extreme conditions.) We note that the gas giants, which lack an ocean, have atmospheres which are not depleted in NH3. If water (or other) chemistry in the interior of ice giants can reduce the atmospheric NH3 mixing ratio to less than the atmospheric mixing ratio of H2S, formation of an NH4SH cloud at pressures near 25 bars can remove virtually all of the remaining NH3, leaving primarily H2S at higher altitudes. The radio data also requires an atmospheric opacity source at high altitudes (near 1 bar) which is greater than can be supplied by the equilibrium abundance of H2S. This could be due to another highly volatile species, such as PH3, or H2S if its mixing ratio is allowed to increase with altitude (which a simple lifted-parcel equilibrium model would not allow). We note that recent microwave measurements by the Juno spacecraft at Jupiter (Bolton et al. Science 2017) suggest spatial variations of the NH3 mixing ratio are very complex and do not always follow the predictions of equilibrium thermodynamics.

At the meeting, we will present refined estimates of the abundances and vertical profiles of species in the atmosphere of Uranus, and compare the chemistry and circulation of all the giant planets.

B5.4-0002-18 DISCOVERY AND DEMISE OF A DARK VORTEX ON NEPTUNE

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Hubble Space Telescope images in 2015 revealed a dark vortex at 45° south planetographic latitude, named SDS-2015 for "southern dark spot discovered in 2015." Observed four times over a two-year span, the feature was seen to drift slightly toward the pole, and to decrease in size and contrast. Its companion clouds also grew more centered, particularly in the 2017 observations. Aspects of this evolution are similar to two previous dark spots (in 1989 and 1994), suggesting that a common mode of vortex demise may involve fading contrast and centered companion clouds. Latitudes of 45° to 65° south (home to both SDS-2015 and DS2

seen by Voyager) hosted bands of variable albedo over the past three decades, without any observable fine structure in the zonal wind field. Reasonable assumptions about the vorticity of SDS-2015 and its surroundings lead to a conclusion that the meridional wind shear may be twice as strong at the deep level of the vortex as it is at the level of cloud-tracked winds.

B5.4-0003-18 SPATIAL VARIABILITY IN THE STRATOSPHERE OF URANUS

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Observations of spatial variability in the atmosphere of Uranus have been limited to cloud properties and temperatures in the troposphere from a combination of spacecraft and ground-based observations. We report observations of the spatial distribution of (1) the stratospheric temperature field and (2) the distribution of stratospheric acetylene from ground-based mid-infrared observations using giant telescopes that resolve the planet spatially. (1) Temperatures in the stratosphere were derived from spectral scanning of the H2 rotational S(1) quadrupole using the TEXES spectrometer at the Gemini North observatory in 2007, near Uranus' equinox at high resolution (R=55,000). The H2 S(1) line was mapped by scanning the slit longitudinally across the entire disk of the planet. The observed radiances from the line center emerge primarily from the 0.1-0.3mbar pressure level. As expected for the "thermally-inverted" stratosphere, the planet is limb brightened at all latitudes, generally consistent with the predictions for the temperature structure derived from Spitzer IRS disk-averaged spectra (Orton et al. 2014 Icarus 243, 494). A pole-to-pole cut through the central meridian shows a generally smooth variability, with the (IAU-defined) northern hemisphere emerging from winter darkness marginally brighter than the southern hemisphere, consistent with a smooth meridional gradient of temperatures. A latitudinal cut across the equator reveals an ostensible central brightening, as well as equal brightening toward the limbs. (2) The distribution of C2H2 in the stratosphere was derived from images of thermal emission made in 2009 using the mid-infrared imager/spectrometers VISIR at the Very Large Telescope and T-ReCS at the Gemini South Observatory using a 13.04-µm moderate-band (NeII-2) filter. Because the continuum in this spectral region is so faint, the upwelling radiation is dominated by acetylene emission from roughly the same pressure level at the radiation from the H2 S(2) quadrupole line. Although the general center-to-limb structure is consistent with predictions from the C2H2 distribution derived from the low-eddydiffusion rate models fitting the Spitzer IRS data (Orton et al. 2014 Icarus 243, 471), there is a strong latitudinal gradient with elevated C2H2 emission poleward of 25° latitude in both hemispheres. Given the apparent smooth meridional variability of temperature, this implies a distinct boundary of higher vs. lower C2H2 abundance regions. This boundary is most likely to be maintained dynamically, being quite different from the expectations of photochemical models with temporal and spatial dependence.

B5.4-0004-18 VLT/VISIR SPECTROSCOPY OF ICE GIANT STRATOSPHERES IN PREPARATION FOR JWST/MIRI

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The James Webb Space Telescope (JWST) MIRI instrument will provide global, spatiallyresolved 5-30 µm spectroscopy of Uranus and Neptune in 2020. These data can be inverted to determine the spatial variability of atmospheric temperatures, winds, and composition from the troposphere to the stratosphere. The results will offer unique constraints for radiative, dynamical, and chemical models of the ice giant atmospheres ahead of future missions to these destinations. Latitudinal temperature gradients have already been identified in both ice giant tropospheres (by Voyager 2 and ground-based 17-20 µm imaging, Orton et al., 2015, doi: 10.1016/j.icarus.2015.07.004; Fletcher et al., 2014, doi:10.1016/j.icarus.2013.11.035), and in Neptune's stratosphere via ground-based imaging, showing the presence of a warm polar vortex (Orton et al., 2007, doi:10.1051/ 0004-6361:20078277). Imaging of Uranus' stratosphere has proven challenging (see Orton et al., this meeting), and spatially-resolved spectroscopy of both stratospheres has been even harder. To date, only low-spectral-resolution (R 100) observations from Keck/LWS and Gemini-S/TReCS (Fletcher et al., 2014), along with high-spectral-resolution (R 85,000) observations from Gemini-N/TEXES (Greathouse et al., 2011, doi:10.1016/j.icarus.2011.05.028), have probed the spatial distribution of Neptune's stratospheric temperatures, and none have detected Neptune's summer polar vortex that is evident in photometric imaging.

We acquired VISIR long-slit spectroscopy of Neptune's CH4 emission from 7.1-8.7 µm (R 300) and C2H6 emission from 11.5-11.7 µm (R 3500) on September 13th 2009 (programme ID 083.C0163B). Neptune's polar hotspot was evident in 12.3-µm acquisition imaging and 11.6-µm spec tra, suggesting elevated temperatures and/or ethane within the seasonal vortex. However, the hotspot was not visible in 7.1-8.7 µm spectra, suggesting either (i) that stratospheric temperatures are not elevated within the vortex; or (ii) the slit did not properly align on the south pole, highlighting the difficulties involved in slit spectroscopy. JWST/MIRI will resolve this conundrum, and we present simulated IFU (Integral Field Unit) images based on the photochemical distributions of Moses et al. (submitted) and reasonable assumptions of latitudinal temperature gradients. In addition, we present a marginal detection of the 11.3-13.5 µm spectrum of Uranus (R 250) from September 16th 2008 (programme ID 081.C-0505B), revealing acetylene emission from the Uranian stratosphere. The warm stratospheric emission appears to be localised at mid-to-high latitudes in both spring and autumn hemispheres, whereas the equator appears cold. Comparisons to photochemistry model predictions suggest that this must be driven by an equator-to-pole circulation system in Uranus' middle atmosphere, an idea which will soon be tested by JWST.

B5.4-0005-18 SPATIAL STRUCTURE IN NEPTUNE'S STRATOSPHERIC CH4 EMISSION, AS MEASURED BY VLT-VISIR

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Neptune's atmosphere is dynamically active despite receiving limited solar radiation. In Neptune's southern polar stratosphere, a 'hot spot' of enhanced CH_4, C_2H_2 and C_2H_6 emission is evident. Fletcher et al., 2014 suggested subsidence and therefore adiabatic heating in a polar vortex as the source of the brighter mid-infrared emission while Orton et al., 2007 suggested this resulted from upward propagating waves originating in the troposphere. Greathouse et al. [2011] also suggested that waves may be important at lower latitudes to explain temporal variability in the C_2H_2 and C_2H_6 meridional distributions between observations in 1989 and 2007. In this paper, we will present observations made by VLT's VISIR (The VLT spectrometer and imager for the mid-infrared, [Rio et al., 1995]) instrument In September 2008. At 7.8 microns, Neptune's stratospheric CH_4 emission exhibits both latitudinal and longitudinal structure, which might be further evidence that Neptune's stratosphere is dynamically active at lower latitudes. We will test different image deconvolution techniques to optimize the effective spatial resolution. Subsequently, we will perform a forward-model analysis of the VLT-VISIR observations in order to investigate how much of the observed latitudinal/longitudinal variability in CH_4 emission is a result of changes in temperature or the vertical profile of CH_4. Results will also be compared with the near-coincident H-band Keck-NIRC2 [Wizinowich et al., 2000] observations to search for potential correlations between the stratospheric and tropospheric morphology.

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B5.4-0006-18 A DIFFERENT NATURE OF SOLAR WIND INTERACTION AT THE ICE GIANT MAGNETOSPHERES?

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The mysterious magnetospheres of Uranus and Neptune have barely been explored by spacecraft, yet they are distinct from all other solar system magnetospheres in many respects. Determining how each magnetosphere is coupled to the flow of solar wind plasma from the Sun is central to understanding energy flow through each planetary system, in which different elements are coupled (magnetosphere, moons, rings, and atmosphere). Here we assess how the solar wind interacts with each ice giant magnetosphere via magnetic reconnection. Analytical models of conditions at the magnetopause are combined with current understanding of reconnection onset to predict where reconnection may occur on each boundary. We highlight the dynamic location of reconnection sites, and potential seasonal dependence of coupling to the solar wind via this mechanism. We also consider the role of the "viscous-like" interaction between the solar wind and each ice giant magnetosphere, exploring the possibility that the relative important of the two modes of interaction may be different at the outermost planets. This topic represents only one of the many compelling aspects of magnetospheric science to be addressed by a future ice giant mission.

B5.4-0007-18 IMPACT CRATER DISTRIBUTIONS OF THE URANIAN SATELLITES: NEW CONSTRAINTS FOR OUTER SOLAR SYSTEM BOMBARDMENT

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Impact crater distributions of regular Outer Solar System satellites and large Kuiper Belt Objects are vital constraints for models of Outer Solar System impactor populations and impact fluxes [e.g., 1]. Data from the Galileo, Cassini, and New Horizons missions have provided important constraints at Jupiter and Saturn and in the Kuiper region [e.g., 2-5]; however, little has been developed for region in between, i.e., the Uranus and Neptune systems. This is partially because close-up imaging of these systems has not been obtained since Voyager 2. Nevertheless, analyses of Voyager 2 imaging of Neptune's moon Triton potentially indicated its crater distribution did not look like that seen at Jupiter, leading to a tentative suggestion that the impactor population had changed as it moved inward from Neptune [e.g., 6-7]. However, because craters had not yet been measured at that time for Kuiper Belt Objects, the possibility of an evolution of the impactor population could not be resolved. We now have that information from New Horizons imaging of Pluto and Charon, which seems to indicate crater distributions within the Kuiper Belt have a shallow slope at diameters (D) < 10-20 km, more like distributions at Jupiter and Saturn than at Triton, which has a steeper slope for these diameters [e.g., 5]. The reason for this is currently unresolved.

A key piece of missing information that may help resolve this conundrum is the crater sizefrequency distributions (SFDs) of the uranian satellites. However, characteristics of the craters on these satellites are still not agreed upon [e.g., 8]. The two efforts, one led by Robert Strom and the other by Jeff Plescia, performed just after the Voyager 2 flyby disagreed about the density of craters with D < 70 km on Titania, Oberon, and Umbriel, and D > 20 km on Miranda [summarized by 8]. Since this time no new analyses have been performed to attempt to resolve these discrepancies.

Therefore, we have identified and measured craters in the imaged regions on all five of the mid-sized uranian satellites - Miranda, Ariel, Umbriel, Titania, and Oberon - using newly calibrated Voyager 2 images (Paul Schenk, personal communication) imported into JMARS. We then computed the crater spatial density of the region analyzed using a kernel density computation that keeps the circular kernel radius across the surface constant in kilometers

(=10º latitude). The resulting density maps are used to define terrain boundaries based upon changing crater density, along with observed geologic boundaries, so we can explore if and how the crater SFD has changed with time. We then compare our crater SFDs with those from Strom and Plescia using the relative

(R) plot format [9]. Once the likely characteristics of the uranian satellite crater distributions have been settled, we will compare to the crater distributions of other Outer Solar System bodies from Jupiter to the Kuiper region.

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B5.4-0008-18 TRITON: THE CONNECTION BETWEEN ROSETTA, NEW HORIZONS AND A FUTURE ICE GIANTS MISSION

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Several planetary missions have made observations intended to evaluate the origin and evolution of volatiles in solar system atmospheres. This is an important topic that connects how planets, moons and small bodies formed to the question of past or present habitability. Comet isotope observations have been ongoing and have played a crucial role in this research. Measurements of the D/H in cometary water and 14N/15N in NH3, in particular, have been critical for evaluating the origin of water and nitrogen in the terrestrial planet atmospheres and for that of Saturn's moon Titan. We have conducted comparative studies modeling the escape, photochemistry and evolution of the atmospheres of Titan and Pluto to try to understand whether the nitrogen in these atmospheres originated as N2 or NH3 in the protosolar nebula. The origin of Titan's nitrogen has been well constrained, but uncertainties about isotope processes in Pluto's atmosphere leave the origin of Pluto's nitrogen difficult to resolve. Because of their similarities, Triton is subject to the same uncertainties and is of particular interest for understanding the origin of Triton's and Pluto's volatiles as well as of Kuiper Belt Objects in general. We will discuss how Rosetta, New Horizons and a future Ice Giants mission will each contribute to understanding the origin of nitrogen in these atmospheres and to the origin of volatiles in atmospheres throughout outer solar system.

B5.4-0009-18 FUTURE EXPLORATION OF ICE GIANT SYSTEMS AND KBO PLANETS

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In this talk, we will examine a two mission program that achieves Ice Giant, Ocean Worlds, and Kuiper Belt science objectives. This program takes advantage of ground system, spacecraft design, and flight dynamics efficiencies to achieve missions to BOTH Ice Giants at a total cost similar to that of the Mars Science Laboratory rover. This concept includes a Neptune Orbiter with an atmospheric probe and a significant number of Triton flybys that also flies by a Centaur in cruise. The second mission is a KBO dwarf planet flyby mission that includes a Uranus flyby, with the potential to deliver a near-identical, contributed, atmospheric probe. These two missions will together revolutionize scientific understanding of ice giant and dwarf planet origins, the processes that shape the evolution of planets, their satellites, and KBOs, and shed new light on the nature of exoplanets. When combined with the Europa Clipper and New Frontiers Saturn system missions, this approach achieves many of the Planetary Science Decadal's highest priority science objectives, dramatically advancing our understanding of the outer solar system.

B5.4-0010-18 ICE GIANT WORKSHOP

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This time slot is an opportunity for COSPAR participants to discuss future missions and science priorities for the exploration of the ice giants. It will start with a summary of the conclusions from the recently completed NASA/ESA Ice Giant mission study (see Poster by Hofstadter et al. for details), and then describe mission and technology ideas that have been proposed since that study. After reviewing ways the community can provide inputs to NASA's planning process via the Outer Planets Assessment Group and White Papers to the upcoming Decadal Survey, attendees will be invited to comment on and discuss all matters relating to ice giant exploration. The session moderators will allow time for several topics based on the interests of those attending. It is anticipated we will touch upon science priorities within the ice giant systems, mission ideas, and secondary science that can be achieved (including observations that might support Astrophysics, Heliophysics, and Exoplanet objectives).

B5.4-0011-18 IN SEARCH OF LONGITUDINAL VARIATIONS IN THE STRATOSPHERE OF URANUS

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The NASA Spitzer Infrared Spectrometer (IRS) acquired 5-37 micron spectra of Uranus and Neptune between 2004 and 2007. Uranus was observed in Cycle-1 Time November 2004 (Burgdorf et al., 2006, doi: 10.1016/j.icarus.2006.06.006), and again during Directors Discretionary Time very near its equinox in December 2007. The mean of the four observed longitudes in 2007, spaced equally around the planet, have provided the opportunity for the most comprehensive characterisation of Uranus' vertical structure (temperature and hydrocarbon composition) ever obtained (Orton et al., 2014, [paper 1] doi: 10.1016/j.icarus.2014.07.010; [paper 2] doi: 10.1016/j.icarus.2014.07.012). Given the 0.85-m diameter primary mirror, the Spitzer spectroscopy lacked the spatial resolution to show how these properties varied across the planet, meaning that the results of Orton et al. should be considered as global averages. However, in this work we analyse the differences in temperature and composition between the four separate hemispheres to shed light on the variability of Uranus' stratosphere in 2007. The IRS acquired a similar set of spectra for Neptune in May 2004 (Meadows et al., 2008, doi: 10.1016/j.icarus.2008.05.023) and November 2005, which gives us a unique opportunity to compare the longitudinal variability of the two planets for the first time.

We present initial findings that include the discovery of a definite longitudinal variability occurring across the spectrum on both Uranus and Neptune. On Uranus, the tropospheric H2-He continuum looks to be relatively constant from longitude to longitude. The emission as a function of longitude from all stratospheric hydrocarbon species (e.g., methane, ethane, acetylene, etc.) does, however, appear to vary by around 10% from the mean in an approximately sinusoidal fashion. This wavenumber-2 pattern could indicate the presence of planetary wave activity or meteorological phenomena over wide areas in the stratosphere. A similar pattern was observed over the three longitudes used in the November-2004 Uranus dataset, albeit with a smaller amplitude of approximately 5%. Conversely, the November-2005 Neptune data displays much smaller levels of variability between the three longitudes sampled, despite typically being considered the more active planet. Building on the forward-modelling analysis of Orton et al., we will present full optimal estimation inversions (using the NEMESIS retrieval algorithm, Irwin et al., 2008) of the 2007 Uranus spectra at each longitude to distinguish between thermal and compositional variability in the stratosphere.

B5.4-0012-18 A STUDY ON EXPLORING URANUS AND NEPTUNE: SCIENCE OBJECTIVES AND MISSION REQUIREMENTS

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Ice Giant Science Definition Team

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The Ice Giant planets, Uranus and Neptune, are priority targets for future exploration because they challenge our understanding of how planets form and evolve, unique physical properties are on display in their rings, satellites, and magnetospheres, and because ice giants are common around other stars. NASA and ESA recently undertook a mission study whose complete report is available at https://www.lpi.usra.edu/icegiants/mission_study/.

This study identifies the two highest-priority science objectives as • Characterize the planet's interior. • Determine the planet's bulk composition, including noble gases and isotopic ratios.

Ten additional objectives are • Improve knowledge of the dynamo. • Determine the atmospheric heat balance. • Measure the tropospheric 3-D flow. • Characterize the structures and temporal changes in the rings. • Obtain an inventory of moons. • Determine the surface composition of rings and moons. • Map the shape and geology of satellites. • Determine the density and internal structure of satellites. • Characterize Triton's atmosphere. • Investigate solar wind-magnetosphere-ionosphere interactions.

The study finds that Uranus and Neptune are equally compelling science targets. Each planet has things to teach us which the other cannot, so ultimately both systems must be explored.

The study investigated many mission architectures and finds that achieving these objectives would require a well instrumented orbiter making multiple flybys of each major satellite and dropping an atmospheric probe into the planet. The study does not recommend a specific payload, but discusses a range of possible instruments and suggests an orbiter payload of 150 kg is needed.

The information in this abstract is predecisional and is provided for planning and discussion purposes only.

B5.4-0013-18 ELECTROSTATIC SAIL PROPULSION FOR RAPID DEEP SPACE TRAVEL

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Travel time is a limiting factor in our exploration of the outer solar system and beyond. The immense distances, combined with the limitations of rockets, using either chemical propulsion or electric propulsion, has made robust scientific exploration of: the Ice Giants, outer solar system dwarf planets and the heliopause extremely difficult or outright infeasible. Propulsion-intense inner solar system missions such as those that might view the sun at high solar inclinations, are also problematic.

To meet these challenges, NASA is developing Electrostatic Sail propulsion technology. Electric Sails have the potential to enable rapid and robust outer solar system exploration as well as inner solar system missions with high Delta V requirements. Electrostatic Sails use positively charged bare wire tether(s) that extend radially outward from a spacecraft spinning at a rate of about one-third revolution per hour up to one revolution per hour. When a positive voltage is applied to the tether(s), an electric field and associated Debye Sheath is created around them. The sheath stands off of the bare wire tether at a sheath diameter that is proportional to the voltage in the wire coupled with the flux density of solar wind ions within the solar system (or the location of spacecraft in the solar system). Solar wind protons traveling at speeds ranging from 400 to 800 km/sec are electrostatically repelled away from these positively charged Debye sheaths and propulsive thrust is produced in the wires and tethered spacecraft via the resulting momentum transfer. The amount of thrust produced is directly proportional to the total wire length.

Most of the subsystem technologies required to field an Electric Sail are at Technology Readiness Levels (TRL) greater than 4, with several having been previously space-qualified. Engineers and scientists at the NASA George C. Marshall Space Flight Center recently completed Phase 2 of a NASA Innovative Advanced Concepts (NIAC) study are working toward an eventual flight test of the technology. The physics of the Electrostatic Sail, its potential application to science missions, and technological maturity will be described.

B5.4-0014-18 NUCLEAR THERMAL PROPULSION: ENABLING ROBUST MISSIONS TO THE ICE GIANTS

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NASA is developing nuclear thermal propulsion (NTP) stages for future human and robotic scientific exploration of the solar system. First generation systems under development, when coupled with the lift capability of NASA's Space Launch System, will enable spacecraft with dry masses between two and five metric tons to be captured into orbit at Uranus and Neptune with reasonable trip times. No state-of-the-art or near-term new propulsion system can come close to matching this performance. This capability may enable robotic landers the size and mass of Curiosity (900 kg), used for exploring Mars, to be landed on the moons of the Ice Giants. Spacecraft comparable to the Cassini (2500 kg) may also be sent to explore the Ice Giants and their moons.

First generation NTP system will provide high thrust at a specific impulse above 900 s, roughly double that of state of the art chemical engines. And, using Low Enriched Uranium (LEU), comparable to that use in university-class research reactors worldwide, will allow these systems to be developed at a much lower cost than previously-considered NTP systems.

An overview of the propulsion systems being developed, estimated performance for first generation NTP systems (for exploration of the Ice Giants and beyond), as well as a status of the NASA program will be discussed.

B5.4-0015-18 ICE GIANTS EXPLORATION: DUAL AND TWIN SPACECRAFT APPROACHES

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With the progression of the robotic exploration of the Solar System and the continuous advance in exoplanetary studies, filling the gap represented by the limited knowledge we possess of Uranus and Neptune is becoming more and more critical. Not only these ice giant planets represent the archetype for studying one of the most abundant classes of exoplanets, but their characteristics and those of their satellite systems have been shaped by the earliest and most violent phases of the life of the Solar System. Understanding them is therefore an essential step in understanding our place in the galactic context. Because of their similarities and differences, both ice giants are compelling targets and much can be learned by their comparative study. With this rationale in mind in 2013 we submitted to the European Space Agency the ODINUS white paper (http://odinus.iaps.inaf.it), where we described the scientific case of exploring both planets and their satellites in the framework of a single European L-class mission. To achieve this ambitious goal, we proposed the first mission scenario based on the use of two identical spacecraft to two different planets. Both the scientific case and the original twin orbiter scenario were assessed as feasible by ESA and were further refined and consolidated by the ODINUS team during the following interactions the scientific community. The recent joint NASA-ESA study for future missions to the ice giants (https://www.lpi.usra.edu/icegiants/) allowed for confirming the feasibility of the dual/twin spacecraft approach to the two ice giant planets and for considering more ambitious mission profiles, involving larger payloads and the possibility of including atmospheric probes, in the framework of scenarios of international cooperation.

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COSPAR COMMITTEE ON SPACE RESEARCH

Space Studies of the Upper Atmospheres of the Earth and Planets including Reference Atmospheres (C)

COSPAR 2018

42ND ASSEMBLY | 60TH ANNIVERSARY

C0.1-0001-18 UPDATE OF THE EUROPEAN SPACE ENVIRONMENT STANDARD

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The European Coordination for Space Standardization (ECSS) aims to develop and establish a coherent set of standards for use in all European space activities. In this framework the standard ECSS-E-ST-10-04C 'Space Environment' in particular provides models to determine the environmental conditions for space missions. Following aspects are covered by this standard: gravity, magnetic felds, electromagnetic radiation, neutral atmospheres, plasmas, energetic particle radiation, space debris, micro-meteoroids and contamination.

The recent issue of the standards dates back to 2008. Since then many new data sources and models became available. In order to reflect the more recent developments and provide unambiguous guidelines to the space engineering community it was decided to update the standard. The commissioned working group consists of a selection of representatives from European industry and agencies, namely Thales Alenia Space, OHB System AG, Airbus Defence and Space, SES, Centre National d'Études Spatiales, Offce National d'Études et de Recherche Aérospatiales, Deutsches Zentrum fur Luftund Raumfahrt and European Space Agency.

The update activity is in progress and scheduled for final draft release for public review in mid of 2018. This paper aims to present the proposed changes in the various fields to the community with a request for feedback preferably in the scope of the public review exercise.

Please note that the update of this standard is work in progress at the time of the abstract submission. A consolidated view on the update and the potential impacts on spacecraft development will be presented at the conference.

C0.1-0002-18 TOWARDS MODERNIZATION OF ISO 16457 STANDARD: EIGHT PROXY INDICES OF SOLAR ACTIVITY FOR THE INTERNATIONAL REFERENCE IONOSPHERE AND PLASMASPHERE MODEL

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The ISO16457-2014 standard "The Earth's ionosphere model - International reference ionosphere (IRI) and extensions to the plasmasphere" should be re-approved by ISO (International Standardization Organization) as new ISO16457-2019 standard in 2019. In view of the recent recalibration of the sunspot number time series SSN2, a need has arisen to re-evaluate solar and ionospheric indices in the IRI and IRI-Plas models, which are developed using the predecessor SSN1 index. To improve efficiency of the model, eight solar proxy indices are introduced in IRI-Plas system: the daily measured solar emissions - the Ottawa 10.7-cm radio flux F10.7 and the H Lyman-α line at 121.6 nm; the core-to-wing ratio of the magnesium ion h and k lines at 279.56 and 280.27 nm, MgII index; sunspot number SSN1 observed before 05.2015 and modeled afterwards; re-calibrated SSN2 sunspots time series; the ionosonde foF2-based global IG-index; the Global Electron Content, GEC, index; the new ionospheric TEC-noon index based on GPS-derived Total Electron Content measurements at 288 IGS stations for 1998-2018. The regression relations are deduced between the different solar and ionospheric proxy indices smoothed by 12-month sliding window. Relevant subroutines are incorporated in IRI-Plas system (http://ftp.izmiran.ru/pub/izmiran/SPIM/) and IRI-PLas online (http://www.ionolab.org/) for automatic conversion of user's predefined index to other related indices used by the different model procedures. Evaluations of accuracy of IRI-Plas with GPS-TEC and ionosonde data demonstrate advantages and shortcomings of the different selected solar proxies.

C0.1-0003-18 A NEW GLOBAL ELECTRON AND PROTON SPECIFICATION MODEL: GREEN

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The well known AP8 and AE8 NASA models are commonly used in the industry to specify the radiation belt environment. Unfortunately, there are some limitations in the use of these models, first due to the covered energy range, but also because in some regions of space, there are discrepancies between the predicted average values and the measurements. Moreover, new US models AE9/AP9 were developed a few years ago. These models are better than AE8/AP8 in some cases but are still very controversial in some regions of radiation belts. Therefore, our aim is to develop a radiation belt model, covering a large region of space and energy, from LEO altitudes to GEO and above, and from plasma to relativistic particles. GREEN (Global Radiation Earth ENvironment) is a model providing fluxes at any location between L*=1 and L*=8 all along the magnetic field lines and for any energy between 1 keV to 10 MeV for electrons and between 1 keV and 800 MeV for protons. This model is composed of global models: AE8/AP8 and SPM for low energies and local models. Ten years ago we developed the IGE-2006 model for geostationary orbit electrons. This model was proven to be more accurate than AE8, and used commonly in the industry, covering a broad energy range, from 1keV to 5MeV. From then, a proton model for geostationary orbit, called IGP, was also developed for material applications. These models at geostationary orbit were followed by the OZONE model covering a narrower energy range but the whole outer electron belt, a SLOT model to assess average electron values for 2<L*<4, and finally the OPAL model, which provides high energy proton flux values at low altitudes (up to 1336 km). As most of these models were developed using more than a solar cycle of measurements, these ones being checked, cross calibrated and filtered, we have no doubt that the obtained averages are more accurate than AP8 and AE8 for these particular locations. These local models were validated along different orbit with independent data sets or effect measurements. GREEN is not just a collection of various models, it calculates the electron and proton fluxes from the more relevant existing model for a given energy and a given location. Moreover, some existing models can be updated or corrected in GREEN. In 2017, a new version of GREEN was developed (GREEN-V1), in which a new SLOT model (up to L*=5) and a correction of AE8 model at high energy for L*<2.5 have been implemented. Up to now, some efforts have mainly been made to better estimate high energy

electron fluxes, but in 2018, some improvements will be done for energetic proton fluxes and low energy protons and electrons fluxes. Of course, the way the model is developed is well suited to future enhancement with new models developed locally or under international partnerships. In a near future, GREEN model would be accessible for space industry in the OMERE software.

C0.1-0004-18 SPACE WEATHER INFORMATION FOR USE IN SPACE SYSTEMS OPERATIONS

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Effective space systems operations require an accurate knowledge of recent, current, and forecast conditions of the space environment. These conditions change dynamically on timescales of seconds to years and are driven primarily by the Sun's photon and particle interactions with the near Earth environment. We call this phenomenon of short-term variation space weather. ISO TC20/SC14/WG4 is developing an international standard on space weather information for use in space systems operations. The objective will be to describe the main space weather factors affecting space systems operations and to identify tools and parameters needed for effective space weather risk management. We report on the development status of the document that will establish definitions of space weather information and aid in harmonizing key space weather tools provided by international organizations, national government agencies, and industries. Areas covered will include time frames for space weather information as well as environments from galactic cosmic rays through the solar environment within the heliosphere to the near-Earth environment including effects such as ionospheric, magnetic, and radiation storms. A first annex will include a listing of space weather indices with their: 1) description such as content, derivation, assumptions, uncertainties and limitations; 2) application utility to system operation and maintenance; 3) contributors with dates of development, authors/sponsors, collection frequency, locations or instruments; and 4) publication references and index access including URLs. A second annex will include space weather effects to systems by environmental region including Ground Systems, Lower Atmosphere, Upper Atmosphere, Suborbital, Low Earth orbit, Mid-Earth orbit, Geostationary Earth orbit, High Earth orbit, and Interplanetary orbits.

C0.1-0005-18 INTERNATIONAL STANDARD FOR KP PREDICTION

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The Kp index is a global measure of geomagnetic activity and it represents short-term magnetic variations driven by space weather. Kp index is used as an input to various thermosphere and radiation belt models, and it is therefore important to predict it accurately. A prototype model of Kp nowcast and forecast is currently under development. The model predicts the Kp index based on the solar wind measurements from ACE and DSCOVR satellites, recurrency and persistence. We give an overview of the model, describe its concept, design, access to the produced forecast, and demonstrate the forecast results. We also compare the model performance to the historical forecast of the Kp index by other models.

C0.1-0006-18 AE9/AP9-IRENE VERSION 1.5: UPDATED SPACE RADIATION CLIMATOLOGY MODEL

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This presentation describes version 1.5 of the AE9/AP9 family of space radiation climatology models. The most significant update is inclusion of new data sets that change the flux maps. These new data include measurements from Van Allen Probes, Azur, and the HiLET sensor. In recognition of international contributions to the models, we introduce the IRENE nomenclature for International Radiation Environment Near Earth.

C0.1-0007-18 ONGOING AND FUTURE DEVELOPMENT OF THE COSPAR INTERNATIONAL REFERENCE ATMOSPHERE AND RELATED ISO STANDARDS FOR THE EARTH'S ATMOSPHERE.

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The paper will present a discussion of the current and future developments of the COSPAR International Reference Atmosphere and related ISO Standards for the Earth's Atmosphere.

C0.1-0008-18 CURRENT STATE OF SINP MSU MODEL OF SOLAR ENERGETIC PARTICLE FLUXES BASED ON ISO/TR 18147 MODEL. COMPUTATIONS OF THE RISKS FOR MANNED MISSIONS

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The description and basic principles of the model of solar energetic proton fluxes being developed in the Institute of Nuclear Physics of Moscow State University are presented, which is based on the ISO/TR 18147 model of proton fluxes. The development of the model for the fluxes of solar heavy ions with charge number z = 2-28 based on the same principles is described.

The comparison of SINP MSU model with other existing models of solar energetic particle fluxes is shown.

Computations of radiation doses for different scenarios of the manned space missions are made using this model. In particular the results of computations using the prediction of solar activity for the next weak solar cycles 25 and 26 are shown.

C0.1-0009-18 ENERGETIC DEPENDENCES OF HIGH LATITUDE BOUNDARY OF THE OUTER RADIATION BELT AS MEASURED BY RUSSIAN LEO SATELLITES IN 2005-2017

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The empirical model of high-latitude boundary of the outer radiation belt has been updated on the base of LEO satellite measurements of energetic electron fluxes obtained during long time period, larger than one solar cycle (2005-2017). The model was corrected taking into account internal magnetic field secular variations and corresponding magnetic poles movement during the observation period. Analytical equation for the high-latitude boundary of the trapped 100 keV energetic electrons was obtained in dependence on UT, energy and geomagnetic activity level. Forecasting capability of the model was realized in the framework of MSU's Space Monitoring Data Center using the forecast of the DST index. Automatic boundary detection method was developed based on LEO satellite measurements of charged particle fluxes for different energetic channels and at different altitudes. The experimentally obtained position of high-latitude boundary of the outer radiation belt was compared with the results of model calculations.

C0.1-0010-18 ISO STANDARDS FOR LIDAR SYSTEMS REQUIRED FOR METEOROLOGY, AVIATION SAFETY AND WIND FARM APPLICATIONS.

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With increasing, even wide-spread use in meteorology, aviation safety, monitoring and tracking pollution, ISO-TC146-SC5-WG6 has been developing a series of new standards covering the appropriate applications of Lidar and Doppler Wind Lidar Systems. Three standards have already progressed through the ISO process (ISO 28902 parts 1, 2 and 3). Further items, including a standard for Particle back-scatter Lidar (related to meteorology and pollution) and Direct-Detection Doppler Wind Lidar Systems (as will be exploited by ESA's Aeolus Wind Lidar Mission) are the subjects of ongoing and future work. The presentation will briefly describe the previous and ongoing work of the Working Group.

C0.1-0011-18 GENERAL PRINCIPLES OF SPACE ENVIRONMENT SIMULATION TO STUDY ITS EFFECTS ON SPACECRAFT MATERIALS

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Under the aegis of ISO, there have been developed numerous standards that regulate the testing of materials and spacecraft equipment components to the impact of various space environment components: vacuum, radiation, solid particles, etc. ISO documents often consider specific objects to be tested, e.g. thermal control coatings, electronic components, solar elements, but not the space environment itself and its impact on materials in general. However, even for each type of near-Earth orbits a set of space components that are the most important for spacecraft operation, may differ substantially. Therefore, there was a need to develop an ISO document that determines sets of main space environment components for different near-Earth orbits and interplanetary regions, including Moon, Mars and Jupiter environments, and describes main physical and chemical processes caused by effects of the given space environment components on materials as well as criteria of material durability to such an influence.

There are several objective reasons to require improvements in the forecasting of spacecraft material durability in relation to outer space environment impact, namely: increase of the spacecraft lifetime; development of the new spacecraft designs (non-hermetic spacecraft, microsatellites, etc.); application of new materials, including nanomaterials; complexity and sensitivity improvement of the spacecraft onboard equipment; development of new orbits in the near Earth space; implementation of new space projects (manned flight to Mars, building of manned bases on the Moon, etc.).

Such a document has been developed by Russian and Japanese scientists, it was published in 2016 as ISO 17851:2016 Space systems - Space environment simulation for material tests

-General principles and criteria. The paper presents the detailed description of the Standard, considers potential fields of its application along with other ISO documents, and discusses its further development.

C0.1-0012-18 MODELING OF SPACE ENVIRONMENT IMPACT ON NANOSTRUCTURED MATERIALS. GENERAL PRINCIPLES

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Nanomaterials surpass traditional materials for space applications in many aspects due to their unique properties associated with nanoscale size of their constituents. This superiority in mechanical, thermal, electrical and optical properties will evidently inspire a wide range of applications in the next generation spacecraft intended for the long-term (15-20 years) operation in near-Earth orbits and the automatic and manned interplanetary missions. ISO activity on developing standards concerning different issues of nanomaterials manufacturing and applications is high enough. Most such standards are related to production and characterization of nanostructures, however there is no ISO documents concerning nanomaterials behavior in different environmental conditions, including the space environment. In accordance with the resolution of ISO TC20/SC14 WG4/WG6 joint meeting, Technical Specification ISO/NP TS 22295 'Modeling of space environment impact on nanostructured materials. General principles' which describes computer simulation methods of space environment impact on nanostructured materials is being prepared.

This document considers the application of multiscale simulation approach to study physical and chemical processes that may occur in nanostructured materials under the influence of different space components. General guidelines to evaluate the durability of nanostructured materials to the space environment influence on the ground of results mathematical simulation and principles of choosing materials for various fields of space are presented. The document determines ordered sequences of methods that should be applied to simulate different space environment effects on nanostructured materials. Methods and software packages described in this document can be used to evaluate the durability of nanostructured materials to space environment effects and to make recommendations on their usage in various space missions. The Technical Specification is intended for researchers and engineers involved in developing and testing next-generation spacecraft.

C0.2-0001-18 IMAGING MESOSPHERIC WINDS USING THE MICHELSON INTERFEROMETER FOR AIRGLOW DYNAMICS IMAGING (MIADI)

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The first ground based images of mesospheric winds in airglow are presented and discussed in this paper. These were obtained with the Michelson Interferometer for Airglow Dynamics Imaging (MIADI) a ground based field widened Michelson interferometer designed to obtain two dimensional images of the line of sight Doppler wind and irradiance field in the mesosphere. The purpose of this instrument is to measure perturbations in line-of-sight wind and airglow irradiance associated with gravity waves. In its current configuration, the instrument observes an 80 km x 80 km region of the night sky in 33 minutes using the O(1S) emission at 557.73 nm and the OH (6, 2) P1 (2) emission at 839.918 nm. The instrument was installed and tested at a field site outside Fredericton, NB (45.96 N, 66.65 W) during the summer of 2014. Successful measurements over a six hour period were obtained on July 31, 2014. Variations in the meridional and zonal wind were observed that are consistent with a semi-diurnal tide with an amplitude of 35 m/s. Small scale variations (< 10 m/s) were also observed that indicate the presence of gravity waves. In this paper, the instrument concept will be presented and the field measurements and their precision and accuracy discussed.

C0.2-0002-18 AN INTRODUCTION FOR FUV IONOSPHERIC PHOTOMETER ON BOARD FY-3(D) METEOROLOGICAL SATELLITE

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FUV Ionospheric PhotoMeter,one of the four new instruments on board FY-3(D) Meteorological Satellite which was launched on 15th.Nov.2017, measure the atomic oxygen 135.6 nm and nitrogen molecule LBH145nm-180nmemissions.During nighttime, the electron density of the ionosphere is estimated using the measured spatial distributions of brightness from the 135.6 nm emission.During daytime, the ration between atomic oxygen and nitrogen molecule can be estimated by measured the brightness from 135.6nm and 145nm-180nm.In this report, we will introduce the design and performance of the IPM, finally, the primary on-orbit results of IPM will be shown.

C0.2-0003-18 OBSERVATION FOR THE WHOLE ATMOSPHERE OVER TIBET PLATEAU WITH THE ATMOSPHERIC PROFILING SYNTHETIC OBSERVATION SYSTEM (APSOS)

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To understand the whole neutral atmosphere and the coupling from lower to upper atmosphere, a synthetic system called "Atmospheric Profiling Synthetic Observation System (APSOS)" has been developed and funded by the National natural Science Foundation of China (NSFC) since 2012. It is a system mainly consisted of five lidars devoting to observe the vertical structure of atmospheric temperature, wind, air density, water vapor, ozone, CO2, SO2, NO2, aerosol, cirrus cloud, and sodium layer with high vertical and temporal resolution, a W-band Doppler dual polarized radar, a THz radiometer. Three of the five Lidars commonly use a composite optical receiving telescope with equivalent diameter of 2-meter. Seven research institutes and universities have been engaged in this project. Since late 2016 APSOS has been completed the development of each unit. In 2017, APSOS fulfilled the system tests and the whole system has been deployed at Yangbajing, a field site near Lhasa and with altitude of 4300 m ASL for multi - disciplinary observation. In this paper, we will present the system techniques, data and retrieval system, preliminary results of the atmospheric vertical structure of temperature, water vapor, GHGs, high clouds, ozone, aerosols, as well as wind profiles from the lower troposphere to mesopause.

C0.2-0004-18 TOWARD A NEW CAPABILITY FOR UPPER ATMOSPHERIC RESEARCH USING ATOMIC OXYGEN LIDAR: THE TOMEX-PLUS EXPERIMENT

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The Turbulent Oxygen Mixing Experiment Plus (TOMEX-Plus) sounding rocket investigation is presented. This mission will explore the three-dimensional nature of turbulent phenomena near the mesopause through a three-rocket salvo combined with ground-based remote-sensing instrumentation. The centerpiece of the experiment is an ultraviolet lidar system capable of measuring atomic oxygen in-situ, and the progress on its development is discussed. Also described are the other components of the experiment, including in-situ measurements of temperature, density, and winds; two chemical release rockets used to provide context measurements of winds and atmospheric mixing; a ground-based complement of instruments that features imaging of waves through OH airglow measurements and an iron lidar to give context measurements of the temperature and winds; and a modeling component. The architecture of the overall experiment is presented, and the conditions under which the experiment will be performed discussed.

C0.2-0005-18 DEVELOPMENT OF DIFFERENTIAL ABSORPTION LIDAR SYSTEM (DIAL) AT NATIONAL ATMOSPHERIC RESEARCH LABORATORY,INDIA

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A DIfferential Absorption Lidar (DIAL) is developed at National Atmospheric Research Laboratory, Gadanki (13oN, 79oE), India for measurement of ozone concentrations to understand Upper Troposphere Lower Stratosphere (UTLS) exchange processes and statospheric ozone changes. The system measures ozone concentrations in the height regions of 2-45km. The system is developed in two channels, one for tropospheric ozone and another channel for stratospheric ozone monitoring taking ozone absorption crosssection in these regions into consideration. Accordingly ON-OFF wavelength pair of 289 and 299 nm is chosen for tropospheric ozone concentration measurements. The wavelengths are generated by pumping Raman Converter filled with Deuterium, Hydrogen and Argon with fourth harmonic of Nd:YAG laser. The energy at Raman shifted wavelengths are about 20mj with an efficiency of about 10%. The backscattered wavelengths from the atmosphere are collected by Newtonian feed telescopes in multiple receiver concept with 50cm effective aperture. The signals from the telescope are fed to a monochromator by an optical fiber. The monochromator is in Czerny Turner configuration and consists of 1200 lines/mm UV enhanced holographic grating with an efficicency of 60%. All the three wavelengths (266, 289, 299nm) are thus collected simultaneously by using three PMT detectors, with 60% efficiency, in different planes. The signal is then given to a data acquisition unit with analog and photon counting features. The analog and photon counting modes are chosen to give a high dynamic range to the system, from high intensity signal at lower altitudes to low intensity signals from higher altitudes. The analog signal is acquired at 16 bit resolution with sampling rate of 20MSPS. With Photon counting, maximum count rate of 250 MHz is achieved with temporal resolution of 25ns. The ozone concentration profile is obtained from the acquired signal by merging the two types of signals by standard methods. An

ON-OFF wavelength pair of 308-355nm is chosen for stratospheric ozone concentration measurements. The wavelengths are generated with XeCl based Excimer laser and third harmonic of Nd:YAG laser. Same receiver for both tropospheric and stratospheric ozone concentrations with appropriate changes in

optics is used. The tropospheric channel of the system is realised and is in testing stages. The design details, configuration of DIAL system and first observations will be presented.

C0.2-0006-18 OBSERVATIONS FROM RAYLEIGH DOPPLER LIDAR SYSTEM AT NATIONAL ATMOSPHERIC RESEARCH LABORATORY, INDIA

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A Rayleigh Doppler lidar has been developed at National Atmospheric Research Laboratory, Gadanki (13.5° N, 79.2° E) to measure winds in the height region of 10-50km. The system measures mean wind velocities in the height regions where Mie scattering is negligible. The Doppler lidar system is an incoherent system and uses edge technique for wind derivation. The system has an Nd:YAG laser operating at an energy of 600 mJ at 532 nm with 50Hz repetition frequency. The laser line is frequency stabilized and operates in single longitudinal mode. An optical fiber collects the return light from a 750mm diameter telescope and guides the signal to a servo stabilised Fabry-Perot Interferometer, scrambling the light homogenously. The signal is detected by means of Photo Multiplier Tubes (PMT) and the detected signal is given to a data acquisition unit. The FPI acts as amplitude discriminator and its specifications is determined based on the Doppler broadening of the Rayleigh backscattered light. Single Edge technique is adapted in which the backscattered signal is made to fall on the steep falling edge of the transmission characteristics of FPI and changes in the output amplitude is viewed proportional to wind velocities. Any wavelength and energy changes in laser is monitored continuously by a second channel in the receiver and the ratio between the FPI channel and monitor channel gives the parameter deviation. As the vertical velocities are smaller in magnitude and therefore difficult to measure, the study is limited to determine the two horizontal wind components namely Zonal and Meridional winds. The radial winds are calculated as a difference from the reference beam i.e vertical beam, and by knowing the sensitivity of the FPI for zero winds the horizontal winds are computed from beam tilt angle and radial winds. The system was operated on a few cloud free days and the results are presented. Intercomparison of the lidar winds with GPS Radio sonde balloons measured winds have shown good comparison.

C0.2-0007-18 THE DEVELOPMENT OF THE COMPREHENSIVE LIDAR STATION IN YANQING AND UPPER ATMOSPHERIC STUDY WITH LIDAR DATA

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A lidar station was constructed in 2009 in Yanqing (40.5°N, 116.0°E), under the support of Chinese Meridian Project. This lidar is a dual -wavelength lidar, mainly for sodium and atmospheric density observations. The signal noise ratio of this lidar is so high, and then the observations with high spatial or temporal resolutions have been done. Later, based on this lidar, we successfully get the daytime sodium atom layer measurements, as well as the potassium layer detection. Otherwise, under the support of NSFC of China and the State Key Lab, an all solid sodium temperature/wind lidar and a Doppler wind lidar were also developed in recent years. And now we are working on the Ni, Ca+ and Ca layers detection with a new telescope and lasers. Thus a comprehensive lidar station has been developed in Yanqing. Very large amounts data have been obtained by the above lidars, and upper atmospheric study was done with these data. The study mainly includes the properties of mental layers study and gravity wave study: A series of low-thermospheric sodium layer cases were detected by Yanqing lidar and it aroused people's interest worldwide to study sodium layers at high altitudes; The maximum of the seasonal variation of potassium layer density is in winter, different with other potassium lidar observations; The gravity wave activity above Yanqing was obtained and was compared with other lidar results in China. Until now, based upon Yanqing lidar data, more than 30 papers has been published.

C0.2-0008-18 DEVELOPMENTS OF IMAGING LIDAR SYSTEMS RELEVANT TO STUDIES OF THE ATMOSPHERE AND TO SURVEILLANCE

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A novel Imaging Lidar System has been developed and demonstrated, exploiting an innovative multi-element photon-counting photo-detector. The photo-detector has a 32 * 32 element anode proximity-mounted behind a photocathode and micro-channel plate stack. The data stream from the detector provides 100psec time-tagging of individual detected photon events - in addition to the identification of the detection channel. A 16 * 16 registration is currently used while the electronics for the full 32 * 32 unit is under development and testing. When used with an appropriate pulsed laser source, it replaces an individual optical fibre / photon-counting detector at the focal plane of a lidar receiving system, the Imaging Lidar System generates instantaneous 3-D images with a potential range resolution of as little as a few mm. Many tests of this novel Imaging Lidar System have been conducted with a "standard" Nd-YAG laser with 7 nsec pulse duration. Contrary to scanning Lidar systems exploited for autonomous vehicle operations, the range of the Imaging Lidar System is currently up to 3 - 5 km. Although the "extended" pulse duration of the current laser limits the potential range resolution of the Imaging Lidar, the initial results clearly demonstrate the potential of the Imaging Lidar System. A steering system is used to acquire and track specific targets of interest, however, no rapidlyscanning moving parts are required to construct its "instantaneous" images. The initial tests of the Imaging Lidar System have investigated the complex 3-D internal structures of fog banks and clouds, in addition to 3-D imaging of a range of targets.

C0.2-0009-18 THE NEW MERLIN MISSION FOR ATMOSPHERIC METHANE: QUALITY AND PERFORMANCE MONITORING

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After water vapor and carbon dioxide, methane is the most abundant greenhouse gas in the Earth's atmosphere. The new generation space borne Lidar mission MERLIN (Methane Remote Sensing Lidar Mission) will make very sensitive measurements of the methane distribution with unprecedented quality, i.e. 50km averaged methane columns with a precision of < 2%. After its launch, MERLIN will track down methane sources and sinks on a global scale. The instrument will be mounted on a satellite platform flying at 500 km altitude in a Sun synchronous orbit. The instrument will continuously send and receive a pair of pulses at two different wavelengths. One wavelength is centered on CH4 (methane) absorption line Λon 1645.552 nm. The second pulse is a reference at Λoff which is slightly shifted by a few tenths of nm. It is located where CH4 absorption is relatively smaller, but yet it is close enough to have a nearly identical interaction with the atmosphere and the reflecting surface. From the back-scattered signals of both pulses (on and off), the DAOD (Differential Absorption Optical Depth) of methane is measured, and thus its column density. We will present our approach and strategy to perform a key ground segment work component that supports MERLIN scientific activities which is the long-term monitoring of the Lidar instrument and its measurements. This function includes tracking the behavior of the instrument and its subsystems over time as well as verification and validation of the scientific data during the entire lifetime of the mission. It mainly monitors the instrument's performance in response to expected or unexpected natural events or technical situations. These are achieved by analyzing the measurement data and housekeeping information over different time frames. We will additionally show how our expertise in SCIAMACHY can be applied to MERLIN.

C0.2-0010-18 INVESTIGATION SPECTRAL IMAGE THE UPPER ATMOSPHERE OVER REGIONS WITH THUNDERSTORM USING DATA FROM THE SV "TERRA / MODIS"

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The results of the two-level experiment, including registration of the electric field in the surface layer during thunderstorm on TSCRS (Almaty) and synchronous image the top of the cloud cover over the test range from satellite "Terra / MODIS" are presented. Spectral image of the upper atmosphere over of the thunderstorm related to lighting discharge has been created. As a result of the processing of satellite images Terra / MODIS created a new index of "lightning discharge," which will be used to search for and investigation of optical phenomena (such as Sprites, Elves, Blue Jet) over the regions with thunderstorm activity. The developed technique of space picture processing will be used for studying optical phenomena above other regions too.

C0.2-0011-18 A MECHANISM TO EXPLAIN THE VARIATIONS OF TROPOPAUSE AND TROPOPAUSE INVERSION LAYER IN THE ARCTIC REGION DURING A SUDDEN STRATOSPHERIC WARMING IN 2009

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The mechanism to explain the variations of tropopause and tropopause inversion layer (TIL) in the Arctic region during a sudden stratospheric warming (SSW) in 2009 was studied with MERRA reanalysis data and GPS/COSMIC temperature data. During the prominent SSW in 2009, the cyclonic system changed to the anticyclonic system due to the planetary wave with wavenumber 2 (wave2). The GPS/COSMIC temperature data showed that, during the SSW in 2009, the tropopause height in the Arctic decreased accompanied with the tropopause temperature increase and the TIL enhancement. The variations of the tropopause and TIL were larger in higher latitudes. A static stability analysis showed that the variations of the tropopause and TIL were associated with the variations of the residual circulation and the static stability due to the SSW. Larger static stability appeared in the upper stratosphere and moved downward to the narrow region just above the tropopause. The descent of strong downward flow was faster in higher latitudes. The static stability tendency analysis showed that the strong downward residual flow induced the static stability change in the stratosphere and around the tropopause. The strong downwelling in the stratosphere was mainly induced by wave2, which led to the tropopause height and temperature changes due to the adiabatic heating. Around the tropopause, a pair of downwelling above the tropopause and upwelling below the tropopause due to wave2 contributed to the enhancement of static stability in the TIL immediately after the SSW.

C0.2-0012-18 THE RESULTS OF THE TURBOPAUSE ALTITUDE MEASUREMENTS BY THE ARTIFICIAL PERIODIC IRREGULARITIES TECHNIQUE

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Turbopause is the region of the atmosphere below which turbulent mixing dominates, and above it molecular diffusion predominates. The artificial periodic irregularities of the ionospheric plasma [1] (APIs-technique) allows determining the altitude of the turbopause region. The APIs are created in the antinodes of the power standing radio wave produced as a result of the interference of the incident wave and reflected one from ionosphere. The vertical scale of the APIs is equal to one half of wavelength of the transmitted wave. The APIs diagnostics is based upon observation of the Bragg backscatter of the pulsed probe radio waves from the periodic structure. The amplitudes and phases of the probe signals back scattered by the APIs are measured. Time for which the scattered signal amplitude diminishes in e-times after turning out powerful transmitter is the relaxation time of the APIs. The relaxation time above a certain level zt decreases with increasing altitude in accordance to the diffusion law. Below the level zt, the turbulent mixing begins, and zt is the upper boundary of turbopause. Observations of the APIs were carried out in the autumn of 2007-2014 using the SURA facility of (NIRFI-UNN)in Vasil'sursk (56.1°N,46.1°E). The results of determining of zt are presented here. 1)The boundary zt of turbopause was located in average between 97 km and 102 km. 2)The turbopause boundary could vary from 94 km up to 107 km. This altitudinal interval can be considered as the turbopause region.3) In those cases when in the overlying region the instabilities were developed [2], the temporal variations of the zt boundary near its mean level with period 10 min were observed. Their period was equal is closed to the period of internal gravity waves (IGW). This fact indicates the exchange of energies between IGW and the environment.

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G.I. Grigoriev, Advances in Space Research. 2015. Pp. 1185-1193.

C0.2-0013-18 AN ANALYSIS ON THE ASCENT AND DESCENT RATES OF INFLATED METEOROLOGICAL BALLOONS

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Scientific ballooning is part of the exploration in meteorology and atmospheric science. Hydrogen or helium inflated rubber balloons or plastic balloons are released into the atmosphere as carriers of meteorological payloads for atmospheric sounding from the surface of the ground to the upper layers in the atmosphere reaching even 40 km height from mean sea level. The atmospheric data sensed in-situ, by the meteorological sensors tied to the ascending balloons, is collected by the ground based receivers. Apart from the meteorological data received, the ground based radar tracked or GPS based high temporal resolution balloon track data with time based positional coordinates of the balloons provide the fine details of rate of the ascent and descent of the balloon (after the balloon is burst attaining the apogee point in the atmosphere and falls down to the earth).

The buoyant balloon, inflated by the known amount of hydrogen or helium gas is supposed to ascend with a uniform rate of ascent, is perturbed by non-uniform scales of turbulent eddies embedded in the atmosphere causing irregular three dimensional motion of the balloon. This causes a fluctuating vertical profile of the rate of ascent of the balloon.

An analysis on this rate of ascent / descent of the meteorological balloons of various types is carried out. Various hidden details of the atmospheric motions and certain weather phenomena of different height scales are observed from the rate of ascent profiles. The extent of statistical smoothing required to obtain a reliable vertical profiles of the atmospheric parameters is studied and presented here.

C0.2-0014-18 HIGH RESOLUTION PROFILES OF ATMOSPHERIC PARAMETERS USING PISHAROTY GPS-RS INSTRUMENT

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During May-June 2017, short period upper air ascents were conducted from Bangalore University Campus (12.930N, 77.580E), Bengaluru, India, using indigenous GPS-RS instruments and ground based receiver developed by Indian Space Research Organization, Government of India. These instruments were flown by helium filled rubber balloons to collect in-situ data of standard atmospheric parameters (pressure, temperature, relative humidity and horizontal wind speed and direction: PTU and wind). Modulated data was transmitted to ground based receivers to provide the atmospheric data at 1Hz sample rate.

Thus the base raw data of an ascent provides time based altitude, latitude and longitude of the sonde and corresponding data of PTU along with information on number of GPS satellites in view and PDOP at very moment of the data. Using 1Hz sampled raw data and considering the response characteristics of the PTU sensors, suitable smoothing windows are devised for each atmospheric parameter to carry out moving average and obtain the smoothed output at 1Hz rate.

From the smoothed output, vertical profiles of the atmospheric parameters are obtained at high resolution height intervals (at least 300 meters) from the ground level to the level of balloon apogee for each ascent. The derived vertical high resolution data provides the base to study smaller-scale and high frequency atmospheric phenomena.

C0.2-0015-18 COMPREHENSIVE RESEARCH TO DESIGN ROCKET NOSE SHAPE FOR LEO SATELLITES

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From those big machines to those tiny microchips capable of storing 100 times more data, a time has come for advanced engineering techniques to make the world more developed. Now a day's scientists and engineers are trying to convert the abilities of big massive satellites into smaller Nano satellites. Sounding Rocket can be an alternative approach for launching such Nano-satellites into the Lower Earth Orbit. It offer scientists, a vehicle that will carry their instruments to almost any altitude they desire ranging from a few kilometers to thousands of kilometers. It can provide several minutes of observation time above the Earth's atmosphere, insulating the scientific instruments from much of the radiation, plasma, and micrometeoroid flux pervading outer space. With just a few minutes above the atmosphere it would be sufficient to make many fundamental discoveries about the nature of the Sun, the stars, and our celestial environment. Just like the fin of a rocket, nose cone shape plays more important role but the detailed research is not yet done resulting in the comparative study among the conventional nose shapes which are conical, Elliptical, Parabolic Series, Power Series or the HAACK series, which shape will result in the best performance under what circumstances for designing and building a sounding rocket capable of reaching Lower Earth Orbit. Nose cone is the key structural part which decides the overall performance of the sounding rocket and it should be chosen keeping in mind the following parameters: number of stages in the rocket, location of center of gravity, location of center of pressure, design of rocket fins and most importantly the material used and this depends on nose cone to nose cone. This paper deals with the detailed comparative study in support with experimental data and simulations of fluid flow over the nose cone and stress simulations due to the impact of high pressure and temperature. A six-degree-of-freedom study is made on the different nose shapes showing their individual importance and hand calculations are done to obtain exact dimensions using the respective nose cone equations and plotting coordinates and later joining those coordinates in CATIA to obtain a perfectly designed 3-D geometry of each conventional nose cone. Further, the generated 3-D geometry is extracted in "Fluent" and "Static Structural" in ANSYS for fluid flow and stress simulations. This paper discuss the effect of nose shapes on altitude performance depending upon the overall vehicle stability and bending moments about the payload rocket interface.

C0.2-0016-18 RENEWED POSSIBILITIES FOR STUDIES OF THE ATMOSPHERE BY SOUNDING ROCKETS FROM ESRANGE SPACE CENTER, SWEDEN

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From the 1960's to the end of the last millennium one or two Swedish sounding rockets were launched each year, not accounting for all the numerous metrology rockets in the same era.

Now the first three sounding rockets for studies in the atmosphere, within a new Swedish national balloon and rocket programme initiated by the Swedish National Space Board (SNSB) in 2012, have been successfully launched from Esrange Space Center. These three mark the beginning of a new era for advanced sounding rocket studies in the atmosphere from Esrange Space Center.

O-STATES 1 & 2, "Oxygen Species and Thermospheric Airglow in The Earth's Sky" by the Department of Meteorology at Stockholm University (MISU) and Swedish Space Corporation (SSC). A single payload, carrying a core of optical instrumentation, launched twice into different conditions during one single campaign with abbreviated on-site refurbishment between flights.

SPIDER/LEEWAVES, "Small Payloads for Investigation of Disturbances in Electrojet by Rockets" & "Local Excitation and Effects of Waves on Atmospheric VErtical Structure" by the Space and Plasma physics department of the Royal Institute of Technology (KTH), the Department of Meteorology at Stockholm University (MISU) and Swedish Space Corporation (SSC). Two missions combined in one payload carrying an instrumentation of in total 10 + 4 freeflying sensor sets being deployed into the atmosphere from one single rocket.

These will be followed by upcoming missions such as SPIDER-2 (accepted in January 2018).

This is a report on O-STATES 1 & 2, SPIDER/LEEWAVES and upcoming missions and flights as well as future possibilities for studies in the middle and upper atmosphere by sounding rockets from Esrange Space Center, Sweden.

C0.2-0017-18 A NOVEL APPROACH FOR THE DETERMINATION OF ELECTRIC FIELD VECTORS AND ITS USE FOR THE CALIBRATION OF ELECTRON TEMPERATURES AT 110 KM DURING STRONG ELECTRIC FIELD EVENTS.

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The analysis of very strong electric field data has allowed us to test a new technique to obtain the electric field vector by simultaneously sampling the E and F regions with AMISR radars on closely spaced magnetic field lines. A comparison with a reconstruction technique based on sampling the F region from various azimuths shows an excellent agreement between the two techniques. For weaker electric field events this implies that the technique could be used to find E region neutral winds once a multi-azimuth determination of the electric field based on F region measurements has been retrieved. The new technique has been used to calibrate the E region electron temperature at 110 km during strong electric field events. As is now well-known, the E region electron temperatures at 110 km can increase by as much as an order of magnitude or maybe more under very strong electric field conditions. For a particularly strong event we have established that the electron temperature was reaching more than 3500 K when the electric field was of the order of 175 mV/m. The observations were obtained during a smooth variation of the electric field and came from several beams that recorded the temperature independently, meaning that it was documented with an unusually large data sample for this kind of event.

C0.2-0018-18 A STATISTICAL STUDY OF THE RELATIONSHIP BETWEEN RIOMETER ABSORPTION SIGNALS AND PRECIPITATING ELECTRONS

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Ground-based riometers provide an inexpensive means to continuously remote sense the precipitation of electrons in the dynamic auroral region of Earth's ionosphere. Riometer's have been observing fluctuations in cosmic noise power for several decades, at multiple locations across the northern and southern hemisphere. These radio-wave power fluctuations are primarily caused by 1) the variation in power emanating from distant stars and galaxies, across the sky, and (2) absorption of those radio waves by free electrons in the charged ionospheric medium. The first case may be removed by suitable application of a quiet day curve, while the second is directly related to energy dissipation through electron-neutral collisions. With several spacecraft, and advanced numerical models, there exists an opportunity to further investigate how the precipitating electrons relates to the riometer signals, known as cosmic noise absorption. In this study, we present an analysis of how the precipitating electron spectrum relates to the observed riometer signals. A combined drift and conjunction analysis is employed, which brings together multipoint groundand space-based observations and numerical modeling. The result is a multi-year classification of riometer signals as related to geomagnetic activity, and a measure of how those signatures relate to the estimated electron precipitation during this time.

C0.2-0019-18 FIRST TIME DETERMINATION OF THE O+ ION TEMPERATURE ANISOTROPY IN THE F REGION UNDER STRONG ELECTRIC FIELD SITUATIONS AND IMPLICATION FOR THE O+ O COLLISION FREQUENCY.

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Under strong electric field conditions the F region ion temperature becomes anisotropic with larger temperatures perpendicular to the magnetic field than along it. We have quantified this anisotropy through the use of Monte Carlo simulations based on available collision cross section information. Perpendicular to parallel ion temperature ratios as high as a factor of 5 were expected. Using AMISR Incoherent Scatter Radar data based on a sampling of the same magnetic field lines from various directions during particularly strong electric field events, we have obtained a preliminary characterization of this anisotropy and have found to our surprise that it appears to be greater than predicted by theory, in turn indicating that the resonant charge exchange collision cross section used by researchers may actually be underestimated.

C0.2-0020-18 ES-LAYER CRITICAL FREQUENCY INVESTIGATION WITH INCREASED TEMPORAL RESOLUTION

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At present, it is well known that thin plasma layers are formed sporadically in the lower ionosphere, which are referred to as sporadic E (Es) layers and play an important role in the propagation of HF/VHF radio waves. Sporadic E layers often have very high electron concentrations. The main theory explaining Es-layer formation at middle latitudes is the wind shear model, which is based on the collection of positive ions moving in the Earth's magnetic field under the effect of a non-uniform horizontal wind at a certain height in the E region of the ionosphere. Internal gravitational waves (IGW) propagating in the atmosphere can create gradients of vertical velocity, which is necessary for metal ions collection into thin layers, which leads to formation of Es-layers with an increased electron concentration at middle latitudes. These layers (they can already be called "classical Es") exist for several hours, often they have a constant height and a horizontal scale from a few to hundreds kilometers and a heterogeneous structure. The main features of Es-layers have been well studied, in this paper the Es-layer critical frequency with an increased temporal resolution (1 ionogram per minute) is studied for a long time interval. The research algorithm consists in the precise definition of foEs using manual processing of A-maps. The analysis shows the quasi-periodic variations of foEs with a period of 5-15 min. Often the variation of foEs is similar to that of foF2. Additionally, the oscillation periods of foEs well correlate with the appearance of medium-scale TIDs in the F region of the ionosphere at mid-latitudes.

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C0.2-0021-18 ADVANCED SIGNAL PROCESSING TOOLS OF IONOLAB FOR IONOSPHERIC IMAGING

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Temporally and spatially varying, dispersive, anisotropic and inhomogeneous nature of ionosphere makes it a major player in space weather. The determining parameter of ionosphere is the electron density. Yet, electron density cannot be measured or determined directly. Total Electron Content (TEC), which is defined as the line integral of electron density on a given ray path, is an observable parameter of ionosphere that can be estimated from earth based GPS receivers in a cost-effective manner as GPS-TEC. International Reference Ionosphere (IRI), and one of its extensions to plasmasphere, IRI-Plas, are the foremost acknowledged climatic models of ionosphere that provide electron density profile and hourly, monthly median values of critical layer parameters of the ionosphere for a desired location, date and time from 60 to 2,000 km and 20,000 km in altitude, respectively. One of the most important advantages of IRI-Plas is the possible input of GPS-TEC to update the background deterministic ionospheric model to the current ionospheric state. This option is highly useful in regional and global tomography studies and HF link assessments. IONOLAB group developed unique IONOLAB-TEC that includes IONOLAB-BIAS algorithm that forms the basis of 1-D TEC estimation, that is available at www.ionolab.org. Combining TEC in a given region using IONOLAB-MAP algorithm provides very high resolution interpolated TEC maps both in space and time. Using IRI-Plas as a background model and updating the ionospheric state using GPS-TEC, IONOLAB group developed Computerized Ionospheric Tomograpy, IONOLAB-CIT, and ray propagation algorithm, IONOLAB-RAY. Both IONOLAB-CIT and IONOLAB-RAY use state-of-the-art signal processing in a unique manner to fuse the model with GPS-TEC. The reconstructed state of ionosphere with IONOLAB algorithms allows the most reliable 1-D, 2-D, 3-D and 4-D imaging of electron density profiles and HF and satellite communication link simulations. This study is supported by TUBITAK 115E915 and joint TUBITAK 114E092 and AS CR 14/001.

C0.2-0022-18 IMPROVING THE TOPSIDE IONOGRAM SCALER WITH TRUE-HEIGHT (TOPIST) ALGORITHM TO AUTOMATICALLY SCALE ISIS/ ALOUTTE DIGITAL IONOGRAMS

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Abstract: [1][2] More than 1/2 million digital ionograms from the Alouette-2, ISIS-1, and ISIS-2 ionospheric topside sounders are now available as a result of the data restoration project for the original analog telemetry tapes recorded between 1965 and 1984 from 24 globally distributed ground stations as part of the International Satellites for Ionospheric Studies (ISIS) program designed primarily to produce vertical topside electron density profiles Ne(h). [3] The Topside Ionogram Scalar With True-Height (TOPIST) software was designed to automatically invert ISIS-2 topside ionogram traces into vertical electron-density profiles. It has been used for the automatic inversion of the ionogram reflection traces on more than 250,000 ISIS-2 digital topside ionograms into topside vertical electron density profiles Ne(h). However, it encounters problems that can lead to misleading results when processing ISIS-1 topside-sounder data due to the much higher altitudes reached by ISIS-1 (up to 3,500 km) compared to ISIS-2 (1,400 km). In this research we aim to improve the resonance detection process in TOPIST so as to get the best starting point at the satellite for the trace inversion leading to the correct topside Ne(h). Such improvements would allow to reap the greatest benefit from the current efforts being made to produce enhanced ISIS-1 digital topside ionogram files that are more suitable for automatic processing.

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C0.2-0023-18 AN MF/HF RADIO ARRAY FOR RADIO AND RADAR IMAGING OF THE IONOSPHERE

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The Aguadilla Radio Array is intended for broad-band medium and high-frequency (MF/HF, roughly 2 to 25 MHz) radio and bistatic radar observations of the ionosphere. The array is being installed at the Interamerican University Aguadilla Campus, located in northwestern Puerto Rico. The array will consist of multiple antenna elements, each of which is a single active (electromagnetically short) crossed electric dipole. Elements in the core array are arranged in a partly regular and partly semi-random pattern providing a good distribution of baseline vectors, with 6-meter minimum spacing to eliminate spacial aliasing. In addition, five elements are located in a partial ring around the central core, providing a roughly four times expanded region in u-v space for improved image resolution and quality. Phase is maintained between the core and ring elements via cabled connections to a central location. Relocatable cable-less array elements will also be included, in which phase is maintained between elements by through the use of GPS-disciplined rubidium clocks. Primary scientific goals of the array are to study the mechanisms of ionospheric radio emissions stimulated by the Arecibo Observatory highpower high-frequency radio transmitter through the creation of high-resolution radio images of the emission region, and to study ionospheric structure and dynamics via wide-area coherent radar imaging of the ionosphere in collaboration with the University of Colorado and NOAA Versatile Interferometric Pulsed Ionospheric Radar (VIPIR), located at the USGS San Juan Observatory in Cayey, Puerto Rico. In addition to ionospheric research in collaboration with the Cayey and Arecibo Observatories, the goals of the project include the development of radio sounding, polarization, interferometry, and imaging techniques, and training of students at the university and high school levels.

C0.2-0024-18 A NEW AURORAL VHF RADAR FOR E-REGION IONOSPHERE STUDIES: FIRST RESULTS

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The Ionospheric Continuous-wave E-region Bi-static Experimental Auroral Radar (ICEBEAR) is an ionospheric radar located in Saskatchewan, Canada. The new radar was designed and developed at the University of Saskatchewan for E-region radar studies and became operational in December, 2017. The ICEBEAR radar system configuration is bi-static with the transmitter site about 170 km south-west of the receiver site, with the receiver site located close to the University of Saskatchewan in Saskatoon, Canada. The transmitter signal is a modulated continuous-wave radio signal with a center frequency of 49.5 MHz. The ICEBEAR radar applies modern advanced digital radio and/or software defined radio techniques, including highly accurate timing. A unique property of the radar is both high temporal and spatial resolution simultaneously. Nominal operation is to use a 10,000 symbol binary pseudo random code with a single symbol code length of 10 µs, although any radar code is possible. This gives a high spatial resolution of 1.5 km and a high temporal resolution of 100 ms. This, coupled with the interferometry abilities of the radar, allows for detailed 'maps' or 'images' of the E-region.

The scientific objectives of the ICEBEAR radar are for studies of E-region plasma irregularities and Magnetosphere-Ionosphere (MI) coupling. This paper presents initial results from the ICEBEAR radar and is focused on E-region plasma irregularities and meteor observations. Long term objectives are for MI coupling studies, such as the distribution and evolution of field-aligned-currents (FACs) from the magnetosphere, their relation to discrete arcs and their dynamics, ELF resonances, etc.

This paper presents first observations of E-region plasma irregularities from the new ICEBEAR radar and new insights into their physics.

C0.2-0025-18 IONOSPHERIC THREE-DIMENSIONAL GPS-TEC TOMOGRAPHY OVER JAPAN AND ITS STATISTICAL VALIDATION WITH IONOSONDE AND COSMIC OCCULTATION MEASUREMENTS

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Measurement of ionospheric total electron content (TEC) by using ground-based GPS receivers is now widely used, which we refer to as GPS-TEC. In Japan, there is one of the densest network of GPS receivers that is named as GEONET (GNSS Earth observation network system) operated by Geospatial Information Authority of Japan (GSI). We have developed three-dimensional (3D) tomography analysis based on the constrained least-squares fitting method, and applied it to the GPS-TEC data from GEONET. We started the real-time analysis with 15 minutes interval and about five minutes latency since March 2016. In this paper we report that we analyzed most of GEONET data since 1996 by using the supercomputer of Kyoto University. We assign one core of the supercomputer to one-day analysis (15-minute interval from 200 GPS receivers), and achieved that processing time for one-year data was about 30 hours only. The results are statistically validated through comparisons with ionosondes and COSMIC occultation measurements. The maximum density from the 3D tomography showed good agreement with the foF2 parameter from ionosondes. We also found that the F2-peak of the 3D tomography density profile is lower in density, and higher in altitude compared with corresponding parameters from the COSMIC occultation measurements. These results of the 3D tomography analysis start being used by other ionospheric studies.

C0.2-0026-18 THE NIGHTTIME WINTER ANOMALY (NWA) EFFECT - A PROMINENT FEATURE OF THE MID-LATITUDE IONOSPHERE AT THE AMERICAN AND ASIAN LONGITUDE SECTORS

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The ionospheric Nighttime Winter Anomaly (NWA) was reported at the first time more than three decades ago based on Total Electron Content (TEC) and vertical sounding data. The aim of this talk is to provide further observational evidence that the NWA effect occurs regularly under low solar activity (LSA) conditions at the American and Asian longitude sectors where the geomagnetic latitude exceeds the geographic latitude by more than 10° in the Northern and Southern hemispheres, respectively. The NWA effect will be analysed using Faraday rotation measurements on geostationary satellites, ground and space based dual frequency measurements on signals from Global Navigation Satellite Systems (GNSS) and vertical sounding measurements covering a time span of more than 40 years since the 70s. In particular, the derived TEC and peak electron density data (NmF2) but also the equivalent slab thickness illustrate clearly the occurrence of the NWA effect under LSA and geophysical conditions mentioned above. Of particular interest is the close coupling of the NWA with the Mid-Summer Nighttime Anomaly (MSNA) that becomes manifest in the Weddell Sea and Okhotsk Sea anomalies. The talk will convincingly demonstrate the close relationship of these different ionospheric anomalies. The observations confirm earlier explanations considering strong ionosphere-plasmasphere and associated interhemispheric coupling as the main origin. A coordinated modelling study will investigate the potential of dynamic forces such as thermospheric winds and electric fields to understand the coupling mechanism in detail.

C0.2-0027-18 THE NIGHTTIME WINTER ANOMALY (NWA) - CONTRIBUTIONS TO EXPLORE COMMON IONOSPHERE-PLASMASPHERE COUPLING MECHANISMS WITH THE MID-SUMMER NIGHTTIME ANOMALY (MSNA)

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The ionospheric Nighttime Winter Anomaly (NWA) was first reported in the 1980-ies resulting from total electron content (TEC) data based on Faraday rotation measurements as well as due to vertical sounding data of ionosondes. It has been shown to be a regular phenomenon at mid-latitudes under low solar activity conditions for certain longitudinal sectors, which are characterized by large offsets between geographic and geomagnetic parallels. From the outset of this finding, it was supposed that the interhemispheric plasma transport and the plasmaspheric storage plays an important role for this effect. The thermospheric wind circulation and the global dynamo electric field act in favour of corresponding interhemispheric plasma fluxes. Immediately related to the NWA effect are midsummer nighttime anomalies (MSNAs), which are characterized by the fact that nighttime upper ionosphere plasma densities might be larger than daytime densities in the local summer. Particularly known in this respect are the Wedell Sea Anomaly (WSA) and the Okhotsk Sea Anomaly (OSA). By means of global numerical modelling of the coupled system of thermosphere, ionosphere-plasmasphere, and magnetosphere together with its electrodynamic interconnection, we will show the close relationship of these various anomalies. The causes for the NWA are plasmaspheric storage as well as interhemispheric transport processes. They appear to occur regularly during nighttime hours for certain longitudinal sectors, while they become prominent in particular during low solar activity conditions in the local winter ionosphere. Both the wind induced vertical transport of ionospheric plasma along the geomagnetic field lines and the action of magnetospheric and thermospheric

(dynamo) electric fields will be investigated by numerical simulations with respect to plasma fluxes into and out of the plasmaspheric reservoir.

C0.2-0028-18 GLOBAL MORPHOLOGY OF IONOSPHERIC SPORADIC E LAYER USING FS3/ COSMIC GPS RADIO OCCULTATION DATA

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Ionospheric sporadic-E (Es) activity and global morphology have been studied using the 50-Hz signal-noise-ratio amplitude and excess phase measurements from the FormoSat-3/ Constellation Observing System for Meteorology, Ionosphere and Climate (FS3/ COSMIC) GPS radio occultation (RO) observations. The results are presented for data collected during the years of the last sunspot cycle from mid-2006 to the end 2017. The FS3/COSMIC generally performed more than 1000 complete E-region GPS RO observations per day, which were used to retrieve normalized L1-band amplitude standard deviation (SDL1) and relative electron density (Ne) profiles successfully. More or less 25 percent of those observations were identified as Es events based on SDL1 and peak SDL1 altitude criteria. We obtained that the peak SDL1 values of Es events are approximately and linearly proportioned to the corresponding logarithms of peak Ne differences. We also obtained five major zones in which the seasonal and/or local-time variations of Es-layer occurrence are markedly different. The five zones include two extended geomagnetic mid-latitude zones (15° < magnetic latitude (ML) < 55°, and -55° < ML < -15°), geomagnetic equatorial zone (-5° < ML < 5°), and two auroral zones (70° < ML, and ML <

-70°). The Es-event climatology, namely, its variations with each identified zone, season, and local time have been documented.

C0.2-0029-18 THE INVESTIGATION OF CUSP IRREGULARITIES ROCKET PROGRAM

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Two sources of ionospheric plasma irregularities are considered to be of major importance for disruption of satellite communication and navigation in polar regions: 1) the Gradient Drift Instability (GDI), and 2) the Kelvin Helmholtz Instability (KHI). GDI is driven by plasma drift across a steep plasma density gradient of the correct sign perpendicular to the magnetic field (drift in the opposite direction sets up polarization fields that stabilize vs. destabilize the plasma). KHI requires plasma flow-shears to dominate the structuring of irregularities. The Investigation of Cusp Irregularities (ICI) rocket program has been developed to investigate these plasma instabilities and formation scintillation irregularities. High resolution measurements are critical to get realistic quantities on the growth rates. In situ observations demonstrate that cusp ionosphere precipitation can give rise to km scale plasma structures on which grow rates are down to a few tens of seconds compared to earlier measures of ten minutes based on ground

observations. This has to do with the spatial resolution required for these measurements. Growth rates for the KHI instability is found to be of the same order, which is consistent with growth rates calculated from the EISCAT Svalbard Radar. I.e. both instability modes can be highly efficient in the cusp ionosphere, and they may co-exist. The ICI-5 rocket, which is the Norwegian contribution to the Grand Challenge Initiative - Cusp (https://www.andoyaspace.no/the-grand-challenge-initiative/), will carry two 4DSpace modules, from which 12 daughter payloads will be deployed in order to explore the 3D nature of plasma turbulence in the ionosphere cusp.

C0.2-0030-18 ESTIMATION AND STATISTICAL ANALYSIS OF THE 3D ELECTRON DENSITY GRADIENTS IN THE POLAR CAP F REGION USING THE ADVANCED MODULAR INCOHERENT SCATTER RADAR SYSTEM

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Remote sensing of the polar cap ionosphere by the Advanced Modular Incoherent Scatter Radar (AMISR) system is utilized in this study to evaluate the 3D electron density gradients and to analyse their properties. Electron density gradients in the polar F region ionosphere are essential for structuring processes through the gradient-drift instability (GDI). The information about the typical strength of gradients is important for the theoretical studies and modeling of the GDI waves, but rarely available because of significant experimental challenges in evaluation of the gradients, particularly at small scales and in 3D. In this study, multi-point density measurements of the Resolute Bay Incoherent Scatter Radar (North) (RISR-N) working in a special high-spatial-resolution mode are employed to address the above question in a systematical manner. The 3D gradient vectors as well as their horizontal and vertical components are estimated for the first time and analyzed statistically utilizing a large RISR-N data set. The vertical components of the gradient strength vectors are larger than their horizontal counterparts, especially in the lower portion of the F region (below 220 km). The sharpness of the density gradients reveals a significant increase around magnetic midnight due to a decreased effect of the solar smoothing. Further, sharp density gradients occur during magnetically quiet time, possibly because of the presence of the polar holes and reduced plasma precipitation. The peak of occurrence for the horizontal components of the gradient strength vectors occur at 0.5×10−6 m−1, whereas 15.5% of horizontal gradients exceed 10−5 m−1. These gradients are strong enough for a direct generation of GDI waves at decameter scale (i.e. in linear regime), which implies that nonlinear turbulent cascade is not necessarily required for at least some GDI waves.

C0.2-0031-18 IMAGING STUDY OF METEOR ECHOES USING VHF INTERFEROMETRIC RADAR

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Combined observation with multifrequency and multireceiver techniques implemented in a VHF interferometric radar was made in this study to investigate the meteor echoes occurring often in the height interval of 70 and 110 km. The experiment was carried out by using the Middle and Upper atmosphere Radar (MUR) with twenty receivers and five frequencies (46.25, 46.375, 46.5, 46.625, 46.75 MHz). MUR is operated and maintained by the Kyoto University, Japan. Adaptive constrained methods based on the Capon method were used with these multireceiver and multifrequency echoes, respectively, to determine the angle of arrival of the echoes and the range distribution of meteor heads and trails. Preliminary results show that the range and angular distributions of the intensity, retrieved from the multifrequency and multireceiver radar echoes, can identify the fragmentation and bifurcate trails of the meteors.

C0.2-0032-18 A NEW TECHNIQUE FOR MEASURING THE LIFETIME OF BURSTS OF ELECTRON PRECIPITATION FROM SOUNDING ROCKET MEASUREMENTS

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Sounding rocket measurements of electron precipitation typically have an inherent uncertainty in distinguishing between spatial and temporal variability. For very short bursts of precipitation in the cusp region a new technique is presented that allows an estimate of the lifetime of these events using sounding rocket optical measurements. Specifically, ratios (and absolute brightness) of the auroral red and green lines will vary significantly as the lifetime of the precipitation becomes short, due to the long and different lifetimes of these emissions; 110s for the red line and 0.8s for the green line. Thus, at very high altitudes (above 250 km or so) where both emissions are excited predominantly by electron impact on O atoms, the ratio of these two emissions will vary dramatically as the lifetime of the electron precipitation changes from long timescales (minutes) to short time scales (fraction of a second). This technique is explored using data from the RENU2 mission which was launched north from Andoya Rocket Range on December 13, 2015, reached altitudes above 400 km, and encountered intense cusp aurora in the vicinity of Svalbard. For this study data are used from the near-zenith pointing photometers which measured the red and green emissions, and data from other instruments which measured the electron spectra, electron temperature, and neutral winds all at high temporal resolution. Using these data along with modeling it is shown that the optical data suggests that many bursts were observed with lifetimes well below one second.

These results will be compared to estimates from the electron spectrometer and electron temperature data. The implication for the spatial extent of these bursts will also be discussed.

C0.2-0033-18 GADANKI ACTIVE PHASED ARRAY MST RADAR SYSTEM WITH ENHANCED CAPABILITIES FOR HIGH RESOLUTION ATMOSPHERIC OBSERVATIONS: SYSTEM DESCRIPTION AND INITIAL RESULTS

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High power VHF radar operated at around 50 MHz is a powerful tool to probe the atmosphere with high temporal and spatial resolutions. Such radars have been used extensively for studying atmospheric dynamics in the troposphere, lower stratosphere and mesosphere including short and long term wind variabilities with application to satellite launch missions and developing model, understanding convective and precipitation systems, and probing ionospheric plasma irregularities that are detrimental for satellite-based communication/navigation applications. Realizing the importance of the atmospheric dynamics and ionospheric parameters, a major project has been undertaken to develop a high power active array MST radar with incoherent scatter capability at NARL. This radar system, operating at 53 MHz, uses the existing antenna array of the Indian MST radar built in the

early nineties. The new system uses solid state transmitters each feeding one antenna and multiple receivers for implementing various radar techniques, such as Doppler beam swinging (DBS), spaced antenna (SA), post beam steering (PBS), spatial domain interferometery (SDI) and imaging techniques. Importantly, the system is highly scalable depending on the scientific application. The system is also designed to be functional as an incoherent scatter radar for measuring height profiles of ionospheric electron density, electric field, wind, composition, and electron and ion temperatures, which are not being measured in our country. This paper is meant to describe various subsystems and capabilities of the newly developed high power active array MST radar and some sample results obtained thus far. This scalability provides new insight on the optimization of such radar for wind profiler applications.

C0.2-0034-18 OBSERVATIONS OF PLASMA INSTABILITY CONDITIONS USING THE RESOLUTE BAY INCOHERENT SCATTER RADARS

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We consider plasma instability mechanisms in the polar cap F-region, using observations from both the North and Canada faces of the Resolute Bay Incoherent Scatter Radars (RISR-N and RISR-C). A volumetric interpolation algorithm is used to determine both plasma density and 3D gradients at all points within the combined RISR fields of view. Gradients and plasma drift velocity vectors, found with this technique, determine the susceptibility of the background ionosphere to various instability mechanisms in the polar cap. The results may lead to better understanding of plasma irregularity growth and regions of scintillation in the dynamic polar cap.

C0.2-0035-18 OBSERVATIONS OF THE DIURNAL CYCLE OF OUTGOING SHORTWAVE RADIATION FROM THE DEEP SPACE CLIMATE OBSERVATORY

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Outgoing shortwave radiation at top of atmosphere is a critical component of the Earth's energy budget (ERB). It's dependent on the solar energy which is reflected from objects on the surface, therefore the shortwave radiation can be measured only in the sunlit side. The Deep Space Climate Observatory (DSCOVR) is designed to continually monitor the sunlit side of the Earth at L1, so it provides a great opportunity to measure shortwave radiation from DSCOVR. Due to the enough distance from L1 and the Earth, it can measure the full disk. DSCOVR is equipped with two Earth-observing instruments: the National Institute of Standards and Technology Advanced Radiometer (NISTAR) and the Earth Polychromatic Imaging Camera (EPIC). NISTAR measures irradiance of sunlit face of the Earth and the data can be used to study changes in Earth's radiation budget caused by nature and human activities. The Instrument can measure total radiation and longwave radiation, thus, the shortwave radiation can be caculated by the former subsects the latter. EPIC generates full disk image in one picture and take images in 10 narrow spectral ranges. In this paper, we mainly discuss the shortwave radiation observations acquired by the DSCOVR. According to the holistic view of the DSCOVR, we simulate the outgoing shortwave radiation data. We make three contributions. First, we establish a new coordinate system that is suitable for the outgoing shortwave radiation onboard DSCOVR. Second, we proposed a method to simulate the data viewed from DSCOVR. Finally, the change of diurnal cycle of the outgoing shortwave radiation is discussed.

C0.2-0036-18 NEW STRATEGY FOR AUGMENTING IWV ESTIMATIONS USING REMOTE SENSING SATELLITES AND GPS TROPOSPHERIC PATH DELAYS

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Water vapor (WV) is one of the greenhouse gases which plays a key role in global warming, and since it's the most variable component in the troposphere, investigation of its distribution and motion is of great importance in meteorology and climatology studies. One of the main difficulties for using WV for such studies is that it varies constantly across the lower part of the atmosphere, thus leading towards considerable amount of efforts been devoted for improving its spatial and temporal estimation. Radiosondes have long been the main observing platform for monitoring WV in the atmosphere and are still widely used to provide WV profiles, however their sparse distribution and limited temporal resolution makes it almost impossible to precisely detect the horizontal boundaries between moist and dry air. Consequently, several other approaches emerged for estimating the amount of WV in the troposphere. Currently, most of the related studies uses WV estimations derived from only one technique such as tropospheric GPS path delays or multi-spectral reflected measurements from different meteorological satellites such as the METEOSAT series. Constructing WV maps using only interpolated GPS zenith wet delay (ZWD) estimations has a main disadvantage due to the fact that it doesn't take into account clouds which are located outside the integrated GPS paths.

Here, we present a newly developed methodology for augmenting Integrated Water Vapor (IWV) estimations using both remote sensing satellites and GPS tropospheric path delays. The suggested strategy is based first on the ability to estimate METEOSAT-10 7.3 μm WV pixel values by extracting the mathematical dependency between the IWV amount calculated using GPS ZWD and the METEOSAT-10 data. For the second phase, the strategy combines these two approaches, using also METEOSAT-10 10.8 μm channel, in order to evaluate the WV amount at cloudy conditions when preforming the interpolation between adjusted GPS station inside the network. The suggested approach has the potential to improve the accuracy of the estimated regional WV maps and allows to obtain the total water amount at the atmosphere, both in the form of clouds and vapor.

C0.2-0037-18 INCOHERENT SCATTER RADAR STUDIES OF PHOTOELECTRON-ENHANCED LANGMUIR WAVES IN THE F REGION

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Photoelectron-enhanced Langmuir waves detected with a large incoherent scatter radar provide information about the photoelectrons that generated them. At Arecibo Observatory the determination of the Langmuir wave frequency versus altitude yields extremely accurate measurements of F region electron density profiles (0.1% to 0.03% error bars in 2 s with 150 m resolution). The first results from wideband (electron phase energies of 5 eV - 51 eV), highresolution (0.1 eV) spectral measurements of photoelectron-enhanced Langmuir waves made with the 430 MHz radar at Arecibo Observatory are presented. In the F region, photoelectrons produced by solar EUV line emissions (He II and Mg IX) give rise to Langmuir wave spectral peaks/valleys. These and other structures occur within an enhancement zone extending from electron phase energies of 14 eV to 27 eV in both the bottomside and topside ionosphere. However, photoelectron-thermal electron Coulomb energy losses can lead to a broadened spectral structure with no resolved peaks in the topside ionosphere. The Langmuir wave energy spectra obtained in the enhancement zone exhibit a unique relation in that phase energy is dependent on pitch angle; this relation does not exist in any other part of the energy spectrum. The pitch angle results do not impact the accuracy of the electron density profile measurements noted above. Finally, large fluctuations in the difference frequency between the upshifted and downshifted plasma lines are evident in the 14 eV to 27 eV energy interval. At high phase energies near 51 eV the absolute intensities of photoelectron-excited Langmuir waves are much larger than those predicted by existing theory. The new measurements call for a revision/improvement of photoelectron-enhanced Langmuir wave theory in several key areas.

C0.2-0038-18 RETRIEVING CHARACTERISTICS OF INERTIA GRAVITY WAVE PARAMETERS WITH LEAST UNCERTAINTIES USING HODOGRAPH METHOD

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We have analyzed wind velocities measured with high resolution Global Positioning System (GPS) radiosondes which have been flown continuously for 120 h with an interval of 6 h from Hyderabad. Hodograph method has been used to retrieve the Inertia Gravity Waves (IGW) parameters. Background winds are removed from the time series by detrending whereas polynomials of different orders are removed to get the fluctuations from individual profiles. Butterworth filter is used to extract monochromatic IGW component. Another filter Finite Impulse Response (FIR1) is tried in a similar manner to test the effects of filters in estimating IGW characteristics. Results reveal that the fluctuation profiles differ with the change of polynomial orders, but the IGW parameters remain same when Butterworth filter is chosen to extract the monochromatic wave component. The FIR1 filter produces results with a broader range. The direction of wave propagation can be confirmed with additional temperature information.

C0.2-0039-18 HF RADIO OBSERVATIONS OF THE F-LAYER RESPONSE FROM THE 21 AUGUST 2017 TOTAL SOLAR ECLIPSE

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The transit of the moon between the sun and earth disrupts the flux of ionizing radiation that maintains the daytime ionosphere. This produces a large "hole" in the ionosphere that allows HF (3 to 30 MHz) radio waves penetration in regions where reflection would normally occur. The HF radar and communications links which normally would cover 10's of MHz are now completely eliminated or reduced to only a few MHz. The ability to understand and model this process is validated using ground-to-ground propagation tests and first principles models of the ionosphere.

On 21 August 2017 the Total Solar Eclipse over the United States on a path from Oregon to South Carolina removed the Solar Ionization Radiation that maintains the ionosphere during the day. The eclipse process, which is like sunset without the atmospheric attenuation at dusk, had a large-area, time-dependent impact on the F-Layer ionosphere. High Frequency

(HF) diagnostic experiments to measure the changes of the ionosphere were conducted using

(1) propagation from Virginia to the West Coast of Florida and to the Yucatan Peninsula of Mexico and (2) Idaho Falls, ID to the Canadian ePOP satellite. Interpretation of the one-way, oblique ionogram and trans-ionospheric data provide implications for operations of HF systems and testing of the propagation through models of the disturbed ionosphere.

Data have been collected software defined receivers (SDR's) located on the ground in nearly identical propagation azimuths from a ground HF transmitter. Existing ground transmitters are available to make oblique ionograms. The ground receiver sites were chosen to place HF ionospheric reflection points centered along the path of the total eclipse that occurred on 21 August 2017. The satellite propagation tests with the Canadian ePOP satellite used an HF transmitter beam the interested the ePOP satellite orbit. As predicted by the NRL SAMI3 Model, the electron densities in the F-layer were substantially reduced at the time of totality. Using this same model, the computed electron densities provided the plasma refraction model for HF raytracing between the observation transmitter and receiver points. Range and Doppler frequency observations for ground to satellite paths through the eclipse are nearly straight lines. The HF ray path computations clarify the modes that were available for point-to-point propagation in the modified plasma during the eclipse. Disagreements of theory and measurements for both the frequencies bands and the group paths for HF propagation through eclipse region ionosphere need to be examined with regard to improving the predictive model. Several changes in the SAMI3 model that could improve the agreement with observations include (1) using a different neutral atmosphere model, and (2) coupling eclipse zone neutral winds and electric fields.

The data and theory comparison presented here were focused on the time of total eclipse at the crossing time for the propagation paths. The oblique ionogram data is analyzed throughout the total eclipse event to estimate the decay and replenishment of the ionosphere. The impact of an eclipse-like event has be examined for affect on both HF radar and communications systems. Similarly, the HF beacon transmissions through the low-density ionosphere at total eclipse were received on the ePOP satellite radio receiver instrument (RRI) in low-earth-orbit.

The observation technique using existing HF chirp transmitters and inexpensive SDR's deployed on the other side of a totality zone at ground and satellite platforms may be applied and enhanced during future eclipses. The oblique sounder technique is sensitive to horizontal gradients in the bottom side ionosphere. Multiple HF ray paths in the 2 to 20 MHz band can help locate the progress of the eclipse driven disturbance in the ionosphere. The spatially resolved disturbances may include both electron density reductions and gravity-wave associated density fluctuations.

C0.2-0041-18 CONVECTIVE STRUCTURES OF SODIUM LAYER IN LOWER THERMOSPHERE AT LOW-LATITUDE REGION

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The atmospheric sodium layer normally occurs in the mesopause (80-105 km) region, but rarely in the lower thermosphere region (>105 km) at low latitude. We observed a kind of peculiar sodium layer in lower thermosphere at Haikou (19.99°N, 110.34°E)-the thermospheric convective sodium layer (TCSL) in a lidargram. The TCSL's sodium density unstably developed over time and appeared as several discontinuous convective shapes vertically. It is the first time convective sodium layer observed in the lower thermosphere region (105-120 km). Based on Haikou lidar data, we obtained 14 TCSL events during 180 nights from March 2010 to August 2012. Most of the apogees of the TCSL events are higher than 108 km. A TCSL event lasts several hours and is composed of several convective structures, with each vertical shape lasting 5-30 min. All TCSL events occurred during spring and summer, and generally appear near midnight (22:00-00:00 LT). The TCSL has potential regional feature and appears to be related to the thermospheric sporadic E (Es) layers, winds, and field-aligned ionospheric irregularities (FAI).

C0.2-0042-18 STUDY OF TROPOPAUSE HEIGHT FROM UPPER AIR OBSERVATIONS USING GPS-RADIOSONDES OVER BENGALURU, INDIA

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The upper air observations such as temperature, relative humidity and wind are most important meteorological parameters and are used as initialization of the analyses of several numerical weather prediction models for operational weather forecasting. Accurate measurements of the vertical structure of temperature and water vapour fields in the troposphere are extremely important for all types of forecasting, especially regional, local forecasting and now-casting. Several experimental campaigns were made using indigenously developed GPS radiosonde by ISRO that were intended to make upper air observations. The observations were carried out at 00 and 12 UT from Bangalore University, Bengaluru, India about 8-10 days prior to satellite launch by ISRO from Satish Dhawan Space Centre (SDSC), India, about 350 km away from Bengaluru. The GPS radiosondes were used for observing the variation of pressure, temperature, relative humidity and wind with one second resolution, and transmitting data on real-time to SDSC to run the NWP model for studying the stability of atmosphere before launch of satellites. The results show the variation of temperature, relative humidity, wind and height of tropopause over Bengaluru with seasonal variability. The horizontal movement of balloons with wind were compared with trajectories of HYSPLIT and the detailed analysis of wind during different seasons over the station is discussed.

C0.2-0043-18 WIND RETRIEVAL OF MIDDLE AND UPPER ATMOSPHERE BASED ON NON-FULL CIRCULAR FRINGE OF FABRY-PEROT INTERFEROMETER (FPI)

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Fabry-Perot Interferometer (FPI) has been used widely for wind measurements of the middle and upper atmosphere. To date, most of FPIs have been based on full-closed circular fringe, which needs 15-25 min to obtain a group of wind velocity (zonal and meridional). A data processing method is proposed for non-full circular fringe of FPI, which can support CCD with enough area of observations in several directions simultaneously. The method is focused on the center determination of non-full fringe. It includes radial cross-section, peak coordinate determination, and center calculation. Based on the calculated center, the fringe is annular summed. Then its radius is determined subsequently using Gaussian fitting. Finally, the wind is retrieved from the fringe radius. For validation, fringes from two ground-based FPIs were used, which are deployed in Kelan (38.71 °N, 111.58 °E) and Xinglong (40.40 °N, 117.59 °E) in China. The results retrieved from non-full fringes of FPIs were compared with that from full-closed circular fringe. The averaged wind deviation between them demonstrates reasonable difference with 5.38 m s-1 for 892.0 nm airglow emission, 5.81 m s-1 for 630.0 nm emission, and 3.03 m s-1 for 557.7 nm emission. Besides, wind results of Xinglong FPI are compared roughly with measurements of meteor radar which is deployed in Ming Tombs of Beijing (40.3°N, 116.2°E).

C0.2-0044-18 ANALYZE ON THE ARCTIC TROPOPAUSE WITH GNSS RADIO OCCULTATION MEASUREMENTS

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Based on the GNSS (Global Navigation Satellite System) radio occultation measurements from the COSMIC mission (Constellation Observing System for Meteorology, Ionosphere, and Climate mission), the tropopause characteristics over the Arctic including height, temperature and pressure are analyzed during 2008-2010.The spatiotemporal structure of the Arctic tropopause is examined with two thermal definitions, the lapse-rate tropopause and coldest point. And the seasonal and intra-seasonal cycle is comprehensively studied. It shows that the prominent feature, a thick and unstable layer exists over the Arctic in winter frequently within the upper troposphere and lower stratosphere region. The spatial pattern transform from the symmetrical in summer to asymmetrical in winter. As well, some potential physical mechanisms are discussed.

C0.2-0045-18 REGIONAL ELECTRON DENSITY MODELING USING VARIOUS SPACE GEODETIC DATA

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The ionospheric delay is one of the most significant error sources in positioning using Global Navigation Satellite Systems (GNSS) data. Investigation and elimination of this effect requires an understanding of the distribution of ionospheric electron density. In addition, the ionosphere electron density and the Total Electron Content (TEC) along the line of sight between satellite and receiver are two important parameters in many fields, including ionosphere physics and telecommunication. The use of base-functions is one of the possible approaches for multi-dimensional modeling of the ionosphere parameters. On global scale, spherical harmonic functions are used to model the ionosphere parameters. However, on regional scale, using these functions will result in great errors. Therefore, in this research, the capability of using B-spline base-function along with Chapman profile function is investigated for regional ionospheric modeling over Iran. B-spline base-functions describe the electron density distribution horizontally and the Chapman profile function illustrates the electron density distribution in vertical. Due to the nonlinearity of mathematical model, the outputs of the International Reference Ionosphere (IRI-2012) model are used as initial values. The National Cartographic Center of Iran (NCC) has established a network of one hundred GPS stations: the Iranian Permanent GPS Network for Geodynamics (IPGN). The main task of the GPS stations is to collect and store raw GPS data and send them to Tehran processing center on a daily basis for final processing. The required data for our investigation are ground based measurements of the IPGN network and ionospheric information obtained from Formosat-3/Cosmic Radio Occultation data. We expect to increase accuracy and reliability of the final model by integrating these two observation techniques.

C0.2-0046-18 TEC VARIABILITY IN EQUATORIAL IONOSPHERE BASED ON BDS-GEO DATA

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With the development of GNSS systems, the coherent multi-frequency L band transmissions are now available from a number of geostationary satellites. These signals can be used for ionospheric TEC estimations in the same way as widely used GPS/GLONASS signals, taking the advantage of almost motionless ionospheric pierce points [1]. Among these geostationary satellites, Chinese BDS-GEO are of the peculiar interest, providing the best noise pattern in TEC estimations, which corresponds to those of GPS/GLONASS systems [2].

In this work we discuss the capabilities of BDS-GEO data for studying ionospheric variability driven by space weather and meteorological sources at different time scales. Analyzing data from a number of IGS receivers we present seasonal variations of geostationary TEC in near equatorial ionosphere and its relation to Solar activity, as well as day-to-day TEC variability driven by Solar flares, geomagnetic storms, SSWs and typhoon activity. We also discuss seasonal and diurnal variations of ROTI index constructed from geostationary TEC estimations and its relation to the EPB occurrence. Our results show large potential of geostationary TEC estimations with BDS-GEO signals for continuous monitoring of low-latitude and equatorial ionosphere.

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C0.2-0047-18 COMMUNICATION PARAMETERS DERIVED FROM IONOLAB-RAY ALGORITHM

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The performance of HF communication depends on the realistic representation of ionosphere and wave propagation. IONOLAB-RAY is an algorithm, models propagation in anisotropic, inhomogeneous and time dependent ionosphere. Propagation path is calculated based on ray tracing, applied on the spherical 3D grid model of ionosphere. Appleton-Hartree formula is used to calculate refractive index for each step. Electron cyclotron frequency, collision frequency and geomagnetic field are the inputs of Appleton-Hartree formula, so that anisotropicity is represented. The ionosphere parameters for given time and position of each voxel are obtained from IRI-Plas, which can be assimilated by Total Electron Density (TEC) data to bring a realistic modification. IONOLAB-RAY also calculates attenuation, phase velocity, group velocity and time delay. Multiple runs can be applied for each set of inputs, so that propagation paths and communication parameters can be obtained for each run. In order to perform a reliable long distance communication the wave parameters like frequency, azimuth and elevation of the transmitted wave, attenuation and time delay are needed to be predicted properly. By analyzing the outputs of multiple runs of IONOLAB-RAY, optimum values of input parameters which make attenuation and time delay minimum, can be decided. There are some models like International Telecommunication Union's REC 533, Ionospheric Communication Analysis and Prediction Program, Voice of America Communication Analysis and Prediction Program, Ionospheric Communication Enhanced Profile Analysis and Circuit Prediction Program, and Advanced Stand Alone Prediction System that can be used to assist in frequency management and related endeavors. All these are based on statistical models of ionosphere, but they cannot support the needs of user, when the ionosphere behaves different than statistical models, especially under storm. The ionosphere model in IONOLAB-RAY is supported by the assimilation of TEC data into IRI-Plas, which most recent data is obtained in 15 minutes. Thanks to the structure of the algorithm, parameters for each ray path are calculated and the best communication performance is picked out between the scenarios. This feature of IONOLAB-RAY will be an alternative to Real Time Channel Evaluation method and serves for remote sensing. This study is supported by TUBITAK 115E915 and joint TUBITAK 114E092 and AS CR 14/001. Keywords: Ionosphere, IRI-Plas, HF Communication, Ray Tracing, IONOLAB.

C0.2-0048-18 SPACEBORNE L-BAND SAR IMAGING OF HIGH LATITUDE PLASMA DENSITY IRREGULARITY UNDER PARTICLE PRECIPITATION

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We present coordinated observations of the high latitude ionosphere simultaneously performed by Lband SAR satellite and incoherent scatter radar techniques. Small scale plasma density irregularity is studied by the Advanced Land Observation Satellite 2 L-band Synthetic Aperture Radar (SAR) and the European Incoherent Scatter (EISCAT) radar at Tromsø, Norway. Fine scale SAR imaging captured the horizontal distribution of image azimuth shift caused by Total Electron Content (TEC) gradients at enhanced ionization up to about 300 km height observed by the EISCAT UHF radar. The irregular electron density structure is characterized by subkilometer patches to tens of kilometer structures aligned in east-west direction. TEC gradients can be estimated by using single image SAR sub-band data. Results suggest that these observed structures are likely associated with density irregularities caused by precipitating electrons that cascaded into smaller scales by plasma instability processes. This study suggests that spaceborne SAR may achieve mapping of small scale TEC disturbances as a new ionospheric observation tool especially when combined with other measurements.

C0.2-0049-18 SPACED-RECEIVER GPS SCINTILLATION EXPERIMENT ON HIGH LATITUDES.

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We present an analysis of the spaced-receiver GPS scintillation data measured at high latitudes. With help of correlation analysis we estimate ionospheric drift velocity and basic geometrical properties of irregularities in ionospheric electron concentration for different geomagnetic conditions. We show also a comparison of estimated quantities with those obtained using other experimental facilities.

C0.2-0050-18 COSMIC RADIATION AND THE EARTHS ATMOSPHERIC PROCESSES

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In this paper, an updated overview of cosmic ray eects on terrestrial processes such as electrical properties have been provided, global electric circuit, lightning, cloud formation, cloud coverage, atmospheric temperature, space weather phenomena, climate, etc. It is suggested that cosmic rays control short-term and long-term variations in climate. There are many basic phenomena which need further study and require new and long-term data set. Some of these have been pointed out.

Keywords: Cosmic rays; global electric circuit; ion-aerosol; cloud variation; weather and climate; global warming.

C0.2-0051-18 INFLUENC OF IONOSPHERIC PLASMA PERTURBATIONS ON THE ULF NOISE POLARIZATION SPECTRA DURING HIGH GEOMAGNETIC ACTIVITY.

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The dependence of the polarization spectra of the background ULF noise (0.5-20 Hz) on the level of geomagnetic activity is investigated on the basis of analysis of the long-term monitoring data at two reception sites separated at a distance of about 120 Km (460 W, 560 N and 43.630 W, 55.660 N.). It was found a decreasing of the value of fb in the polarization parameter (eps) spectrum at the beginning of the magnetic storm, when the Kp index increases. fb is the boundary frequency which separates the regions of the spectrum with left and right polarization of the noise. Also it was found that the Q-factor of the sub-IAP resonator (an ionospheric resonator at altitudes of 80 -300 km [1]) decreased during periods of the main phase of strong magnetic storms when the value of Kp index exceeds 7. This was expressed in a decreasing of absolute value of the (eps) and in a increasing of the value fb. fb increased above the frequency of the first Schumann resonance during periods of complete disappearance of the spectral resonance structure. The lowest values of fb (0.5-1 Hz) are observed in the recovery phase due to the large optical thickness of the ionospheric layers at the sub-IAP resonator altitudes. It was shown that there are no significant variations in the model polarization spectra calculated using the IRI-2012 during strong magnetic storms, which are observed in the experimental data. Profiles of electron density Ne at altitudes of 80-300 km were corrected basing on a comparison of the calculated spectra with the experimental spectra and with the ionosonde data. As a result, the calculated spectra close to the observed ones were obtained. The effect of horizontally inhomogeneous sporadic Es-layers arising during the recovery phase of a magnetic storm on the ULF noise spectra was investigated. A comparative analysis of the features of the ULF noise spectra during periods of high geomagnetic activity at different latitudes was also performed. Work was financially supported by the RFBR the grant №№ 18-05-00108, 18-42-520035.

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C0.2-0052-18 OBSERVATION OF ISOLATED DISTURBANCES IN THE IONOSPHERIC TEC

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We have developed an algorithm for detecting various forms of TEC fluctuations obtained by processing GNSS data. This method was used to map isolated disturbances related to the Travelling Convection Vortex (TCV). To detect TCV event we used magnetometer data from the ground arrays CANMOS and CARISMA. TEC fluctuations were obtained by processing GNSS data from IGS and UNAVCO stations. The use of array of GPS receivers enables us to monitor the origin and dynamics of disturbance and also to obtain its physical parameters such as its amplitude and propagation speed along the ionosphere. For processing GPS data we used an algorithm that allows to detect isolated TEC fluctuations of specific duration and to find their location (and the corresponding time) on the map. In this way we successfully find a considerable agreement between data from ground-based magnetometers and ionospheric TEC data. The formation of TCV is observed almost simultaneously in both data time series and it is localized in a very small map region. We observed the related disturbances in a form of an isolated peak in a TEC data with a rather high amplitude. It reveals itself as a very fast TEC variation with a derivative up to 5 TECu/min and higher near a place of the TCV formation. Away from an «epicenter» of TCV-related disturbance its amplitude slowly decreases. We have also estimated the horizontal propagation speed of ionospheric disturbance. The calculated speed values (about some km per sec) are in agreement with expected velocities of the ionospheric projection of the solar wind flow around the magnetopause and with those calculated using magnetometer data. These results proved that GPS/TEC technique is sufficiently sensitive to monitor a formation and movement of relatively fast phenomena such as TCV.

C0.2-0053-18 INFLUENCE OF DIFFERENT IONOSPHERIC DISTURBANCES ON THE GPS SCINTILLATIONS AT HIGH LATITUDES

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In this work we compare the influence of auroral particle precipitation and polar cap patches (PCP) on scintillations of the GPS signals in the polar ionosphere. We use the GPS scintillation receivers at Ny-Ålesund and Skibotn, both operated by the University of Oslo. The presence of the auroral particle precipitation and polar cap patches was determined by using data from the EISCAT 42m radar on Svalbard. We analyzed more than 100 events for years 2010-2017, when simultaneous EISCAT 42m and GPS data were available. For some of the events, the optical aurora observations on Svalbard were also used. We consider the following types of the auroral precipitation: i) the dayside and morning precipitation, ii) precipitation on the nightside during substorms, iii) precipitation associated with the arrival of the interplanetary shock wave. All considered types of ionospheric disturbances lead to enhanced GPS phase scintillations. For the polar cap patches, the morning and daytime precipitation (i), and precipitation related to the shock wave (iii), the phase scintillations index reaches values less than 1 radian. We observe that auroral precipitation during substorms leads to the greatest enhancement of the phase scintillation index (up to 3 radians). Thus, the substorm precipitation has the strongest impact on the scintillation of GPS radio signals in the polar ionosphere.

C0.2-0054-18 REACTION OF THE IONOSPHERE ON THE SOLAR ECLIPSE MARCH 20, 2015 ACCORDING TO OBLIQUE SOUNDING

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The results of studies of the response of the ionosphere to the solar eclipse on March 20, 2015 according to data of oblique sounding on the paths in the Eurasian region are presented. Solar eclipse on March 20, 2015 took place in condition of very strong magnetic storm in the phase of its recovery. To detect the response of the ionosphere to the solar eclipse, oblique chirp sounding was carried out on paths with various lengths and orientations. During the eclipse there was an increase in the amplitude of signal, especially noticeable on long Pevek (68.77N, 170.12E) - Yoshkar-Ola (56.62N, 47.87E) path with large coverage phase of 0.75 ÷ 0.77, when amplitude growth was 3 ÷ 5 dB. On the paths with the maximum phase coverage of 0.62 ÷

0.66 (Vasil'sursk (56.1N, 46.1E) - Nizhny Novgorod (56.1N, 44.1E), Vasil'sursk - Yoshkar-Ola, Mikhnevo (54,95N, 37,75E) - Yoshkar-Ola) the decrease in 1FMOF was 8 ÷ 10%. On the paths with maximum phase coverage of 0.73 ÷ 0.79 (Lovozero (68N, 35E) - Nizhniy Novgorod, Norilsk (69.36N, 88.36E) - Nizhny Novgorod, Lovozero - Yoshkar-Ola), the decrease in 1FMOF and 1F LOF was 12-14% and 22-33% respectively. According to measurements of the variations of MOF and LOF for the Eand F-layers, as well as the variations in the group delay time of the radio signals within the eclipse interval, wave disturbances with period within the limits of 25-50 minutes are recorded, which we associate with generation of disturbances during motion of the lunar shadow in the atmosphere of the Earth. At the same time during the eclipse, quasiperiodic variations of these parameters were observed on a number of paths with a period of 50 ÷ 80 min, but with the onset of variations before the eclipse began. Probably, these variations were the result of a superposition of disturbances from two sources associated with the ionospheric effects of a magnetic storm and a solar eclipse.

The work was supported by the Ministry of Education and Science of the Russian Federation under contract 3.7939.2017/8.9.

C0.2-0055-18 HEIGHT-LATITUDE STRUCTURE OF THE HAYASHI WAVES IN THE NORTHERN STRATOSPHERE AND LOWER MESOSPHERE IN WINTER

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By using the winter (from November to March) ERA-Interim reanalysis geopotential, temperature, zonal and meridional wind data in the troposphere, stratosphere and lower mesosphere (up to the 0.1 hPa isobaric level) for 1979-2016, an analysis of the Hayashi spectra for wave disturbances with zonal wave numbers 1 k 10 and with periods from 2 to 156 days is performed. In this, contributions of the eastward traveling (E), westward traveling (W), propagating (P), stationary (S) and total (T) waves are estimated. The climatological spatial-temporal distributions Hayashi waves are integrated by wave number and frequency. As a result, were received integrated height-latitude distributions of waves E, W, P, S and T. It has been established that magnitude of wave energy for geopotential, zonal and meridional wind has two peaks: in the upper stratosphere - lower mesosphere and in the area of the tropopause. For temperature one peak also occurs in the upper stratosphere, and the lower maximum divided by tropopause on two parts: above and below the tropopause. The resulting empirical model of the height-latitude distributions of wave characteristics can be a contribution to the COSPAR International Reference Atmosphere (CIRA).

C0.2-0056-18 MAPPING OF ELECTRICAL CONDUCTIVITY FROM GROUND SURFACE UP TO THE IONOSPHERE DURING SEISMICALLY ACTIVE PERIOD

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It has been well established through numerous works that small-scale perturbations of lithospheric origin can induce significant anomalies at tropospheric and ionospheric heights. One of the possible sources is the unusual perturbation of the near-ground vertical atmospheric electrostatic field Ez prior to earthquakes. There are numerous channels through which the seismo-ionospheric coupling can happen, the most effective being the electromagnetic channel whose effects can be identified as perturbations in received VLF signal amplitude/phase and in the ionospheric total electron content (TEC). Although from both ground based and satellite observations, we have gained sufficient knowledge about the nature of such possible perturbations associated with seismo-ionospheric anomalies, the right justification of such observations becomes very difficult because of the lack of concrete theory that can explain all the physical processes associated with such coupling mechanisms. In this paper, we aim to investigate deeper into the physical background of the electromagnetic channel and to develop a self-explanatory model that can corroborate this mode of coupling between the lithosphere and ionosphere. We start by calculating the atmospheric conductivity right from the ground surface up to ionospheric F-region altitudes. The atmospheric conductivity is dependent on numerous factors and thus it is further divided into several segments. The conductivity in each segment are then coupled to generate a single altitude profile. This conductivity is then used to calculate the electrostatic potential and the electric field. Because of this electric field, the electrons in the ionosphere experience a drift velocity and using a linear relation, we calculate the electron density distribution. This electron density profile is then incorporated into the Long Wavelength Propagation Capability (LWPC) code to determine the VLF signal amplitude. We found that under anomalous radon emanation (twice as normal), the conductivity at 10 km altitude increases by 20% which influences the overall conductivity profile and in turn the sub-ionospheric radio signal propagation.

SPACE STUDIES OF THE UPPER ATMOSPHERES OF THE EARTH AND PLANETS INCLUDING REFERENCE ATMOSPHERES (C)

IONOSPHERIC DISTURBANCES OBSERVED THROUGH VERY LOW FREQUENCY RADIO WAVES (C0.3)

C0.3-0001-18 IONOSPHERIC STUDIES USING VLF RADIO WAVES: ACTIVITIES OF ICSP NETWORK

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Indian Centre for Space Physics is monitoring several stations with several types of VLF receivers and antennas for about 15 years. It conducted Indiawide summer and winter campaigns, monitors solar flares, eclipses, gamma ray bursts, soft gamma-ray repeaters, lightning etc. By treating the Earths atmosphere as a gigantic detector, it has computed effects of these perturbations on the ionosphere and compared with the observed results. Our theoretical results agree with observations. We also solved the inverse problem, namely, prediction of injected spectrum from the VLF amplitudes. One of our major directions is the study of anomalies in VLF signal amplitude prior to major earthquakes. Similarly, we study the generation of Atmospheric Gravity waves, OLRs at every instances of perturbations. Our scientist's multiple visits to Antarctica yielded very exciting results. We were able to explain the signal shape and amplitude using LWPC code and also using other atmospheric models. We present a comprehensive review on our activities in this very vibrant field of research area.

C0.3-0002-18 RECENT ADVANCES IN THE STUDY OF SUBIONOSPHERIC VLF WAVE PROPAGATION ANOMALIES

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In this paper we report new advances on the detection of propagation anomalies within the Earth-Ionosphere Waveguide (EIW) produced by external perturbations. These anomalies reflect changes of the subionospheric propagation properties of Very Low Frequency waves within the EIW. We use VLF data provided by known instrumental networks localized in South America like SAVNET, LAVNET, to monitor indirectly the properties of the lower ionosphere D-region. This technique allows to study and discuss the D-region response and dynamics to disturbances caused by the entry of energetic photons and particles from the outer space, or by the upward propagation of waves from the Earth atmosphere. Perturbations responsible include the long-term and transient explosive changes of the solar activity as well as fast outbursts from remote cosmic sources. Solar eclipses are also known to trigger changes of the structure of the EIW, and therefore produce detectable propagation anomalies. We will also show how the VLF technique can be used to describe the quiescent lower ionosphere boundary over specific regions like the South Atlantic Magnetic Anomaly. Finally, we also discuss how the use of this technique was important in some cases to provide early warnings of seismic activity.

C0.3-0003-18 THE EFFECT OF ERUPTIVE AR LOCATION ON THE VLF SIGNAL PERTURBATION, IS THERE AN ASYMMETRY?

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In terms of geomagnetic disturbances, some works demonstrate that the solar flares producing CMEs from the western side of the solar disk affect the Earth's environment more than those coming from the eastern side. In our study, we used the VLF signal, propagating along the NRK-ALG GCP, to probe the ionospheric D region (60-90 km) in order to show the existence of Est/West asymmetry in terms of solar flares disturbances efficiency. For this, we correlated the amplitude of the signal perturbation with the heliographic coordinates of the NOAA active region (AR) that produced flares. The considered data are recorded during the rising phase of the solar cycle 24 and happened at solar zenith angle SZA = -45 °. The results show that the heliographic location of the eruptive AR plays an important role on the perturbation amplitude of the VLF signal. Indeed, we found that the eruptive AR from the northwest quadrant produced an important perturbation amplitude than the northeast one. On the other hand, this effect appears reversed where the Southeast eruptive AR produced more important perturbation amplitude than the southwest one.

C0.3-0004-18 ATMOSPHERIC INFLUENCES ON THE D-REGION IONOSPHERE AS REVEALED BY VLF/LF RADIO SIGNALS

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We investigate atmospheric influences on the D-region ionosphere and possible connection between stratosphere and the D-region ionosphere over a different time-scale ranging from few days to several months using the Very Low frequency (VLF) radio signals from three transmitters (namely, the NLK, NPM and NWC) observed at several receiving stations within Japan. Variations of nighttime VLF signal amplitudes, total column Ozone density and stratospheric temperature at 31 km altitude show a strong connection for some propagation paths that exists for several months. We have also found stratosphere-ionosphere connection that exists for several days corresponding to a Sudden Stratospheric Warming (SSW) event of 2009. An enhancement of the nighttime VLF signal amplitude during the SSW event is noted. The strength of quasi 16-day planetary waves is also found to increase during the SSW event consistent with stratospheric temperature enhancement.

C0.3-0005-18 IONOSPHERIC DISTURBANCES: GYROKINETIC SIMULATION OF ION-TEMPERAT GRADIENT MODE IN THE PRESENCE OF RADIO-FREQUENCY WAVES

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In our earlier work (REDS Plasma Science and Technology,171, 52 (2016)) the ion temperature driven modes was studied in the presence of radio frequency waves by the use of Gyro-Kinetic simulation Code. It was shown that the radio frequency waves through the ponderomotive force can stabilize the ion temperature gradient instabilities and contrary to the usual belief no radio frequency wave induced flow generation hypothesis was required. This might be a major way to explain many unknowns in the space plasma and can also help to create a transport barrier in the fusion energy generation. In this work we extend our earlier work to investigate the consequent transport and report the effect on the ion turbulent diffusivity.

C0.3-0006-18 MODULATION OF VLF RADIO WAVE PROPAGATION BY SGR X-RAY BURST: NUMERICAL RECONSTRUCTION WITH MONTE CARLO SIMULATION

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Sudden outburst of ionizing radiation in form of X-rays and γ rays from astrophysical transient sources, such as, X-ray bursts from Soft Gamma Repeaters (SGR), Gamma-ray bursts (GRB) etc., in spite of their large distance from earth, are quite capable of modifying the plasma properties in earth's lower ionosphere and middle atmosphere. One such series of bursts from SGR J1550-5418 on 22 January 2009, detected in Very Low Frequency (VLF) network across South America is investigated. A sincere effort has been made to reconstruct the observed modulation in VLF signal amplitude during the series of bursts using computer simulation, starting from observed spectra and lightcurve of the incident photons. A state of the art Monte Carlo simulation method using GEANT4 detector simulation program, an ion chemical evolution scheme and Long Wave Propagation Capability (LWPC) code, based on mode theory of VLF propagation in earth-ionosphere wave guide are used for the modeling of the VLF amplitude modulation detected in two distinct receiver points in South America. We gain some valuable insight in the modeling process on the chemical and dynamic evolution of lower ionosphere and part of the atmosphere below it under the ionizing influence of those extragalactic transient sources.

C0.3-0007-18 PROBING SOLAR FLARE AND GEOMAGNETIC STORM DRIVEN MAGNETOSPHER IONOSPHERE DYNAMICS IN D-REGION IONOSPHERE USING VLF SIGNAL PROPAGATION CHARACTERISTICS

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When propagating in the Earth-ionosphere waveguide, the amplitude and phase of VLF/LF radio signals are sensitive to changes in the electrical conductivity of the lower ionosphere. This characteristic makes it useful in studying sudden ionospheric disturbances, especially those related to prompt X-ray flux output from solar flares and gamma ray bursts (GRBs). However, strong geomagnetic disturbances and/or storm conditions are known to produce large and global ionospheric disturbances, which can significantly affect VLF radio propagation in the D region ionosphere. In this paper, using the data of three propagation paths (at latitudes 40-54°), we characterise and analyze the trend in variations of VLF radio signal under varying solar and geomagnetic space environmental conditions to identify flare and geomagnetic footprints on the D region ionosphere via the diurnal signature of the signal.

C0.3-0008-18 STATISTICS AND SINGLE EVENT STUDIES OF SOLAR FLARE RELATED DISTURBANCES OF SUB-IONOSPHERIC MID-LATITUDE VLF PATHS IN THE PERIOD 2009-2017

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In this study we analyze sub-ionospheric very low and low frequency (VLF/LF) measurements related to solar flare disturbances. The x-ray flux measurements are NOAA GOES data. We show variations in VLF/LF amplitude and phase of eight radio paths for the time span 2009- 2017, in particular single X-class solar flare events and statistical results during this solar cycle 24 period.

The VLF/LF receiver is located in Graz, Austria, the mid-latitude station is part of a multistation network [1]. The main scientific objective of the facility is seismo-electromagnetic investigation in combination with lithosphere-atmosphere-ionosphere coupling (LAIC) mechanisms. To reach the goal non-seismic influences on the signals have to be considered, e.g. meteorological effects [2] or complementary results from satellite measurements [3]. For the upper boundary of the VLF waveguide, the Dand E-region, the electron densities of the semiempirical Faraday-IRI (FIRI) model are considered [4-6].

At the moment more than 400 VLF/LF amplitude and phase fluctuation events from C/M/Xclass flares are in the database and a reliable monitoring service is established. As outlook, we further investigate to disentangle natural and artificial VLF/LF amplitude and phase variations in order to characterize and classify various sources, among them possible modulations related to seismic events.

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C0.3-0009-18 MONITORING OF D AND E LAYERS OF THE IONOSPHERE USING GPS

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The variation of nonequilibrium two-temperature plasma parameters and the population of the orbital degenerate states of the Rydberg complexes, respectively, are observed in the D and E layers of the ionosphere during periods of increasing solar activity. This directly affects the operation of any of the systems based on the use of GPS radio signals passing through these layers. Since direct observation of the D and E ionospheric layer states is almost impossible, the question of using the GPS system for plasma diagnostics in these layers comes to the fore. First of all, we are talking about observations of changes in the concentration and temperature of electrons at an altitude of 110 km and the determination of their altitude profiles in the range of 60-110 km, where, as is known, GPS signals undergo the greatest distortions. To this end, it is possible to use the satellite radio occultation method, which is widely used for solving climatic problems. This method makes it possible to determine the altitude profiles of GPS signal propagation delays. However, the solution of the inverse problem will allow qualitatively, but not quantitatively, to obtain the altitude profiles of the considered quantities from relative measurements. Therefore, the obtained results should be supplemented with ground-based measurements of the power of the incoherent radiation flux at 1.4 and 5.0 GHz, which will ensure the reliability of the detected electron concentrations and temperatures. The control will be realized with the help of the code "Rydberg". Repeated GPS satellite measurements can provide information about the macroscopic dynamics of D and E layers containing Rydberg complexes and free electrons. In particular, we are talking about changing the thickness of the luminous layer in time, which leads to an additional contribution to the formation of GPS errors. In this connection, the obvious question arises about the dependence of the power of the incoherent radiation flux on time. It should also be noted that the influence of positioning errors on the passage of a satellite signal and the formation of microwave and infrared radiation is exerted by the entire luminous layer 80-110 km thick in the vertical direction and up to 1000 km and more when it propagates along, i.e. as a result of an integral contribution to the overall picture of the phenomenon. Therefore, certain details of the internal heterogeneities of the layer structure do not play an essential role here. Naturally, they are of interest for special questions of radiophysics and ionospheric dynamics, but do not have a noticeable effect on GPS signals received on Earth.
This work was supported by the Russian Foundation for Basic Research (grant no. 16-05-00052-a).

C0.3-0010-18 THE CONTRIBUTION OF THE D LAYER OF THE IONOSPHERE TO THE VALUE OF THE TEC DURING X-RAY FLARES

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The measurements of the total electronic content (TEC), carried out from the data of global navigation satellite systems, are an important parameter for studying the processes taking place in the ionosphere. At the same time, it is assumed that the F region of the ionosphere makes a significant contribution to the value of the TEC. However, the results of many studies have revealed that during powerful X-ray flares, the ionization of the D region can increase substantially, reaching values of 106 cm-3. In this paper, we analyze the changes in the parameters of the D region during flares of the M and X classes. At the same time, the ionization of the D layer is compared with the experimental values of the TEC obtained at the «Mikhnevo» geophysical observatory (54 ° 57’N, 37 ° 46’E). It is shown that a correct interpretation of TEC variations under powerful heliogeophysical perturbations requires taking into account the ionization of the lower ionosphere.

C0.3-0011-18 IONOSPHERIC GPS TOTAL ELECTRON CONTENT RESPONSE OVER INDIAN REGION TO THE SOLAR FLARES OF THE YEAR 2017

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A solar flare is a sudden brightening in an active region usually near a complex group of sunspots of the photosphere, which produces immediate increases in the ionospheric ionization of varying degrees at different heights, together called the Sudden Ionospheric Disturbances (SIDs) or the ionospheric solar flare effects. The disturbances have important effects on radio communications and navigations over the entire radio spectrum reviewed that SIDs were generally recorded as the sudden increase in total electron content(TEC). The Total Electron Content

(TEC) is computed from Global Positing System (GPS) from Bangalore (13.02°N, 77.57°E) and

Hyderabad (17.417°N, 78.551°E) IGS station for the year 2017. We study the effect of solar flares on ionosphere during the year 2017 which is a high solar active year. We analysis the enhancement of TEC during the solar flare for Indian region. The magnitude of enhancement in ionospheric TEC to be dependent on the class of the flare. We compare the TEC variation with D-region electron density characteristics as obtained from theoretical simulation.

C0.3-0012-18 THE IONOSPHERE OVER THE THUNDERSTORM AREA - REGISTRATIONS FROM DEMETER AND SWARM SATELLITES AND WERA SYSTEM

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One of the important aspects of lightning phenomena at low altitudes is that the energy release is happening in highly localized regions of space leading to formation of spark channels with temperatures 25000K and plasma with electron densities exceeding 1017cm3 TLEs (sprites, jets, elves, halos) are associated with the electromagnetic connections and interactions between atmosphere, ionosphere and magnetosphere and with strong thunderstorm activity. DEMETER has clearly shown, that thunderstorms and sprites can affected the ionosphere even at altitude of its orbit (680km). The Swarm constellation comprises 3 identical satellites. Two of them are operating on the circular, polar orbits with initial altitude 460. Third one has also circular orbit, but with altitude 530. The orbits of the first 2 satellites are in almost the same plane, but third one is close to be perpendicular to the first two. The payload containing Vector Field Magnetometer, Absolute Scalar Magnetometer and Electric Field Instrument among other allows to study the effects in the ionosphere generated by thunderstorms. The discussion of the observation done by DEMETER and Swarm satellites will be given in the presentation. The discussion of the cross correlation between the ground based (WERA system) and Swarm registration of the ULF/ ELF waves related to the thunderstorm and TLE's will additionally be presented.

C0.3-0013-18 TOPSIDE IONOSPHERIC EFFECTS OF THE ANNULAR SOLAR ECLIPSE OF 15TH JANUARY 2010 AS OBSERVED BY DEMETER SATELLITE

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We studied effects of the annular solar eclipse of 15th January 2010 on the topside ionosphere using the DEMETER satellite data. Measurements of the electron-ion density and electron temperature by the ISL (Instrument Sonde de Langmuir) and IAP (Instrument Analyseur de Plasma) instruments on board the DEMETER satellite during the eclipse time over the low latitude (40) Indian ocean area are presented. We found decrease in electron density by about 25% and decrease in ion density by about 33% from the reference orbits at the altitude of the satellite (660 km). Electron and ion temperatures were also found to have decreased by 200- 300 K at the same altitude. Instead of simple decrease as in ion density, electron temperature showed a complex wave-like oscillation as solar eclipse progressed. Electron density decreased to a minimum value before the maximum obscuration and again started to increase before passing through another minimum at the time of maximum obscuration. Both the minima are located at the 10 degree geomagnetic latitude. Variations of electron and ion densities were found to follow the average solar illumination experienced by the satellite and its conjugate points at satellite altitude on the magnetic field lines connecting these two points, while the electron temperature showed no such correlation.

C0.3-0014-18 COORDINATED SATELLITE OBSERVATIONS OF THE VLF TRANSMISSION THROUGH THE LOW LATITUDE D-LAYER USING EMISSIONS FROM LIGHTNING

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Both ray theory and full-wave models of Very Low Frequency transmission through the ionospheric D-layer predict that the transmission is greatly suppressed near the geomagnetic equator. We use data from the low-inclination Communication/Navigation Outage Forecast System satellite to test this semi-quantitatively, for broadband Very Low Frequency emissions from lightning. Approximate ground-truthing of the incident wavefields in the Earth Ionosphere Waveguide is provided by the World Wide Lightning Location Network. Observations of the wavefields at the satellite are provided by the Vector Electric Field Instrument aboard the satellite.

We find that in most broadband recordings of radio waves at the satellite, very few of the lightning strokes result in a detectable radio pulse at the satellite. However, in a minority of the recordings, there is enhanced transmission of Very Low Frequency lightning emissions through the D-layer, at a level exceeding model predictions by at least an order-of-magnitude. We show that kilometric-scale D-layer irregularities may be implicated in the enhanced transmission. This observation of sporadic enhancements at low magnetic latitude, made with broadband lightning emissions, is consistent with an earlier review of D-layer transmission for transmission from powerful man-made radio beacons.

C0.3-0015-18 ULF ELECTROMAGNETIC FIELD IN THE UPPER IONOSPHERE EXCITED BY LIGHTNING

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We have theoretically estimated ULF spectra on the ground and at ionospheric altitudes in the ULF frequency range 0.1-6.0 Hz excited by a lightning stroke in the lower atmosphere. This frequency band comprises typical frequencies of the ionospheric Alfven resonator and the ionospheric wavegude. The spectra of both horizontal magnetic and electric components are shown to reveal the spectral resonant structure in the upper ionosphere. The feasibility of the detection of ULF response in the upper ionosphere to isolated lightning stroke and stochastic thunderstorm activity by low-orbiting satellites with magnetic or electric sensors onboard is discussed.

C0.3-0016-18 MODELING OF DIURNAL VARIATION OF VLF SIGNAL OVER SIGNAL PROPAGATION PATHS OF VARIOUS CHARACTERISTICS

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Characteristics of Very Low Frequency (VLF) signal depends on solar illumination profile across the propagation path. For a short path, the illumination range may not be so wide in general but for a longer or a medium path, the solar zenith angle varies widely over the path and this has a significant influence on the propagation characteristics. To study the effect, we monitor the diurnal variation of VLF narrow-band signal for a number of propagation paths, such as, NWC-IERC, NWC-Maitri (70.75°S, 11.67°E), NWC-Bharati (69.4°S, 76.17°E), NWCMaitri, VTX-IERC, VTX-Maitri, VTX-Bharati, VTX-Dunedin etc. The full illumination or full darkness over the path mostly occurs for shorter paths, where for longer paths partly illuminated conditions are there which influences the model interferences taking place in the propagating signal. To analyze and simulate those paths, first we categorize them according to their lengths. Then we reproduce the signal variations of VLF signal using solar zenith angle model coupled with Long Wavelength Propagation Capability (LWPC) code. We divided the whole path into several segments and computed the solar zenith angle (χ) profile. We assumed a linear relationship between the Wait's exponential model parameters, such as, effective reflection height (h1), steepness parameter (β), and χ. The h1 and β values were later used in the

LWPC code to obtain the VLF signal amplitude at a particular time. The same procedure was repeated to obtain the whole day signal. Nature of the whole day signal variation from the theoretical modeling is also found to match with our observation to some extent mainly for short propagation paths. For longer paths, the matching is moderate because of the limitations in the code.

C0.3-0017-18 MODELING OF THE LOWER IONOSPHERIC RESPONSE AND VLF SIGNAL MODULATION DURING A TOTAL SOLAR ECLIPSE USING IONOSPHERIC CHEMISTRY AND LWPC

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The Earth is enveloped by a zone of ionized plasma known as the ionosphere that protects us from the outside hostile environment caused by several solar and extra-terrestrial phenomena. Solar eclipse is one such perturbing agent that exhibits a unique feature of controlled diminution and regain of the incoming solar radiation due to partial or total blocking of the Sun by the lunar disc for a definite period of time. It also provides an excellent opportunity to study such effects as we get to know its time of occurrence much prior to the actual event and thus can prepare ourselves accordingly. One such event (Total Solar Eclipse) took place in the Indian subcontinent on July 22, 2009. Indian Centre for Space Physics (ICSP) conducted a week long campaign to record Very Low Frequency (VLF) data transmitted from the VTX transmitter (18.2 kHz) before, during and after the eclipse from more than a dozen places. All the locations exhibited shifts in the received signal amplitude, either positive or negative depending on the propagation path-length. The interpretation of such effects on VLF signals require a better understanding of the D region ion chemistry which is not available till date. This paper is intended to use our previous knowledge of some of the parameters and explain the observations. We start from calculating the obscuration function and determination of the variation of ionizing radiation during the eclipse period. This information is then used in calculating the rate of ionization. We then incorporate a D-region ion chemistry model to determine the height profile of electron density. These electron densities are then used in the Long Wavelength Propagation Capability (LWPC) code to find the VLF signal modulations. In this process, we have been successful in two ways. First, we have been able to reproduce the trend of signal variation (both positive and negative) from a pure theoretical approach and second, we have been able to improve our knowledge of some of the D-region ion-chemistry parameters.

C0.3-0018-18 THE INFLUENCE OF SEISMIC ACTIVITY ON THE DEVELOPMENT OF THE FORMATION OF HETEROGENEITIES IN THE SPORADIC LAYER ES

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Based on the study of small-scale in homogeneities in the night sporadic layer of Es, which arose in the August 1986 earthquake preparation periods with a magnitude of 4.0 < M <5.5 and an epicentral distance of R < 250 km, criteria for large ranges of translucency of the sporadic layer Es - f0Es 2fbEs were developed. To detect seismo-ionospheric disturbances, the method of superposition of the epoch is used, since this method is more informative in the detection of seismo-ionospheric effects. It is shown that the duration of the existence of intense continuous small-scale irregularities of the sporadic Es layer in the seismically active period with the f0Es 2fbEs translucency criterion is from 2 to 6 hours 1-2 days before the earthquake. It is assumed that the duration of manifestation of seismo-ionospheric precursors can be associated with deformation processes in the earth's crust and various faults, that the duration of manifestation of seismo-ionospheric precursors can be as well as dissimilar properties of the environment of the epicentral zone.

C0.3-0019-18 IONOSPHERIC PERTURBATIONS IN D-LAYER DETECTED AT VLF RECEIVER IN TASHKENT

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Monitoring of the Dand F-layers of ionosphere over Central Asia territory is being performed on the permanent basis starting year 2008 when one Very Low Frequency (VLF) receiver and two SuperSID receivers. The results obtained at Tashkent VLF station are applied to earthquake electromagnetic precursors, lightning, and Solar flares and to ionospheric disturbances originating from gamma ray flares of Soft Gamma-Ray Repeaters connected with evolution of strongly magnetized neutron stars believed as magnetars. Several Solar events are observed and the analysis has shown that there is simultaneous correlation between the times of change of amplitude of the waves and the Solar flares. Features of the lightning discharge generated by radio atmospherics are studied and its effectiveness in D-region ionosphere diagnostics is examined.

C0.3-0020-18 NUMERICAL MODELING OF POSSIBLE LOWER IONOSPHERIC ANOMALIES ASSOCIATED WITH THE MAY 12, 2015 NEPAL EARTHQUAKE

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We present the results obtained from numerical simulation of the anomalies in the sub-ionospheric Very Low Frequency (VLF) signal amplitude received at Ionospheric and Earthquake Research Centre and Optical Observatory (IERCOO under Indian Centre for Space Physics), India associated with a major earthquake on May 12, 2015. The signal is received from the JJI transmitter operating at 22.2 kHz before, during and after an earthquake of Richter scale magnitude M =

7.3 occurring at a depth of 18 km at southeast of Kodari, Nepal on May 12, 2015 at 12:50 PM local time. This earthquake was followed by numerous aftershocks, a major aftershock being on May 16 with magnitude M = 6.7. From the received signal, it is observed that the terminator times, both sunrise and sunset (SRT and SST) shifted towards nighttime, thereby increasing the overall day length. The maximum increase in day length is found to be 32 minutes. These shifts in terminator times is numerically reproduced using the Long Wavelength Propagation Capability (LWPC) code. The path under study (JJI-IERCOO) bears a special feature that it has a high longitudinal variation and thus the solar illumination is different at different points on the path. This is taken into account by varying the ionospheric parameters, namely, the effective reflection height (hi) and the steepness parameter (β) according to the true movement of the terminators over the path. In this way, the signal amplitudes on a normal non-seismic day is reproduced. Next, to generate the additional effects due to the seismo-ionospheric coupling processes, additional modifications are made for that portion of the propagation path that lie inside the seismically affected area. By doing this, we have been able to regenerate the observed increase in day length. The maximum shift obtained from simulation is 25 minutes. We also found that increase in the ionospheric parameters resulted in the observed night ward shifts of the terminator times. We further calculated the electron density profiles using the Waits formula and found the electron density to decrease significantly before the earthquake.

C0.3-0021-18 THERMAL ANOMALIES: AS LITHOSPHERIC - TROPOSPHERIC INTERACTION AND PRECURSORY EFFECT OF LARGE EARTHQUAKE

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We present the effect of air ionization during and prior to large earthquakes. During and prior to large earthquakes, radon discharge from different cracks and faults is the primary source of air ionization. The newly formed ions coagulates with water molecules and drastic change in air temperature and relative humidity is observed. These changes extend up to the increment of surface latent heat flux also and can be observed though various remote sensing satellite as well as in many ground based measurements of surface air heat and other thermal parameters. We are presenting the change in air temperature, relative humidity and surface latent heat flux parameters as a precursory phenomenon of Nepal 2016 and Honsu 2011 Earthquakes. As the thermal excitation profile is different for land and sea, we compare the variation of pre-seismic thermal parameters for Nepal (land) and Honsu (near sea) earthquakes.

C0.3-0022-18 POSSIBLE CORRELATION OF VLF SIGNAL ANOMALIES WITH SEISMIC ACTIVITIES

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There are several types of natural disasters. Among them, earthquake is one of the greatest disasters which may cause loss of lives and property damages. The physical processes leading to seismic activities are very complex. The occurrence of earthquake is connected to Earth's crustal dynamics which involves in movements of tectonic plates. The conventional way for the prediction of earthquakes is related to monitoring of crustal structure movements, but this method has not yet yield satisfactory results. Furthermore, this method failed to provide any short-term predictions. In last few decades, scientists noticed that before any seismic event takes place, some disturbances in the ionosphere take place also. Thus, it is suggested that ionospheric disturbances may be used as precursors of earthquakes [e.g. Pulinets et al., 2004]. Since VLF radio waves propagate inside the wave-guide formed by lower ionosphere and Earth's surface, this signal may be used to identify ionospheric disturbances due to seismic activity. We have analyzed VLF signals to find out the correlations, if any, between the VLF signal anomalies and seismic activities. We have done both the case by case study and also the statistical analysis using a whole year data. In both the methods we found that the night time amplitude of VLF signals fluctuated anomalously three days before the seismic events. Also we found that the terminator time of the VLF signals shifted anomalously towards night time before few days of any major seismic events. We calculate the D-layer preparation time and D-layer disappearance time from the VLF signals. We have observed that this D-layer preparation time and D-layer disappearance time become anomalously high 1-2 days before seismic events. Also we found some strong evidences which indicate that it may possible to predict the location of epicentres of earthquakes in future by analyzing VLF signals for multiple propagation paths.

C0.3-0023-18 STUDY OF THE CHARACTERISTICS OF SMALL, INTERMEDIATE AND LONG VLF RADIO WAVE PROPAGATION PATHS BY USING LONG WAVELENGTH PROPAGATION CAPABILITY (LWPC) CODE

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New Zealand ropagation of Very Low Frequency (VLF) radio signal through the Earth-Ionosphere waveguide strongly depends on the plasma properties of the ionospheric D layer. Solar extreme ultraviolet radiation plays the central role in controlling physical and chemical properties of the lower ionospheric layers and hence determining the quality and propagation characteristics of a VLF signal. The nature of interference among different propagating modes varies widely with the length of the propagation path and also with the direction of propagation. The number of waveguide dominating modes, modal attenuation and mode conversion strongly differ from path to path. Also the ionospheric reflection parameters as prescribed by Wait's two component model (h' and) differ. Here we present a comparative studies of the modal attenuation and ionospheric parameters for three types of path lengths using Long Wavelength Propagation Capability (LWPC) code. We use (a) short path VTX-IERC (GCP < 2000 km), (b) intermediate paths NWC-IERC, NWC-Bharati and NWC-Dunedin (2000 km < GCP < 6000 km) and long paths VTX-Maitri, NWC-Maitri, VTX-Bharati and NWC-Bharati (GCP > 6000 km) for out study. By examining the path dependency of the waveguide modes, we also study the spatial distribution of VLF signal over the propagation path theoretically and compare the results with observed data.

C0.3-0024-18 SOME THOUGHTS OF CURRENT AND FUTURE PROBLEMS IN IONOSPHERIC PHYSICS

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There are a considerable number of current and future problems in ionospheric physics. I will try to mention a few of them to stimulate discussion and thought about what they are and how to approach them. Besides the topics that I am able to mention, I suspect that the panel members and audience will be able to come up with many more.

C0.3-0025-18 OBSERVATION OF ANOMALOUS BEHAVIOUR OF THE D-LAYER PREPARATION OR DISAPPEARANCE TIME DUE TO EFFECT OF THE SOLAR FLARES BY ANALYZING VLF SIGNALS.

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The ionosphere is a very important part of the Earth's upper atmosphere. Electrons are not distributed uniformly in the ionosphere and depending on this factor, ionosphere has different layers namely D, E and F. Different ionospheric layers generally exist during day and night time. During day-time when the main source of the ionization of the ionosphere is Sun, the lower most layer of ionosphere is D-layer. But during the night-time when Sun is absent and cosmic ray is the main source of the ionization of the ionosphere, this D-layer disappears and E-layer becomes the lower most region of the ionosphere. "Very Low Frequency" (VLF) is one of the bands of the Radio waves having frequency 3-30KHz, which propagates through the Earth-ionosphere wave-guide. In relation to propagation of radio waves through ionosphere, low mass and high mobility cause electrons to play a vital role. Normally, patterns of VLF signal depend on regular solar flux variations. However, during solar flares extra energetic particles are released from Sun, which makes the changes in the ionization of the ionosphere and these changes can perturb VLF signal amplitude. Usually if a solar flare occurs during any time of day, it only affects the amplitude and phase of the VLF signals. But in the present work, we found the if the flare occurs during D-layer preparation / disappearance time, then it will not only affect to amplitude and phase of the VLF signals but also to terminator times of VLF signals. We have observed that the sun set terminator time of the VLF signals shifted towards night time due to the effect of a M-class solar flare which occurred during the D-layer disappearance time. The shift is so high that it crossed 5σ level. To explain this observed effect, we are now trying to a make model using the ion-chemistry and LWPC code.

C0.3-0026-18 STUDY OF PRE AND CO-SEISMIC TROPOSPHERIC AND IONOSPHERIC ANOMALIES

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Understanding of pre and co-seismic phenomena is extremely complicated as the physical mechanism behind this study is nonlinear and multiparametric. It is well established that the lithospheric change due to seismic hazards can be coupled with atmospheric and ionospheric perturbations by using various channels. These are mainly chemical, thermal, acoustics, and electromagnetic phenomena which act as link between the lithosphere, atmosphere and ionosphere and this is known to be the Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) mechanism. We present the signature of such mechanism during and prior to various seismic events. We present both statistical and case-wise studies. We mainly emphasized the effects during the historical Honsu earthquake in March 2011 and Nepal earthquake in 2015 and simultaneously study all the possible thermal, acoustic and ionospheric anomalies associated with these to earthquakes. We also present a methodology proposed for LAIC mechanism and the intermediate results of the different stages of the coupling mechanism.

C0.3-0029-18 MAGNETOSPHERIC-IONOSPHERIC COUPLING DURING THUNDERSTORM LIGHTNING AS OBSERVED FROM ENERGETIC PARTICLE BURST

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Lightning discharge originates electromagnetic waves propagating in all directions through the earth-ionosphere waveguide. A small component of such wave enters into the earth magnetosphere and propagates along the magnetic field lines as a whistler mode wave. During this propagation, they interact with radiation belt electrons and due to this some of the electrons get trapped or precipitated in the ionosphere as a sporadic patch of excess ionization. The trapping electrons increase the count rate in the inner radiation belt and this particle count rate can be measured through satellite observation. Low Earth Orbital (LEO) satellite observes count rate of energetic particle burst in Van Allen Radiation Belt. We mainly use data from Medium Energy Proton and Electron Detector (MEPED) instrument associated with NOAA 15 satellite for this study. We use WWLLN network and global lightning data to get the lightning information. A significant increase of count rate is observed in MEPED data. We also corroborate our findings by the excess ionization due to lightning as observed from amplitude modulation of Very Low Frequency radio signal.

C0.3-0030-18 EVOLUTION OF VLF AND TEC IRREGULARITIES OBSERVED DURING THE BARDARBUNGA VOLCANO OF 2014/2015.

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In this work, we analyze the VLF/LF waves of 37453.125 Hz transmitted from Grindavik, Iceland and received in the Kiel Longwave Monitor, Germany for the year 2015. We did a graphical analysis of the variation of the intensity of the field associated with the VLF/LF of the respective frequency along with time. The comparison of sunrise and sunset terminator and D-layer formation times with the standard 2 lines was done. For several months of 2014 and 2015, several anomalies were observed in both the sunrise terminator times and D-layer formation times. We also calculated the trend, dispersion and night time fluctuations associated with VLF waves and found some irregularities. This gives us a possibility that the changes in these timings might be associated with intense volcanic activity which was observed in Iceland which stated off in Bardarbunga in August 2014 and ended only on 27th February 2015. In addition, we also analyzed the evolution of TEC during the volcano using the data of various GPS satellites in Iceland.

SPACE STUDIES OF THE UPPER ATMOSPHERES OF THE EARTH AND PLANETS INCLUDING REFERENCE ATMOSPHERES (C)

RECENT ADVANCES IN EQUATORIAL, LOWAND MID-LATITUDE MESOSPHERE, THERMOSPHERE AND IONOSPHERE STUDIES (C1.1)

C1.1-0001-18 EQUATORIAL PLASMA BUBBLES RELATED TO MSTID: SIGNATURE OF TROPOSPHERE TO IONOSPHERE COUPLING

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Equatorial ionosphere over the South American continent has been observed by ground-based GNSS receiver network (TEC maps and de-trended TEC), Ionosondes (foF2 and hF) and optical imagers (OI6300 and OH). Mesospheric gravity waves (MGW), medium scale ionospheric disturbances (MSTID), and equatorial plasma bubbles (EPB) were successfully monitored. Occurrence of MSTID and MGW in the afternoon to evening followed by EPB was observed in several cases in September 2015. We found that both MGW and MSTID were related to strong tropospheric convection activities. Also found was that the inter-bubble distances are approximately same to the horizontal wavelength of MSTID, suggesting that MSTIDs could be one of the possible forcing mechanism to generate EPBs.

C1.1-0002-18 CHARACTERIZATION OF LARGE SCALE TIDS BY ANALYSIS OF CLASSICAL IONOSPHERIC DATA IN EUROPEAN REGION

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Records of the standard ionospheric characteristics provided by ionosondes are analysed to detect distinct variations associated with the overpassing Large Scale Travelling Ionospheric Disturbances (LSTIDs). When observed in a sufficiently dense network of ionosondes, such as the one currently operating in the European region, coherency of the Fourier harmonics of these variations across different observatory sites can be inspected. If presence of such coherent variations is established in the time series, their cross-correlation analysis provides the horizontal phase velocity (azimuth and magnitude) of the LSTID propagation in the region, obtained under assumption of the planar wave propagation. Data analysis during periods of the geomagnetically disturbed conditions indicates presence of distinct LSTID signatures with dominant periods of 70-90 minutes and dominant southward velocities of 300 - 600 m/s. The agreement of the results deduced with independent data sources and technique confirms the presence of LSTIDs, potentially attributed to the auroral activity. These results confirm the potential of the correlation method for monitoring LSTID activity in support of the recently started TechTIDE research project and its practical applications.

C1.1-0003-18 ON THE ONSET CONDITIONS AND SEEDING OF EQUATORIAL PLASMA BUBBLE IN INDIAN SECTOR

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Equatorial plasma bubbles (EPB) are highly detrimental for satellite based communication and navigation applications in the low latitude region. Identifications of the precursors and finding the onset conditions for the growth of the Rayleigh-Taylor instability are the key for developing successful prediction model for the occurrence of the equatorial plasma bubble. Attempts have been made to study the role of gravity waves initiation of equatorial plasma bubble using various radio optical and in-situ observations, which include large-scale wave structure (LSWS), satellite trace (ST), multi-reflected echoes (MREs) as the signature of seed perturbations. In the recent past using ionosonde observations it has been shown that temporal variability of the F-layer height can be used as seed perturbation of gravity wave origin for determining the onset of equatorial plasma bubble. Considering the likely potential of such observations in developing prediction capability of equatorial plasma bubble, we have examined ionosonde data from the Indian longitudinal sector. Results show that the occurrence/ non-occurrence of plasma bubble has any simple relation with the perturbation of the F layer height and the height of the F layer. The main finding is that the temporal variation of the F-layer height is not a reliable precursor of seed perturbation determining the onset of plasma bubble. Further analysis of ionosonde data in terms of satellite trace (ST) and multi-reflected echoes (MREs) has also not provided any conclusive results in determining the onset condition. In view of the above we have examined the spatial variations of Airglow observations made at 630nm to examine the seed structures in question, which provided more meaningful precursor so far as the seeding is concerned. These results are presented and discussed in the light of current understanding and developing forecast strategy of equatorial plasma bubble (EPB).

C1.1-0004-18 STUDIES ON IONIZATION DEPLETIONS OF EQUATORIAL PLASMA BUBBLES ON TRANSIONOSPHERIC RADIO SIGNALS USING GNSS DURING THE EQUINOCTIAL MONTHS OF 2011 - 2016.

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This paper represents the studies on ionization depletions in form of TEC bite-outs of equatorial plasma bubbles on transionospheric radio signals received from Kolkata (latitude: 22.58oN, longitude: 88.38oE geographic; 32oN magnetic dip) is situated near the northern crest of the equatorial ionization anomaly (EIA) in the Indian longitude sector, using Global Navigation Satellite System (GNSS) during vernal and autumnal equinoxes of 2011 through 2016. It is observed that when a plasma bubble moves across a satellite link, scintillations and ionization are usually encountered. The apparent duration of the bite-outs may be different from the true east-west duration, as observed with geostationary links, because of the presence of a relative velocity between the irregularity cloud and the satellite. The trajectory of a GNSS(GPS/ GLONASS/GALILEO) satellite plays a vital role in observing the bubble characteristics. The distributions of amplitude and the parameters characterizing the ionization depletions, namely, the duration, depth and the leading and trailing edge slopes of the bubbles have been obtained during the same equinoctial months of 2011 through 2016. It is evident that the range error, extent of the bubble and ionization gradients measured in these equinoctial months of the equatorial region provides the worst case figures for system designers. The high range error (3-4 m) is observed during these equinoctial months. The statistical distribution of the TEC depletions showed some significant results. The maximum amplitude has been noted about 23.25 TECU (corresponding range error 3.7m at L1 frequency) with a median depletion of about 5.92 TECU during the vernal equinox of 2011. The majority of the bubbles were found to have Observed Duration (ObD) between 10-20 minutes with a maximum of 28.14 minutes with a median value of Actual Duration(AcD)of 2.37 minutes translates to nearly 150sec of possible satellite signal outage.Similar statistical distribution have been studied during the other equinoctial months of 2011-2016.

C1.1-0005-18 RADAR NETWORK IN THE EQUATORIAL IONOSPHERE FOR SPACE WEATHER CAPABILITIES: THE EQUADERN PROPOSED PROJECT

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The Earth's equator is uniquely the region where the magnetic field lines lie approximately horizontal within the ionosphere. The morphology is thus entirely distinct from that at higher latitudes where the field threads more nearly vertically through the ionospheric layer. It is the most complex region of the Earth's ionosphere due to its interactions, instabilities and also hosts to the most complex phenomena in the upper atmosphere. There are several unresolved questions regarding the dynamics of the equatorial ionosphere, its electrodynamics and the physical processes that govern the region. The success of the Super Dual Auroral Radar Network (SuperDARN) in observing both the occurrence and important characteristics of ionospheric plasma irregularities in auroral latitudes, polar latitudes (PolarDARN) and midlatitudes (StormDARN) indicates that such a system may also be successful in the equatorial region. In this work, we examine the science questions such as equatorial plasma bubbles and spread F formation that the deployment of a SuperDARN style radar in the equatorial region would be able to address, both individually and in conjunction with other space-based and ground-based instrumentation. The proposed radar network is similar in style and technique to the SuperDARN radar network. The radar network will be used to study the equatorial ionosphere over a long interval of time, at least one solar cycle. The deployment of a radar network in the magnetic equator is called the Equatorial (Dual) Electroject Radar Network (EquaERN/EquaDERN). The proposed project will provide simultaneous observations of both electric and magnetic variations over the magnetic equator both individually and in conjunction with other space-based and ground-based instrumentation. The network of radars will clearly improve our understanding of the dynamics of the equatorial ionosphere and our understanding of its role in balancing the large-scale ionospheric current system, and will contribute to our ability to adequately model ionospheric and plasmaspheric densities and also enhance our understanding of global ionospheric processes which will improve the space weather capabilities of the International space science communities.

C1.1-0006-18 IMPACTS OF LOWER ATMOSPHERIC WAVES ON THE EQUATORIAL UPPER ATMOSPHERE

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This paper deals with the influence of the lower atmospheric waves on the dip equatorial ionosphere in general, and the day-to-day variability of the Equatorial Electrojet (EEJ) in particular. The analysis carried out using the data from various optical and radio probing instruments over Trivandrum (8.5oN, 77oE, 0.5oN dip lat.), revealed that the equatorial upper atmosphere responds significantly to the forcings from the lower atmosphere. It has been found that the Planetary Waves (PWs) and Gravity Waves (GWs) play a major role in producing the variability on the quiet time equatorial upper atmosphere. While the PWs modulate most of the parameters of the equatorial ionosphere to their respective periodicity, the gravity waves play significant role in producing Counter Electrojet (CEJ) and Equatorial Spread F. Among the PWs, the quasi 16-day wave plays a major role in modulating the day-to-day variability of the EEJ. The PWs alter the strength, duration and time of the EEJ significantly. Another noteworthy observation is the periodic occurrence of CEJ during the northern hemispheric Stratospheric Sudden Warming events. The Planetary wave-tidal interactions and subsequent modification in the tidal components is found to be responsible for the observed variations. The paper discusses these aspects in detail.

C1.1-0007-18 EQUATORIAL EVENING PREREVERSAL VERTICAL DRIFT AND SPREAD F/ PLASMA BUBBLE IRREGULARITY DEVELOPMENTS UNDER DISTURBANCE TIME ELECTRIC FIELDS AND WINDS

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Equatorial plasma bubble/spread F (EPB/ESF) irregularity development can suffer large variability on a day-to-day basis due to the highly variable dynamic state of the evening ionosphere. An important cause of the ESF variability lies in the prereversal enhancement in the F region vertical plasma drift (zonal electric field), that is subject to large modifications under forcing from magnetospheric disturbances, when penetrating inter-planetary electric fields, and disturbance dynamo electric field, cause large enhancement, or total suppression, of the PRE, and hence of the ESF development. Additionally the disturbance meridional/ trans-equatorial wind can cause total suppression of the ESF development independent of the modification of the PRE vertical drift. Many details regarding the nature of the impact of the penetration electric fields on the PRE vertical drift and that of the disturbance winds on ESF growth lack our understanding. In this paper we have analyzed data on F layer heights and vertical drifts obtained from Digisondes operated in Brazil, including from conjugate point observations, to investigate the connection between magnetic disturbances occurring during and preceding the sunset hours and the consequent variabilities in the PRE vertical drift and EPB/ESF development. The impact of the prompt penetration under-shielding eastward electric field and that of the over-shielding, and disturbance dynamo, westward electric field on the evolution of the evening PRE vertical drift, and that of disturbance meridional/trans-equatorial wind on EPB/ESF development are briefly examined.

C1.1-0008-18 ANALYSIS AND HINDCAST EXPERIMENTS OF THE 2009 SUDDEN STRATOSPHERIC WARMING IN WACCMX+DART

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The ability to perform data assimilation in the Whole Atmosphere Community Climate Model eXtended version (WACCMX) is implemented using the Data Assimilation Research Testbed (DART) ensemble adjustment Kalman filter. Results are presented demonstrating that WACCMX+DART analysis fields reproduce the middle and upper atmosphere variability during the 2009 major sudden stratospheric warming (SSW) event. Compared to specified dynamics WACCMX, which constrains the meteorology by nudging towards an external reanalysis, the large-scale dynamical variability of the stratosphere, mesosphere, and lower thermosphere are improved in WACCMX+DART. This leads to WACCMX+DART better representing the downward transport of chemical species from the mesosphere into the stratosphere following the SSW. WACCMX+DART also reproduces most aspects of the observed variability in ionosphere total electron content (TEC) and equatorial vertical plasma drift during the SSW. Hindcast experiments initialized on January 5, 10, 15, 20, and 25 are used to assess the middle and upper atmosphere predictability in WACCMX+DART. A SSW, along with the associated middle and upper atmosphere variability, is initially predicted in the hindcast initialized on January 15, which is 10 days prior to the warming. However, it is not until the hindcast initialized on January 20 that a major SSW is forecast to occur. The hindcast experiments reveal that dominant features of the TEC can be forecast 10-20 days in advance. This demonstrates that whole atmosphere models that properly account for variability in lower atmosphere forcing can potentially extend the ionosphere-thermosphere forecast range.

C1.1-0009-18 NUMERICAL SIMULATION OF TRAVELING IONOSPHERIC DISTURBANCES GENERATED BY UPWARD PROPAGATING GRAVITY WAVES

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It has been recognized that gravity waves (GWs) play an important role on the momentum and energy budget in the thermosphere/ionosphere. In this study, using a whole atmosphereionosphere coupled model (GAIA) with a high horizontal resolution, behaviors of Traveling Ionospheric Disturbances (TIDs) generated by upward propagating GWs in the thermosphere are investigated. The horizontal resolution of GAIA is 1 degree longitude by 1 degree latitude, which is adequate to simulate large-scale GWs. The GAIA contains the region from the ground surface to the upper thermosphere, so that we can simulate excitation of gravity waves in the lower atmosphere, their upward propagation to the mesosphere and thermosphere, and their impacts on the thermosphere/ionosphere system. The GAIA can simulate TIDs because interaction processes between the ionosphere and neutral atmosphere are included. The equatorward (poleward) TIDs become dominant during the daytime (nighttime) due to the filtering effect of GWs by poleward (equatorward) thermospheric winds. The dominant horizontal wavelength and period of the simulated TIDs are 500-1500 km and 30-90 min, respectively. The dominant wavelength and period of TIDs are the same as those of GWs near 250-300 km height. We discuss seasonal and longitudinal variations of TIDs and their relation to GW activity in the thermosphere.

C1.1-0010-18 EFFECT OF SOLAR FLUX AND COMPOSITIONAL VARIATIONS ON THE VARIABILITY OF OXYGEN DAYTIME OPTICAL EMISSIONS OVER LOWAND MID-LATITUDES

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Daytime oxygen airglow intensity variability provides us with a means of remote investigations of the upper atmospheric behaviour. The dayglow emissions typically show a diurnal pattern with a peak at around noontime, especially during geomagnetic quiet conditions. The photochemical and empirical models show that the emissions vary as a function of solar zenith angle and solar flux. Thus, both, larger solar flux magnitudes and smaller solar zenith angles, contribute to larger dayglow brightness as the yield of excited oxygen atoms is expected to be greater in those conditions. However, seasonal dayglow emission variability obtained from measurements at low-latitudes (Hyderabad, India; 170 N, 800 E; 8.70 N Mag. Lat.) and midlatitudes (Boston, USA; 42.20 N, 710 W; 48.30 N Mag. Lat.) show different behavior with regard to solar flux variation. While the low-latitude emission variability is dependent on solar flux variations, the variability over mid-latitudes is not. This paper will discuss the cause(s) of this discrepancy with regard to relative effects of variation of compositional versus solar flux on the daytime airglow emissions at the lowand mid-latitude locations.

C1.1-0011-18 THE ELECTRODYNAMICS OF THE EQUATORIAL LOWER IONOSPHERE

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Equatorial electrodynamic processes play fundamental roles on low latitude upper atmospheric dynamics and plasma density distribution, and on the occurrence of plasma structures and irregularities with a large range of scale sizes. The most complex equatorial electrodynamic processes occur in the lower ionosphere where there are large temporal changes in thermospheric neutral wind and plasma drift coupling. This is particularly the case in the evening and early night periods when rapid altitudinal variations in the plasma density significantly affect the occurrence of equatorial plasma irregularities. Over the last few years, numerous experimental, theoretical and modeling studies have examined the electrodynamics of the evening equatorial ionosphere. In this presentation, we initially examine recent experimental studies of these processes during geomagnetic quiet-times using mostly Jicamarca radar measurements. We also discuss recent modeling studies of the evening electrodynamic plasma drifts, and of their relationship to thermospheric neutral winds, and generation and the evolution of equatorial plasma irregularities. We also briefly examine storm time effects on lower ionospheric equatorial plasma drifts, their relationship to disturbance neutral winds and their season dependent effects on equatorial plasma waves. Finally, we suggest possible future experiments and numerical modeling studies necessary for the better understanding of this highly complex ionospheric region.

C1.1-0012-18 ON THE SQ CURRENT SYSTEM SIGNATURES MEASURED IN LATIN AMERICA

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The present work shows the first results of the study about the seasonal variation of the Solar quiet (Sq) Earth's magnetic field based on magnetic measurements from the Embrace Magnetic Network (MagNet). This is made at several latitudes in South America, covering the equatorial and low latitudinal region. For this study, we used data covering the period from 2010 to 2016, during the ascending phase of the solar cycle 24. Besides being an integrating part of the process to deviate the South American K, known as Ksa, the Sq variations are discussed in terms of their signature in the Quiet Day Curve. In addition, the effect X-Ray solar flares observed in the magnetic data collected by the Embrace MagNet are used to estimate the southern focus of the Sq current system.

C1.1-0013-18 CHARACTERISTICS OF IONOSPHERIC STORMS IN EAST ASIA

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The ionosphere experiences intense response during the geomagnetic storm and it varies with latitude and longitude. The DPS-4 digisonde measurements and GPS-TEC data of ionospheric stations located at different latitudes in the longitudinal sector of 90-130°E during 2002 to 2016 were analyzed to investigate the ionospheric effects in the different latitude of East Asia during geomagnetic storm. Geomagnetic storm cases are selected according to the Dst index and available observed data, they are in different seasons and different solar activity levels. Results show that for the middle and high latitude, the short-lived positive disturbance associated with the initial phase of the every storm was observed in each season and then the disturbances were negative till the termination of storm. At the low latitude, storm-time disturbances of foF2 have obvious diurnal, seasonal and solar cycle characteristics. It's notable that geomagnetic activities occurred at local time nighttime can cause stronger and longer responses of foF2 at the low latitude. All in all, the obvious negative phase ionospheric storms often occurred at the low latitude. The differences of the responses of foF2 and TEC are also investigated.

C1.1-0014-18 MODELING THE LOWER PART OF THE TOPSIDE IONOSPHERIC VERTICAL ELECTRON DENSITY PROFILE OVER THE EUROPEAN REGION BY MEANS OF SWARM SATELLITES DATA AND IRI UP METHOD

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An empirical method to model the lower part of the ionospheric topside region from the F2- layer peak height to about 500-600 km of altitude over the European region, is proposed. The method is based on electron density values recorded from December 2013 to June 2016 by Swarm satellites, and on foF2 and hmF2 values provided by the IRI UP (International Reference Ionosphere UPdate) method recently proposed by Pignalberi et al. (2018), which is a method developed to update the IRI model relying on the assimilation of foF2 and M(3000)F2 data routinely recorded by a network of European ionosonde stations. Topside effective scale heights are calculated by fitting some definite analytical functions (-Chapman, -Chapman, Epstein and Exponential) through pair of values (N(hsat), hsat) recorded by Swarm and pair of values (NmF2, hmF2) output by IRI UP, with the assumption that the effective scale height is constant in the altitude range considered. Calculated effective scale heights are then modeled as a function of foF2 and hmF2, in order to be operationally applicable to both ionosonde measurements and ionospheric models. The method produces two-dimensional maps of the median effective scale height binned as a function of foF2 and hmF2, for each of the considered topside profiles. A statistical comparison with COSMIC/FORMOSAT-3 collected Radio Occultation profiles is carried out to assess the validity of the proposed method, and to investigate which of the considered topside profiles is the best one. The -Chapman topside function displays the best performance compared to the others. Anyway, the results shows also the possibility to use a two-layer profile consisting of a sum of -Chapman and Exponential functions to properly describe the topside region.

C1.1-0015-18 THE IONOSPHERIC AND THERMOSPHERIC RESPONSES TO GREAT SOLAR FLARES: OBSERVATIONS AND MODELING

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A solar flare causes a sudden increase in solar irradiation including the X-ray wavelengths and the extreme ultraviolet (EUV). The sudden enhanced solar irradiation produces the extra ionization at all ionosphere heights from D region to F region. Then additional heating via ionneutral collision also causes some variations in thermosphere. The ionospheric responses to solar flares have been studied by many scientists. Compared to the ionospheric responses, the studies on the thermospheric responses to solar flares are much fewer due to the few high resolution thermosphere observation. The observations from CHAMP accelerometer show only the large enough solar flare (like X5 and larger flares) can cause thermosphere neutral density increase significantly. In this study, we further study what is the threshold value of solar flare for the significant thermosphere change. Furthermore, we studied the evolution of the thermosphere and ionosphere responses with increasing solar flare class. Both the ionosphere and thermosphere show an amplification effect. And also we studied the coupling responses of the ionosphere and thermosphere by modeling a super solar flare of X40. The results show the ionosphere responses can last more than 4 hours, which is mainly due to the great thermosphere changes. The quick expansion of the thermosphere results in an uplift of the ionosphere to higher heights where recommendation rate is less. In addition, we also investigated the electrodynamics variations of ionosphere by explore exploring the equatorial electric field and electrojet in the ionosphere at Jicamarca during some solar flares. It is verified that solar flares increase dayside equatorial eastward electrojet but decrease dayside eastward equatorial electric field, revealing a negative correlation between equatorial electrojet and equatorial electric field. The decreased equatorial electric field weakens the equatorial fountain effect and depresses the low-latitude electron density.A solar flare causes a sudden increase in solar irradiation including the X-ray wavelengths and the extreme ultraviolet (EUV). The sudden enhanced solar irradiation produces the extra ionization at all ionosphere heights from D region to F region. Then additional heating via ion-neutral collision also causes some variations in thermosphere. The ionospheric responses to solar flares have been studied by many scientists. Compared to the ionospheric responses, the studies on the thermospheric responses to solar flares are much fewer due to the few high resolution thermosphere observation. The observations from CHAMP accelerometer show only the large enough solar flare (like X5 and larger flares) can cause thermosphere neutral density increase significantly. In this study, we further study what is the threshold value of solar flare for the significant thermosphere change. Furthermore, we studied the evolution of the thermosphere and ionosphere responses with increasing solar flare class. Both the ionosphere and thermosphere show an amplification effect. And also we studied the coupling responses of the ionosphere and thermosphere by modeling a super solar flare of X40. The results show the ionosphere responses can last more than 4 hours, which is mainly due to the great thermosphere changes. The quick expansion of the thermosphere results in an uplift of the ionosphere to higher heights where recommendation rate is less. In addition, we also investigated the electrodynamics variations of ionosphere by explore exploring the equatorial electric field and electrojet in the ionosphere at Jicamarca during some solar flares. It is verified that solar flares increase dayside equatorial eastward electrojet but decrease dayside eastward equatorial electric field, revealing a negative correlation between equatorial electrojet and equatorial electric field. The decreased equatorial electric field weakens the equatorial fountain effect and depresses the low-latitude electron density.

C1.1-0016-18 MID-LATITUDE IONOSPHERIC D-REGION DISTURBANCES DURING THE

MAJOR SSW EVENTS OF 2009 AND 2016 OBSERVED THROUGH SUB-IONOSPHERIC RADIO SIGNALS

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We present mid-latitude D-region disturbances during the northern hemispheric major Sudden Stratospheric Warming (SSW) events of 2009 and 2016, in different solar conditions, as sensed by sub-ionospheric VLF/LF radio signals. We have analysed VLF/LF radio signals from four transmitters (NAA, NRK, NPM, NLK) received at eight places in Europe, USA and Japan during these events. The 2009 event was the most intense SSW event in recent past, while the SSW of 2016 consisted of two warming events within months. Significant anomalies in nighttime and daytime VLF/LF amplitudes (3-10 dB) have been found for all propagation paths associated with stratospheric temperature rise at 10 hPa level during the SSW events. Modification of the lower ionospheric boundary conditions and corresponding modal interference effects between the different propagating waveguide modes are found responsible for the anomalous variation of VLF/LF amplitudes during the two SSW events. Simulation of VLF/LF diurnal variation are carried out using the well known Long Wave Propagating Capability (LWPC) code within the earth-ionosphere waveguide to quantify the ionospheric anomalies caused by the respective SSW events.

C1.1-0017-18 ON THE RESPONSE OF INDIAN EQUATORIAL AND LOW-LATITUDE IONOSPHERE TO SUDDEN STRATOSPHERIC WARMING DURING 2009 AND 2013

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The vertical coupling between the lower and upper atmosphere is one of the major drivers of dayto-day variability of the ionosphere. The variability of low-latitude ionosphere is intricate as it is also coupled laterally to the high-latitude dynamical processes. Sudden stratospheric warming (SSW) is one such meteorological phenomenon which occur in polar winter stratosphere and causes large variations in the upper atmosphere. The present study investigates the variability of low-latitude ionosphere of the Indian region to the two major SSW events occurred during 2009 and 2013. The equatorial electrojet (EEJ) strength obtained from geomagnetic field variations and total electron content (TEC) derived from using Global Positioning Satellite (GPS) system at several stations in India have been in the present study. Results reveal a significant difference in the response of equatorial electrodynamics and low-latitude ionosphere during the two events. The National Center for Environmental Prediction (NCEP) wind data at 10hPa (30km) level and the meteor wind radar data installed at dip equatorial station, Trivandrum (8.5°N, 77.1°E, 0.5°N), have been used to identify any cause-effect relationship between observed variations in low-latitude ionosphere and stratospheric warming events. The results suggest the strong role of quasi-biennial oscillation (QBO) in modulating the effect of SSW over low-latitudes.

C1.1-0018-18 NEW RESULTS ON THE EFFECTS OF PROMPT PENETRATION ELECTRIC FIELD ON EQUATORIAL IONOSPHERE

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In the last few years, a number of results obtained on the effects of prompt penetration electric field on the equatorial ionosphere have made significant impact on our understanding and raised new questions. First, it was found that long duration prompt penetration events may not constitute similar processes at a phenomenological level. This result has a direct bearing on the understanding of the shielding time constant which is taken to be around 30 min based on theoretical considerations. Second, it was also found that even small changes in the solar wind density only under northward IMF Bz condition can generate perceptible prompt electric field disturbances on the equatorial ionosphere. Third, it was shown that inductive electric field perturbations due to substorms during storms can be significantly high, additive or subtractive in nature and hence has the capacity to modify the prompt penetration electric field effects significantly. Fourth, it was also found that IMF By component can, on occasions, change the generally accepted polarity of prompt penetration electric field effects on equatorial ionosphere. In addition to the above results, it was also shown that geo-effectiveness of Co-rotation Interaction Region (CIR) events can be gauged based on prompt penetration electric field effects on equatorial ionosphere and CIRs are generally geo-effective as long as the solar wind azimuthal flow angle is within 6 degrees at the first Lagrangian Point (L1) of the Sun-Earth system. On the other hand, it is also found that even if the passage of an Interplanetary Coronal Mass Ejection (ICME) at 1 AU does not generate main phase of a storm, it can still be geo-effective in terms of prompt penetration electric field effects on equatorial ionosphere. The presentation will address these new aspects related to the effects of the prompt penetration electric field on equatorial ionosphere.

C1.1-0019-18 C/NOFS OBSERVATIONS BELOW THE EQUATORIAL IONOSPHERIC F-REGION LEDGE AT NIGHT

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During the last year of the Air Force C/NOFS mission, the satellite had an opportunity to sample below the F-region bottomside ledge. This presented an opportunity to gather important new insight regarding the electrodynamics of these critical lower altitudes (< 350 km). Although the data are limited due to spacecraft constraints encountered during this time, plasma density and electric field data observed during the lower altitude portions of these orbits present an opportunity to extend our knowledge of the low latitude nighttime plasma density and its motions below F-region ledge. For example, as in cases where the F-peak was elevated near sunset, we sometimes observe evidence of reversed zonal plasma drifts – i.e., westward drifts at the lower altitudes – even at later local times after sunset. There are important longitude and local time signatures inherent in the measurements that we summarize in our overview of the data gathered by the Vector Electric Field Investigation during its last year of orbit.

C1.1-0020-18 THE ROLE OF PLASMA BUBBLES AND TRAVELING IONOSPHERIC DISTURBANCES IN THE CREATION OF PLASMA BLOBS

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Plasma blobs represent the plasma density enhancements relative to the background ionosphere. Their creation is understood in terms of either equatorial plasma bubbles or traveling ionospheric disturbances (TIDs). However, we do not yet clearly understand how often blobs occur in association with one of those phenomena. This study addresses this question by conducting case studies for each blob event and examining the occurrence climatology. Blob events are identified from the Swarm satellite observations in 2014-2017. The total electron content maps and all-sky images are used to monitor the occurrence of TIDs. The occurrence of bubbles is monitored using the observations of Special Sensor Ultraviolet Spectrographic Imager (SSUSI) on board the Defense Meteorological Satellite System (DMSP) F18. We identify the association of blobs with bubbles or TIDs by examining their simultaneous occurrence at the same magnetic meridian. The distributions of blobs, bubbles, TIDs are derived from Swarm observations, and these results are also used for the investigation of the role of bubbles and blobs in the creation of blobs.

C1.1-0021-18 ANOMALOUS PRE-EARTHQUAKE IONOSPHERIC SIGNATURES OBSERVED AT LOW-MID LATITUDE INDIAN STATION, DELHI, DURING THE YEAR 2015 TO EARLY 2016: PRELIMINARY RESULTS

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Five major earthquake events measuring greater than six on Richter scale (M > 6) that occurred during the year 2015 to early 2016, affecting Indian region ionosphere, are analyzed using F2 layer critical parameters (foF2, hmF2) obtained using Digisonde from a low-mid latitude Indian station, Delhi (28.6°N, 77.2°E, 19.2°N geomagnetic latitude, 42.4°N dip). Normal day-to-day variability occurring in ionosphere is segregated by calculating F2 layer critical frequency and peak height variations (foF2, hmF2) from the normal quiet time behavior apart from computing interquartile range. By and large, significant perturbations are observed in the ionosphere F2 region across Delhi, 3-4 days prior to these earthquake events, resulting in a large peak electron density variation of 200%, indicating towards a possibility of seismo-ionospheric coupling as the solar and geomagnetic indices were normally quiet and stable during the period of these events. It was also observed that the precursory effect of earthquake was predominantly seen even outside the earthquake preparation zone, as given by Dobrovolsky et al. (1979). The thermosphere neutral composition (O/N2) as observed by Global Ultraviolet Imager, across Delhi, during these earthquake events does not show any marked variation. Further, the effect of earthquake events on ionospheric peak electron density is found to be comparable to those due to lower atmosphere meteorological phenomenon of 2015 sudden stratospheric warming event.

C1.1-0022-18 FOUNTAIN EFFECT SIGNATURES ON THE F3-LAYER CHARACTERISTICS FROM THE EQUATOR TO THE EIA CRESTS DURING THE GEOMAGNETIC STORM OF 17 MARCH 2015

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The existence of an additional stratification of the equatorial ionospheric F region, the F3-layer, has been known since the1940s, and it has been explored in detailed for more than a decade. Adding to the large quiet time variability in the F region ionosphere, ionosondes have observed F3-layers during the occurrence of geomagnetic storm induced prompt penetration electric fields (PPEF). The St. Patrick's Day geomagnetic storm on 17 March 2015 is the strongest storm in the 24th solar cycle with the minimum Dst of -223 nT. During the main phase of this storm, two strong prompt penetration electric field phases took place: the first with the southward turning of IMF Bz around 1200 UT, and the second with the onset of a sub storm around 1725 UT leading to strong equatorial zonal electric field enhancements in the Brazilian sector, which was on the day side hemisphere. The F3-layer was observed over a large latitudinal extent of 45 degrees during the two strong PPEF phases that occurred in the main phase of the storm. The F3 is seen from the equator up to the equatorial ionization anomaly (EIA) crests in the northern and southern hemispheres along the Brazilian longitudes. Distinct latitudinal and hemispheric differences are noted in the occurrence characteristics of the F3-layer during both PPEF phases. The influence of the storm-induced super fountain effect on the evolution of the F3-layer over the equatorial and low latitudes is discussed.

C1.1-0023-18 SIMULATION OF THE LOW LATITUDE IONOSPHERE RESPONSE TO DISTURBED WINDS AND ELECTRIC FIELDS: BRAZILIAN REGION

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Modeling the ionosphere during disturbed periods is one of the most challenging tasks due to the complexity of the phenomena that affect the electric fields and the thermosphere environment as a whole. It is well known that depending on the direction of the interplanetary magnetic field disturbance electric fields (undershielding or overshielding) can penetrate from high to low latitudes causing significant disturbances in the electron density distribution and in the equatorial ionization anomaly (EIA) development. Besides that, the large amount of energy deposited in the polar region during disturbed periods will be responsible for the generation of disturbed winds that will flow towards the equator where they produce a disturbance dynamo which also affects the EIA density distribution. The TIDs and TADs are also sources of disturbances that propagate at high velocity reaching the equator 2-3 hours after the beginning of the magnetic storm. In this work we use the Sheffield University Plasmasphere-Ionosphere Model at INPE (SUPIM-INPE), to simulate the drastic effects that were observed at the low latitude ionosphere in the Brazilian region during a very intense magnetic storm event. A few models are tested for the disturbed electric field and for the disturbed wind. The simulation results showed that the observations are better explained when considering a traveling waveform disturbance propagating from north to south at a velocity of the order of 200 m/s.

C1.1-0024-18 STUDY OF IONOSPHERIC PERTURBATIONS IN F-LAYER USING TASHKENTKITAB GPS STATIONS

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Monitoring of F-layer of ionosphere over GPS nodes in the Central Asia territory is being performed on the permanent basis and GPS derived TEC disturbances from two GPS stations located in Tashkent and Kitab are analyzed. The ionospheric anomalies observed during strong local earthquakes (M greater than 5.0) which occurred mostly in and around Uzbekistan in seismically active zones, during years 2010 to 2017 within 1000 km from the observing GPS stations located in Tashkent and Kitab. The solar and geomagnetic conditions were quiet during occurrence of the selected more than 30 earthquakes. We produced TEC time series over both sites and apply them to detect anomalous TEC signals preceding or accompanying the earthquakes. The results show the anomalies occurred 1-6 days before the earthquakes as ionospheric electromagnetic precursors. To identify the anomalous values of TEC we calculated differential TEC (dTEC). dTEC is obtained by subtracting 15 days backward running mean of vTEC from the values of observed vTEC at each epoch.

C1.1-0025-18 TOPSIDE IONOSPHERIC IRREGULARITIES AS DERIVED FROM SWARM SATELLITES OBSERVATIONS

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Combination of ground-based GNSS and space-based low orbit multi-instrumental satellite observations can bring significant advances in our knowledge of physics near-Earth space in quiet conditions and during Space weather events. The present study is based on a joint analysis of the ground-based GPS/GLONASS observations as deduced from 6000 stations together with up-looking GPS measurements onboard the Swarm mission. The ESA's Swarm mission was launched on 22 November 2013 and consisted of three identical satellites - Swarm Alpha (A), Bravo (B) and Charlie (C) - two of them AC fly in a tandem separated by 1.4 degree in longitude at an orbit altitude of 460 km while the third satellite (B) - at an orbit altitude of 510 km. Each satellite is equipped with a zenith-looking antenna and 8-channel dual-frequency GPS receiver that delivered 1 Hz data for precise orbit determination (POD), as well as with a Langmuir Probe instrument for in situ electron density. We developed and sucessefully applied original approaches for detection topside ionospheric irregularities using in situ plasma probe measurements and GPS POD payload data from Swarm satellites. We demonstrate that LEO GPS observations are reliable data source for monitoring the topside ionospheric irregularities occurrence in both high-latitude and equatorial regions and it can essentially contribute to the multi-instrumental analysis of the in situ LEO measurements and ground-based data. In the present study we discuss features of the equatorial plasma irregularities detected by multisatellite observations in the topside ionosphere (above an altitude of 500 km) during main and recovery phases of severe geomagnetic storms in March and June of 2015. We demonstrate results with differences between the obtained climatological characteristics of the equatorial ionospheric irregularities occurrence probability derived from space-based GPS data and storm-induced equatorial irregularities observations (postsunset suppression, night/morningtime occurrence, expansion toward midlatitudes) with specific focus on the equatorial plasma bubbles occurrence in the topside ionosphere. The research is supported by the National Science

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C1.1-0026-18 ELECTRIC FIELDS IN A GEOMAGNETIC STORM

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The ionosphere behaviors quite different from its normal state under geomagnetic active conditions, especially during geomagnetic storms. The ionospheric storm effects are always a research focus. An extreme space weather even occurring on 14-17 July 2012 manifests a geomagnetic storm. This event is characterized by a southward interplanetary geomagnetic field lasting for about 30 h below -10 nT. In this talk, multiple instrumental observations including electron density from ionosondes, total electron content (TEC) from Global Positioning System (GPS), Jason-2, and Gravity Recovery and Climate Experiment (GRACE), and the topside ion concentration observed by the Defense Meteorological Satellite Program (DMSP) spacecraft are used to comprehensively present the regional differences of the ionospheric response to this event and the electric field. We will show the intensive negative storm in the Asian-Australian sector and the difference between sectors. The evolution and role of the electric field in the storm will also be discussed. The storm-time zonal winds as indicated from the movement of composition disturbances region will help to understand the formation of disturbance dynamo processes.

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C1.1-0027-18 TECHTIDE: WARNING AND MITIGATION TECHNOLOGIES FOR TRAVELLING IONOSPHERIC DISTURBANCE EFFECTS

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TechTIDE is a consortium of 13 research and applications organizations in Europe and South Africa formed in November 2017 under the European Union Horizon 2020 framework. Its overarching objectives are design and test of new viable mitigation strategies for the space weather impacts from Travelling Ionospheric Disturbances (TID). TechTIDE will propose near real-time warning services and mitigation technologies and demonstrate their added value for the systems that rely on high fidelity of trans-ionospheric propagation of radio signals, primarily for the purpose of precise navigation (e.g., EGNOS and N-RTK) and high frequency geolocation. TechTIDE is employing an ensemble of six different methodologies for automatic TID identification and tracking using

ionosonde, Doppler radar, and GNSS sensor networks in Europe and South Africa, and conducts its research and development in close collaboration with operators of the technologies affected by TIDs. Unique data products from TechTIDE aim at providing new understanding of the physical processes resulting in the formation of TIDs, and will consequently help to identify their drivers in the interplanetary medium, the magnetosphere, and the atmosphere. The paper discusses involved research methodologies in detail and outlines the strategies for their cross-validation and transition to operations.

C1.1-0028-18 RECENT RESULTS OBTAINED BY THE OPTICAL MESOSPHERE THERMOSPHERE IMAGERS (OMTIS) AT LOW AND MIDDLE LATITUDES

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We review our recent progresses on the observation of the thermosphere and ionosphere using the Optical Mesosphere Thermosphere Imagers (OMTIs), which consist of 21 airglow imagers, 5 Fabry-Perot interferometers (FPIs), three airglow temperature photometers and 3 tilting photometers. They are in automatic operation at Canada, Russia, Finland, Iceland, Norway, Japan, Alaska, Indonesia, Thailand, Australia, and Nigeria. Statistical characteristics of plasma bubbles at Abuja, Nigeria were studied by Okoh et al. (JGR, 2017) with their relation to the GNSS scintillation statistics. Coordinated observations of post-midnight irregularities and thermospheric neutral winds and temperatures at low latitudes were reported by Dao et al. (JGR, 2017) to show the relation of the post-midnight irregularities with the midnight temperature maximum and associated thermospheric winds. Average thermospheric temperatures observed by four FPIs at Norway, Thailand, Indonesia, and Australia for 2-3 years are compared with those estimated by the GAIA model to investigate the validity of the model (Nakamura et al., EPS, 2017). The thermospheric winds obtained by the FPIs at geomagnetic conjugate stations in Japan and Australia are combined with the airglow imaging observations of nighttime medium-scale traveling ionospheric disturbances (MSTIDs) and ionosonde measurements to investigate MSTID generation mechanisms through E-F and hemispheric electromagnetic coupling processes.

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C1.1-0029-18 VTEC VARIABILITY AT MIDNIGHT OVER MID-LATITUDES REGIONS USING PCA

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The effect of the thermospheric vertical neutral wind on vertical total electron content (vTEC) variations including longitudinal anomaly, remaining winter anomaly, mid-latitude summer night anomaly, and semiannual anomaly is studied at mid-latitude regions around zero magnetic declination at midnight during high solar activity. This work studies the spatial and temporal variations of the ionosphere at midnight over mid-latitude regions during 2000-2002 using the Principal Component Analysis (PCA) numerical technique. PCA is applied to a time series of global vTEC maps produced by: the International Global Navigation Satellite System (GNSS) Service and the International Reference Ionosphere (IRI) 2012. Also, the Horizontal Wind Model 2007 (HWM07) is used to improve our climatology interpretation, by analyzing the relationship between vTEC and thermospheric wind, both quantitatively and qualitatively. At midnight, the behavior of mean vTEC values strongly responds to vertical wind variation showing a decrease of about 10-15% with the action of the positive vertical component of the field aligned neutral wind lasting for 2 hs. Remarkable results include: the mid-latitude summer night anomaly in South America and Asia regions, the remnant of the winter anomaly in North America and Oceania regions. Finally, the longitudinal east-west variation is also present. Our results show that at mid-latitudes regions, the IRI 2012 model represents midnight ionospheric mean values with a similar spatial distribution, but the values are always lower than those obtained by GNSS. There are also differences between IRI 2012 and GNSS in represent the different anomalies.

C1.1-0030-18 OBSERVATIONS OF GRAVITY WAVES IN THE AIRGLOW DURING THE NIGHT OF 21 AUGUST 2017 SOLAR TOTAL ECLIPSE OVER BRAZIL

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A coordinate campaign of observations was conducted in the northeast of Brazil during 21 August 2017 solar total eclipse. During this campaign neutral and ionic parameters of the mesosphere-thermosphere-ionosphere system were measured using airglow imagers, Fabry-Perot interferometer, ionosondes, coherent back-scatter radar, meteor radars and magnetometers. The main goal of this campaign was investigated secondary effect of the total solar eclipse in the dynamics and structure of the atmosphere over Brazil. From the airglow images, periodic gravity waves were observed in the mesopause (OH layer) and thermosphere (OI6300 layer). The waves had propagation directions and horizontal parameters compatible with waves that could be generated by the eclipse from the north part of the South America continent. Salient discussion will be present in this paper.

C1.1-0031-18 RECENT DEVELOPMENT ON E REGION IRREGULARITIES INDUCED BY THE FARLEY-BUNEMAN INSTABILITY

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Observations from three closely located VHF radars in Northern Germany during the March 17 2015 storm have revealed several important features regarding the Farley-Buneman instability:

narrow fast echoes (formerly called Type IV) came from the top of the unstable region near 120 km while narrow slow echoes (formerly called Type III) came from below 100 km altitude. In the most unstable region near 110 km, the echoes were more normal, moving at the ion-acoustic speed in the plasma flow direction and decreasing steadily with flow angle. There was, however, an unexpected strong east-west asymmetry. It was determined that narrow fast echoes were generated when the ion drift was moving at a speed equal to the electron drift minus the threshold speed (roughly the ion-acoustic speed). The narrow slow echoes were also slowly growing modes generated, this time, when the electric field was very strong but the electron collision frequency was large. The more turbulent echoes near 110 km were consistent with a theoretical description involving a rotation and decrease of the electric field inside intermittent but elongated finite size structures. Their east-west asymmetry was the combined effect of a tilt in the direction of maximum growth and of a non-negligible ion Pedersen drift under strong electric field conditions. Additional features were revealed because the radars fortuitously acted both as Doppler and target radars, perhaps because of their low sensitivity (the radars having been built for more powerful meteor echoes). For instance, we observed slow narrow echoes from lower altitudes moving like discrete targets at a speed comparable to the ExB drift. This implied that the relativistic precipitation region that generated the low altitude plasma was localized but that it drifted at a speed comparable to the plasma ExB drift.

C1.1-0032-18 FEATURES OF OBSERVING FOR WEAK MSTIDS BY DENSE GNSS SATELLITES NETWORK

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To analyze the weak midlatitude medium-scale travelling ionospheric disturbances we use the sufficiently dense network of GNSS receivers (more than 150 ground-based stations). We show the reason that the monitoring for MSTIDs by GNSS satellites is fragmented. We assume that this is the reason for the differences in the intensity of the appearance of MSTIDs by the data of GNSS and ionosonde. Comparing of satellites R18 and G18 data (at 9:40 UT on September 21, 2016) revealed that the LOS directed to ongoing MSTIDs phase front is preferred for MSTIDs observing. The characteristics of extremely weak MSTIDs with TECp values 0.2 TECU, wavelength 100 km and western direction of phase front moving are presented on two-dimensional TEC perturbation maps. We estimate these parameters as a threshold for monitoring the MSTIDs by GNSS network we used.

C1.1-0033-18 DECORRELATION OF MULTI-FREQUENCY GNSS SIGNALS OBSERVED FROM NORTHERN EQUATORIAL IONIZATION ANOMALY (EIA) CREST LOCATIONS

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Modern GNSS broadcast signals on more than one frequency so that a correction of the delay through the ionosphere can be determined. This could provide more advanced three-frequency correction schemes for which knowledge of correlation of different frequency pairs under conditions of ionospheric scintillations is desirable. A significant factor in decorrelating the signals arises from the different phase decorrelation effects due to diffraction of signals from local random inhomogeneities of the medium of propagation frequently found to develop in the equatorial region during post-sunset hours. Understanding the correlation of signal fades across multiple frequencies is important to assess their collective mitigation effectiveness. If signal fades at two frequencies are highly correlated, the actual aim of the frequency diversity scheme would be defeated. A GNSS receiver capable of tracking GPS, GLONASS and GALILEO at multiple frequencies (L1, L2, L5) is operated at Calcutta (22.58degN, 88.38degE geographic; magnetic dip: 32degN) since April 2013, situated in the anomaly crest region in the Indian longitude sector. In the present analyses, the equinoctial periods of February-April and August-October 2014 have been selected. To observe the effects of signal decorrelations at L1, L2 and L5 during periods of scintillations, correlations were measured between C/N0 deviations recorded at the three frequencies separately for samples of 3-minute interval for S40.2. In order to understand the impact of different nature of scattering at the three frequencies, three scattering coefficients were introduced in the analyses defined in terms of the ratio of difference and sum of C/N0 deviations for a pair of frequencies. Receiver position deviations were calculated at 50Hz sampling and expressed in terms of latitude and longitude in meters. It is found that during February through April 2014, low correlation coefficients between C/N0 deviations at L1, L2 and L5 were associated with high S4, high scattering coefficient and resulting large receiver position deviations for 39

C1.1-0034-18 NEUTRAL AND ELECTRODYNAMICAL VARIABILITY OF DIP EQUATORIAL UPPER ATMOSPHERE DURING SOLAR FLARES

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The present work comprehensively investigates the neutral and electrodynamical processes in the dip equatorial upper atmosphere over Indian longitudes during solar flare events of different ranks. The E and F regions of ionosphere are studied using the high cadence measurements of the Equatorial Electrojet (EEJ) and Total Electron Content (TEC) obtained from the ground based magnetometers and GPS receivers respectively. The thermospheric response in context of neutral-ion coupling is examined using the unique data set of the neutral OI 630.0 nm dayglow obtained from the Multiwavelength dayglow photometer (MWDPM) over Trivandrum in India (8.5° N, 77°E, dip 0.5°N). The study brought out a new finding that the Equatorial Ionization Anomaly (EIA) undergoes significant weakening associated with an X3.8 class flare, while no such changes has been noticed during the M class flares. In addition, it was understood that the response of OI 630.0 nm dayglow can be prompt or delayed depending on the class of the flare. The role of electrodynamics in modulating the flare induced changes in the OI 630.0 nm dayglow has been clearly delineated. The plausible mechanisms explaining these observations are presented in context of the present understanding of the equatorial electrodynamics and its imprint on this dayglow features. We believe that the high cadence ionospheric-thermospheric measurements of this sort during such transient events will help in quantifying the relative contributions of different mechanisms of this unique dayglow for the better understanding the energy budget of equatorial ionosphere-thermosphere system.

C1.1-0035-18 INVESTIGATION OF THE TRAVELLING IONOSPHERIC DISTURBANCES IN TURKEY USING IONOLAB-FAST FOURIER TRANSFORM (I-FFT)

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Ionosphere is a layer of the atmosphere where significant numbers of free electrons and ions are present. The density of the free electrons in ionosphere cause the irregularities and disturbances in the in the VLF, LF and HF signals, magnetic field of the earth and in the local electric field. One of the main parameters of ionosphere, TEC (total electron content) is defined as the line integral of electron density along a ray path. Many researches would explain the mechanism and cause of the disturbances in the ionosphere. One of these disturbances, namely Travelling Ionospheric Disturbances (TIDs), is defined as the wave-like oscillations that are damped with the time. Atmospheric disturbances can propagate from the lower to the upper atmosphere where they may be responsible for the oscillations in the ionosphere in form of TIDs. TEC makes a convenient means for monitoring and detection of disturbances. In this study, the behavior of the IONOLABTotal Electron Content (TEC) estimates obtained from dual frequency groundbased GPS receivers are examined using IONOLAB-Fast Fourier Transform (I-FFT) method for geomagnetically disturbed and quiet conditions of the ionosphere over Turkey. It is observed that IONOLAB-FFT can estimate the frequency and the duration of TIDs with more than 80% accuracy. IONOLAB-FFT can also detect the duration and the frequency of medium scale TIDS and large scale TIDS that are defined in the literature. This study is supported by TUBITAK EEEAG 114E541 a part of the Scientific and Technological Research Projects Funding Program.

C1.1-0036-18 SEASONAL VARIATIONS AND AZIMUTHAL ASPECT SENSITIVITY OF 150- KM ECHOES OBSERVED BY THE EQUATORIAL ATMOSPHERE RADAR

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We present long overdue statistical analysis of the 150-km echoes based on 12 years of observations made using the Equatorial Atmosphere Radar (EAR) located at Kototabang, Indonesia. Analysis shows that while the basic features of the echoes are very similar to those observed from other equatorial/low latitude stations, occurrence and SNR of the echoes have remarkable seasonal dependence. Occurrence rate and SNR of the echoes are much higher in the solstices than in the equinoxes. Notably, both occurrence rate and SNR in the December solstice are marginally lower than those of the June solstice and are remarkably higher than those of both equinoxes. The observed seasonal variations of the 150-km echoes are quite similar to that of Gadanki and are very different from that of Pohnpei, which indicate the potential role of neutral dynamics/electrodynamics in the echoing mechanism. EAR observations also display remarkable azimuthal aspect sensitivity of the echoes. These results are discussed in the light of recently proposed photo-electron induced plasma wave mechanism versus plasma instability mechanism in terms of the origin of the 150-km echoes.

C1.1-0038-18 EFFECTS OF SPACE WEATHER ON THE IONOSPHERE AND LEO SATELLITES' ORBITAL TRAJECTORY IN EQUATORIAL, LOW AND MIDDLE LATITUDE

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We study the effects of space weather on the ionosphere and low Earth orbit (LEO) satellites' orbital trajectory in equatorial, lowand mid-latitude (EQL, LLT and MLT) regions during (and around) the notable storms of October/November, 2003. We briefly review space weather effects on the thermosphere and ionosphere to demonstrate that such effects are also latitudedependent, and well established. Following the review we simulate the trend in variation of satellite's orbital radius (r), mean height (h) and orbit decay rate (ODR) during 15 October 14 November 2003 in EQL, LLT and MLT. Nominal atmospheric drag on LEO satellite is usually enhanced by space weather or solar-induced variations in thermospheric temperature and density profile. To separate nominal orbit decay from solar-induced (accelerated) orbit decay, we compute r, h and ODR in three regimes viz. (i) excluding solar indices (or effect), where r=r0, h=h0 and ODR=ODR0 (ii) with mean value of solar indices for the interval, where r=rm, h=hm and ODR=ODRm and (iii) with actual daily values of solar indices for the interval (r, h, and ODR). For a typical LEO satellite at h=450 km, we show that the total decay in r with respect to EQL, LLT and MLT during the period is about 4.20 km, 3.90 km and 3.20 km respectively; the respective nominal decay (r0) is 0.40 km, 0.34 km and 0.22 km, while solar-induced orbital decay (rm) is about 3.80 km, 3.55 km and 2.95 km. h also varied in like manner. Similarly, the respective nominal ODR0 is about 13.5 m/day, 11.2 m/day and 7.2 m/day, while solar-induced ODRm is about 124.3 m/day, 116.9 m/day and 97.3 m/day. We also show that severe geomagnetic storms can increase ODR by up to 117

C1.1-0039-18 SEASONAL/SOLAR ACTIVITY DEPENDENCE OF EQUATORIAL IONIZATION ANOMALY PARAMETERS

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In this study, we have used International Reference Ionosphere (IRI) maximum plasma density of F2 layer (NmF2) to gain a qualitative insight into the physical processes that accounts for the equatorial ionization anomaly (EIA) intensity parameters vary with season, phase of the solar activity cycle and magnetic activity level, and maximum value of post-sunset drift velocity (PRE) along longitude 358.48 degrees east for very low (F10.7 = 70 sfu), low (F10.7

= 80 sfu), moderate (F10.7 = 150 sfu), and high solar activity (F10.7 = 180 sfu) conditions at fixed local time (2100 LT) and fixed altitude (350 km) corresponding to bottomside F-region for months representing vernal equinox (March), summer solstice (June), autumnal equinox (September) and winter solstice (December). The results show that the southern crest location decreases with increasing levels of solar activity; whereas position of northern crest increases with increasing solar activity levels. When the anomaly is fully developed under high solar activity conditions, the structure of the monthly northern crest location reveals semi-annual variation (broad peaks during March-April, about 13.5 degrees and minimum value in July, around 5.6 degrees, while the pattern of monthly southern anomaly crest location exhibits winter anomaly (peak value in June, about -12.5 degrees, minimum value in October around -18 degrees) while The trough oscillates between about +/- 1 degree, a clear north-south asymmetry feature of EIA. The magnitude of the monthly northern crest shows semi-annual variation as well with broad maximum during February and March with a value of approximately 18.4×1011 el/m3 and minimum value show up in June and July with a value of 8.4×1011 el/m3. Similarly, the magnitude of the monthly southern anomaly crest demonstrates semi-annual variation with peak value in April, about 32.6 ×1011 el/m3 and minimum in July, 17.6×1011 el/m3. Moreover, maximum value of post-sunset drift velocity given by Scherliess/ Fejer (1999) /IRI equatorial model drift is fairly correlated with the magnitude of northern anomaly crest (NAC) (r = 0.38) and the magnitude of southern anomaly crest (SAC) (r = 0.44). Monthly values of NAC indicates correlation value of 0.44 with monthly values of F10.7, but the monthly values of SAC is poorly correlated with F10.7 (r = 0.12).

C1.1-0040-18 WINTER NIGHTTIME ENHANCEMENT AND SUMMER DUSK-TO-NIGHTTIME ENHANCEMENT OF NMF2 AND INTERHEMISPHERIC COUPLING

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The dusk-to-nighttime enhancement (DNE) of summer NmF2 and the nighttime enhancement (NE) of winter NmF2 were investigated using COSMIC radio occultation observations at solar minima. Summer DNE mainly occurs in three regions that depend on geomagnetic configuration and is more prominent in the southern than in the northern hemisphere owing to the particular geomagnetic configuration over the South Pacific (both the declination and inclination are important, neutral winds induce larger upward plasma drift around sunset thanks to this geomagnetic configuration) at higher geographic latitudes where photoionization is still significant at sunset and evening hours. Winter NE shows evident dependence on geomagnetic latitudes, the magnitude of winter NE reaches latitudinal peaks (troughs) at the geomagnetic latitudes of about 40°-50° (60°-70°); and the longitudinal variation of winter NE is also evident. The latitudinal variation of NE was suggested to be related to that of the plasma storage above F2-peak region, geomagnetic inclination, and background NmF2, and the longitudinal variation of NE was found to be related to the longitudinal differences in background NmF2, thermospheric density, and interhemispheric plasma transport. Moreover, the longitude variation of winter NE is dependent on that of summer DNE to some extent via interhemispheric plasma transport, implying that under the effect of geomagnetic configuration, neutral wind induced upward plasma transport in the summer hemisphere is important for the interhemispheric plasma transport from the summer to winter hemisphere.

C1.1-0041-18 PERFORMANCE OF IRI MODELLED TEC AND GROUND BASED MEASURING TEC AT LOW LATITUDE DURING THE ASCENDING PHASE OF SOLAR CYCLE 24

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The widely used International Reference Ionosphere (IRI) model in simulation/modeling of ionospheric studies specifically at low latitudes require performance evaluation. To achieve this objective, we have compared total electron content (TEC) derived from the recent and earlier versions of IRI model (IRI-2016 and IRI-2012) over low latitude Indian station Varanasi (Geographic: 25°16N, 82°59E; Geomagnetic: 14°55N, 154°E) with TEC measured from the GPS receiver installed at Varanasi. The results are in good agreement with correlation coefficient 0.9, and root-mean-square deviations generally around 25-70 % for diurnal comparisons. The seasonal variability of TEC derived by using the different topside options of the IRI model (IRI-2001, NeQuick, and IRI01-corr) are studied and validated for the three seasons. IRI shows good agreement at other times instead of the equinox. Errors in TEC are likely due to peak height and density inaccuracies. IRI is a suitable model for specification of monthly averages of Total Electron Content and can be used to initialize a data assimilation process at times away from solar maximum.

C1.1-0042-18 EFFECT OF INTENSE GEOMAGNETIC STORMS ON LOW LATITUDE IONOSPHERE

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In this paper, we have analyzes the dual frequency signals from GPS satellites recorded at Varanasi (Geographic latitude 25 degree, 16 N, longitude 82 degree, 59 E) near the equatorial ionization anomaly (EIA) crest region in India, to study the effect of intense geomagnetic storms on the variation of total electron content (TEC), during the years 2010-2015. Three most intense storms having Dst-index < -100 nT observed during the above period have been analyzed, which occurred on 15th July 2012, 19th February 2014, and 20th December 2015. The storm induced features in the vertical TEC (VTEC) have been studied considering the monthly mean VTEC value of quiet days as reference level. The possible reasons for storm time effects on VTEC have been discussed in terms of local time dependence, storm wind effect as well as dawn-dusk component of interplanetary electric field (IEF) Ey intensity dependence.

C1.1-0043-18 A NEURAL NETWORK BASED MODEL FOR INFERRING DAYTIME VERTICAL EXB DRIFT FROM GROUND-BASED MAGNETOMETER OBSERVATIONS IN THE INDIAN LONGITUDE

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Ionospheric vertical ExB drift plays an important role in the electrodynamics and plasma irregularities in the equatorial ionosphere. In this paper, we present an artificial neural network for inferring ionospheric daytime vertical ExB drift using ground based magnetometer observations in the Indian sector. For this purpose we have used daytime vertical ExB drift estimated using the mean Doppler shift of 150-km echoes observed using MST radar located at Gadanki (13.5oN, 79.2oE, dip latitude 6.5oN) and difference in magnetic fields (H) observed from Tirunelveli (8.7oN, 77.8oE, dip latitude 0.4oN), a magnetic equatorial location and Alibag (18.5oN, 72.9oE, dip latitude 13.0oN) a location well beyond the electrojet belt. The difference in magnetic fields provides a direct measure of electrojet current, and in turn, the vertical ExB drift velocity in the ionospheric F region. We have used a feed forward neural network with error back propagation to train the network. The network has been trained using 119 days of observations made during 2006-2011, when solar activity was characterized with F10.7 of 60-78 solar flux units. Results obtained on vertical ExB drift from the artificial neural network have been compared with the actual ExB drift measurements. The model successfully reproduces the vertical ExB drift with RMS error of 2.24 m s-1. The model results are also compared with the Scherliess and Fejer model. Remarkable difference between the neural network/actual observations and Scherliess and Fejer model has been noted. The usefulness of the neural network based estimates is presented and the discrepancy between the observations and standard models is discussed.

C1.1-0044-18 IMPACT OF SUDDEN STRATOSPHERIC WARMING OF 2009 ON THE EQUATORIAL AND LOW-LATITUDE IONOSPHERE OF THE INDIAN LONGITUDES: A CASE STUDY

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Sudden stratospheric warming (SSW) is a large-scale meteorological phenomenon occur in the winter hemisphere which lasts several days or weeks. The effect of SSWs is not limited to high-latitude stratosphere alone but rather extends to other altitudes and latitudes. This paper presents the variability in the equatorial electrodynamics and low-latitude ionosphere over the Indian longitudes during a major SSW occurred in January 2009 during the low- solar activity conditions. Results indicate that the intensity of EEJ and the TEC over lowlatitudes (extending up to 30°N) exhibit significant perturbations during and after the SSW peak. One of the interesting features is the deviation of EEJ and TEC from the normal quiet time behaviour well before the onset of the SSW. This is found to be coincided with the beginning of enhanced planetary wave (PW) activity over high-latitudes. The substantial amplification of the semidiurnal perturbation after the SSW peak is seen to be coinciding with the onset of new and full moon. The response of TEC to SSW is found to be latitude dependent as the near-equatorial (NE) stations show the semidiurnal perturbation only after the SSW peak. Another notable feature is the presence of reduced ionization in the night sector over the NE and low-latitude regions, appearing as an 'ionization hole', well after the SSW peak. The investigation revealed the existence of a quasi-16 day wave in the TEC over low-latitudes similar to the one present in the EEJ strength. These results have been discussed in the light of changes in the dynamical background because of enhanced PW activity during SSW, which creates favourable conditions for the amplification of lunar tides, and their subsequent interaction with the lower thermospheric tidal fields.

C1.1-0045-18 IMPACT OF ASYMMETRY BETWEEN THE LEADING AND TRAILING WALLS OF PLASMA STRUCTURES OBSERVED FROM EQUATORIAL REGION OF INDIAN LONGITUDE SECTOR

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This paper represents the impact of asymmetry between the two walls (leading and trailing edges) of the equatorial plasma bubbles observed through transionospheric satellite signals received from a station situated near the northern crest of the equatorial ionization anomaly (EIA) in the Indian longitude sector, using Global Positioning System (GPS) L1 frequency during the equinoctial months of February-April 2011, August-October, 2011 and FebruaryApril 2012. The observed bubbles showed notable asymmetry between the leading (eastern wall of the bubbles) and trailing (western wall of the bubbles) edges. It is observed that the trailing edge slope (the western wall) is much sharper than the leading edge slope (the eastern wall). The leading edge slope has a maximum value of 5.13 TECU/min with a median of about 2.1 TECU/min. The maximum value of the trailing edge slope of 9.8 TECU/min and median of 3.72 TECU/min validate the idea of asymmetric edges of the bubble. Such sharp gradients on the walls of the irregularities imply large pseudorange rates, nearly 157cm/min corresponding to the maximum value of the descending slope. It is evident that the range error, extent of the bubble and ionization gradients measured provides the worst case figures for system engineers. Similar results have been observed during the AugustOctober 2011 and February-April 2012.

C1.1-0046-18 ANALYSIS OF SECULAR VARIATIONS OF EARTH'S MAGNETIC DUE TO EQUATORIAL ELECTROJET FIELD MEASURED AT ECUADORIAN GEOMAGNETIC STATION.

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In this study, we have used the Earth magnetic field (MG) data provided by the ground-based MAGDAS instrument at Jerusalem (JRS) station, located in Ecuador, above the geographic equatorial line. To study the variation of the declination angle, the variation the magnitude of Earth's magnetic field and the secular variation of the horizontal component of MG.

The variation of the declination of the magnetic field presents a linear tendency as function of time at JRS station with a variation of -0.1647 ° per year. The total Earth's magnetic field, from 06-2014 to 12-2016, shows a linear tendency as function of time weakening with a rate of 91 (nT) per year.

We found that the principal frequencies of the variation of horizontal field are f1=1,16*10(-5) [Hz], f2=2,31*10(-5) [Hz], f3=3,4722*10(-5) [Hz] and f4=4,6296*10(-5) [Hz]. Those frequencies are equivalent to periods of 24, 12, 8 and 6 hours respectively.

We found also the presence of a semiannual variation of Sq that is maximized during the months of the equinoxes and minimized during solstice months.

C1.1-0047-18 GEOMAGNETIC ACTIVITY INDEX AP AND THE OCCURRENCE RATES OF GEOMAGNETIC STORMS DURING 1996-2017

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Global geomagnetic activity disturbance index (Ap) and the occurrence rates of geomagnetic storms during the period 1996-2017, comprising solar cycle (SC) 23 (1996-2008) and SC 24 (2008-2017) have been investigated. Our results indicate that geomagnetic activity maximizes at equinoxes during both cycles. Overall annual mean value of Ap index is 13+/-4 nT for cycle 23 and 8+/-2 nT for cycle 24, a decline of 30%. The patterns of geomagnetic activity cycle fairly follow the sunspot number (SSN) cycle with a delay of 1-2 years during Ap index peak. Ap index and SSN are found to be reasonably correlated (r = 0.44) and somewhat significant (p-value = 0.0421). Moreover, analyses of the top 50 geomagnetic storms from minor to severe storms in each solar cycle are compared. Magnetic and solar variability effects with seasonal dependence are evident in the occurrence rates of geomagnetic storm distributions. Yearly occurrences of geomagnetic storms seem to be unsystematic with zero geomagnetic disturbances seen during 1996, 2007-2009 periods of exceptionally low geomagnetic activity and incredibly low solar activity conditions. The higher occurrence frequency of geomagnetic perturbation is likely to occur during geomagnetic cycle peak year than solar cycle peak period. The magnetic cycle peak years 2003 and 2015 indicate 16% and 36% occurrence rates, respectively. The seasonal distribution of geomagnetic storms is noted with equinoctial occurrence rates of 44% for SC 23 and 54% for SC 24. Also, the period 1996-2008 indicates 0% minor, 56% major and 44% severe storms; whereas 62% minor, 34% major and 4% severe storms are observed over the period 2008-2017. Using solar-wind data measured by Advanced Composition Explorer (ACE) satellite at L1 point in Geocentric Solar Ecliptic System (GSM) coordinates, we examine two geomagnetic disturbances scenarios: first, for superstorm that occurred on 31 March 2001 (year of solar activity maximum during SC 23), Ap = 192; second, for intense storm that happened on 8 September 2017 (declining phase during solar cycle 24), Ap =106. We demonstrate that duration and considerable strength of southwardly directed solar-magnetospheric northsouth component of the interplanetary magnetic field (IMF Bz) with associated dawn-dusk y-component of interplanetary electric field (IEF Ey), high solar-wind velocity, with strong solar-wind dynamic pressure associated with coronal mass ejection (CME) events are essential conditions to trigger severe geomagnetic storms with larger intensity as measured by the Dst index. Furthermore, estimates of geoelectric field are made from the first time rate of change in North-South (NS) and East-West (EW) components of interplanetary magnetic fields IMF-Bx and IMFBy, respectively. The results show that induced NS electric field (Ex) component presents larger fluctuations than induced EW electric field (Ey) component. In the first case, amplitude varies between about -0.111 to 0.0538 mV/m for Ex, and -0.179 to 0.0985 mV/m for East-West geoelectric voltages. In the second case, the amplitude of induced geoelectric field varies from approximately -0.0272 to 0.0225 mV/m for Ex and from -0.0454 to 0.0703 mV/m for Ey. The geoelectric fields are relevant for estimating geomagnetically induced currents (GIC) during enormously large geomagnetic disturbances, a threat to modern infrastructure.

C1.1-0049-18 HF RADAR OBSERVATIONS OF PERIODIC IONOSPHERIC IRREGULARITIES AT MIDDLE LATITUDES

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The ionosphere forms the lower boundary of the magnetosphere and couples to the thermosphere. The international SuperDARN consortium of high frequency over-the-horizon radars has been used for over three decades to investigate dynamics of the high latitude ionosphere. More recently a network of mid-latitude radars has been added to SuperDARN to provide extended coverage at times of enhanced magnetic activity. These include the TIGER and Unwin radars in Tasmania and New Zealand respectively, both located at -55°magnetic latitude. In 2014 a new design of HF mid-latitude radar was deployed at Buckland Park, near Adelaide, with a field of view overlapping TIGER and Unwin and extending from near the magnetic pole to around -40°magnetic latitude. The Buckland Park radar detects a range of ionospheric irregularities including MSTIDs and ionospheric perturbations driven by the electric fields of magnetospheric plasma waves. The TIDs may propagate equatorward away from a higher latitude source region and can also be detected with optical imagers and other radio sounders at lower latitudes. The plasma waves produce oscillation features with periods of a few minutes or less over a range of scale sizes. This presentation gives examples and discusses propagation properties and impacts for ionosphere users.

C1.1-0050-18 THE COOPERATION BETWEEN NSSC AND INPE TO INSTALL GROUND INSTRUMENTS FOR SPACE WEATHER OBSERVATION IN BRAZIL

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The International Space Weather Meridian Circle Program (IMCP), which is the extension of Chinese Meridian Project, is proposed to connect ground-based monitoring devices around 120ºE and 60ºW meridian region, which will enhance the ability of worldwide space environment monitoring in a significant way. The IMCP has obtained extensive supports from those countries on the meridian circle. So far, some research institutes and universities, like Canadian Space Agency, Russian Institute of Solar-Terrestrial Physics, Massachusetts Institute of Technology, the University of Adelaide, have signed cooperation agreements with the Meridian Project. Up to now, MOST has highly valued IMCP, which is expected to be launched in the near future in consequence. As a significant observatory of International Space Weather Meridian Circle Program (ISWMCP), the China-Brazil Joint Laboratory for Space Weather, held by the National Space Science Center (NSSC) of Chinese Academy of Science (CAS) and National Institute of Space Weather (INPE) of Brazil, has completed the fundamental construction during the first period. A Na-K lidar was installed in SJ Compose in Dec. 2016, and the operation of lidar is good. Up to now, more than 600h data have been obtained. A Digisonde

(DPS4), a GPS-TEC and a magnetometer were installed in Santa Maria, a southernmost city in Brazil. And in the second period, the cooperation will be enlarged. Good achievements have been obtained under the efforts of both side of China and Brazil, which will deeply facilitate the regional space weather exploring and

obtaining the global space weather information, and show us a good prospect of further joint research and the bright future for the International Space Weather Meridian Circle Program .

C1.1-0051-18 GEOMAGNETIC CONJUGATE OBSERVATIONS OF NIGHTTIME ELECTRIFIED MEDIUM-SCALE TRAVELING IONOSPHERIC DISTURBANCES ALONG WITH THERMOSPHERIC WINDS AND IONOSPHERIC PARAMETERS: UNIQUE INSIGHTS

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The electrified medium-scale traveling ionospheric disturbances (EMSTIDs) occurring as geomagnetically conjugate features in the nocturnal middle latitude F region ionosphere are studied using multi-instrument observations. Airglow imaging of OI 630 nm emission over Sata, Japan and Darwin, Australia are used to identify the occurrence of EMSTIDs. Thermospheric wind measurements made with the Fabry-Perot interferometer observations of OI 630 nm from Shigaraki, Japan and Darwin, Australia are used along with ionosonde observations over Yamagawa, Japan and Darwin, Australia to study the thermospheric and ionospheric characteristics. These are the first results from such multi-instrument observations simultaneously made from geomagnetic conjugate locations. EMSTIDs are generated only when there is significant sporadic E activity, at least in one of the hemispheres. The amplitudes of the EMSTIDs are found to be different between the hemispheres, particularly in the later hours of the night. Thermospheric meridional winds appear to control the EMSTID amplitudes in the respective hemisphere. These results conclusively indicate the importance of sporadic E layers in the generation of EMSTIDs. Further, it shows the significance of interhemispheric coupling between the E and F region ionospheres in the formation and evolution of EMSTIDs.

C1.1-0053-18 REVEALING THE POSSIBLE EARTHQUAKE PRECURSOR IN ULF GEOMAGNETIC FIELD BY WAVELET TRANSFORM MODULUS MAXIMA (WTMM) TECHNIQUE

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The short term Earthquake forecasting has primary significance for human beings in order to alleviate it's disasters. In the present work we have analyzed the geomagnetic field variations in Ultra Low Frequency (ULF) range prior to five strong Earthquakes (M > 6) occurred from 2005 to 2007. The Wavelet Transformation Modulus Maxima (WTMM) method has been used to analyze the data to reveal the short term (i.e. from few days to weeks) earthquake precursors. WTMM method allows calculation of anomalous variation in time-frequency sub-bands depend on sampling rate of the geomagnetic data. It was conclude that the WTMM analysis extract the irregular behavior in ULF data related to various stages of earthquake preparation process. The variation in ULF electromagnetic signal are causally bound with the preceding Earthquake via many sources, which are generated as a result of evolution of mode of deformation of rocks in the course of the earthquake preparation. The radon exhalation from the active faults is a primary source of ULF geomagnetic field variations.

Keywords: Earthquake precursor, ULF signal, radon, Wavelet transforms

C1.1-0054-18 LIMATOLOGY OF THERMOSPHERIC MERIDIONAL WINDS DERIVED FROM SOUTH AFRICAN IONOSONDE NETWORK DURING EXTENDED SOLAR MINIMUM OF 2007-2009

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Thermospheric winds play an important role in the dynamics of the mean behaviour of the midlatitude ionosphere especially during quiet conditions, which are dominant during low solar activity. This study will present equivalent meridional winds derived from ionospheric F2 peak parameters using the servo and Liu et al. (2003) methods during the solar minimum period of 2007-2009. Midlatitude ionosonde data over Grahamstown (33.3°S, 26.5°E), Hermanus (34.4°S,

19.2°E), and Madimbo (22.9°S, 30.9°E) are used to derive the winds. For the first time, local time and seasonal dependency of the derived winds over this region are explored and compared to global trends. The equivalent winds are compared to the winds predicted from the horizontal wind model 2014 (HWM14) and the coupled middle atmosphere thermosphere model (CMAT2) to test the validity of these methods.

Reference Liu, L., X. Luan,W. Wan, B. Ning, and J. Lei (2003), A new approach to the derivation of dynamic information from ionosonde measurements, Ann. Geophys., 2185-2191.

C1.1-0056-18 UNUSUAL VARIATION IN THE FLAYER PRIOR TO LARGE EARTHQUAKE

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In this paper we present the unusual behavior of critical frequency of ionospheric F2 layer during several large earthquakes in the western coast of South America from 2001 to 2005. We define a new parameter from Barbier's theorem and named it as Ionospheric Parameter (F). We consider five large earthquakes having Richter scale magnitudes greater than six ($M > 6.5$) and study temporal variation of this newly defined ionospheric parameter (F). Critical frequency and Virtual height are measured by ground based Ionosonde station at Jicamarca (lat. 11.95 S, long 76.87 W) in Chile which lies at a distance within a radius of 1000 km from the epicenter of the quakes under consideration. The critical frequency of F2 layer (denoted as f0F2) and virtual height of F layer (hF) are used to examine the ionospheric variation during earthquake at a span of ±15 days. We observe significant increase in the evaluated F parameter in 12 to 3 days prior to the earthquakes. The increment is over +3 from the normal variation. The f0F2 values also revealed significant anomaly is considered as a supporting evidence for our observed correlation. We also check geomagnetic indices in order to establish that these anomalies are indeed due to seismic events only.

C1.1-0057-18 SEASONAL VARIATION AND LONG-TERM TREND OF NITRIC OXIDE RADIATIVE EMISSION OVER INDIAN LONGITUDE SECTOR: TIMED-SABER OBSERVATION

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Nitric oxide (NO) density plays a significant role in the understanding of the structure, chemistry and dynamics of MLT region. The NO density in collision with atomic oxygen density produces nitric oxide raditive emission at 5.3µm. We study the seasonal variation and longterm trend of NO 5.3µm emission over Indian longitude sector using sixteen years of NO volume emission rate (VER) observations by TIMED-SABER satellite. The NO intensity is calculated by integrating NO VER over 100-155 km altitude region. The seasonal variation shows maximum NO VER and intensity during August. Whereas, minimum VER and intensity are observed during September. The FWHM for VER is found in the altitude region of 126-130 km. The long-term variation covers the time period from the depletion phase of 23rd solar cycle to the completion of 24th solar cycle. The NO VER and intensity show a clear correlation with solar cycle variation having minimum values observed during 2008-09. We performed cross-correlation analysis between NO intensity and sunspot number. Although the peak sunspot number doesn't correspond to the peak in NO VER/intensity, there is a strong correlation (correlation coefficient= 0.74) between them. Similar cross-correlation analyses between NO intensity and F10.7 solar index and Lyman-α are performed. These cross-correlation analyses show a strong correlation among NO intensity and F10.7 solar index and Lyman-α with correlation coefficient more than 0.7.

C1.1-0058-18 SOLAR AND CHEMICAL INFLUENCE ON TROPICAL (10°N-15°N) MESOPAUSE VARIABILITIES

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ABSTRACT

Mesopause is the coldest region of the terrestrial atmosphere. It is the lowest altitude at which the molecular diffusion begins to play a dominant role. The mesopause is largely affected by radiative forcing associated with absorption of solar ultraviolet (UV) radiation by O2 and O3 and radiative cooling mainly due to CO2 infrared (IR) emissions. The exothermic reactions, O+O+M→O2+M+5.11eV and H+O3→OH+O2+3.34 eV could also affect the mesopause altitude and temperature. In the present study, the temperature and ozone volume mixing ratio (O3 vmr) obtained from Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument on board Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite for the years 2002-2012 (23-24 solar cycles) are used to investigate the solar cycle and chemical influence on tropical (10°N-15°N) mesopause variabilities. It is found that the mesopause temperature and O3 vmr are positively correlated with solar cycle. Though there is no specific seasonal variation found in mesopause temperature; it is higher in September (190K), slightly lower in May and July (185 K), and lowest (175-178 K) during other months. But the mesopause altitudes are comparatively higher (99-100 km) in April and lower (95 km) in September. The factors influencing these mesopause variabilities are investigated for the year 2011 as a case study as it resembles the long-term mean seasonal variation. Further the net heating rates due to (i) solar heating by O2 and O3, (ii) chemical heating due to seven major exothermic reactions among H, O, O3, OH, HO2, (iii) O3 long-wave radiative heating, and (iv) CO2 cooling obtained from TIMED-SABER are used to investigate the mesopause variabilities.

C1.1-0059-18 QUANTIFYING THE SOURCES OF IONOSPHERE DAY-TO-DAY VARIABILITY

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Simulation using the coupled Whole Atmosphere Model (WAM) and Global Ionosphere Plasmasphere (GIP) show significant day-to-day variations in the ionospheric parameters. In the simulation, the auroral precipitation patterns inferred from Television Infrared Observation Satellite (TIROS/NOAA), daily solar irradiance measurements derived from the NOAA GOES X-ray Sensor (XRS), NASA TIMED Solar EUV Experiment (SEE), and NASA SDO EUV Variability Experiment (EVE), and 5-min IMF/solar wind parameters are used to drive WAMGIP during June and July 2012. Overall, simulation is capable of capturing most of variability compared to observations. Results also show that the variability is much larger in the nighttime than in the daytime due to much lower background density in the night and the magnitudes of these variabilities strongly depend on their locations and local times. To quantify the sources of these variability, two more sets of WAM-GIP simulations are carried out intend to separate the impact from the solar activity, geomagnetic activity, and lower atmospheric perturbations. Results show that the lower atmosphere perturbation and geomagnetic activity are the main contributors to the NmF2 variability. For TEC variability, the solar activity, geomagnetic activity and lower atmosphere perturbation contribute almost equally. Our simulation further demonstrates that the TEC variability at low latitudes are largely dominated by lower atmosphere perturbation and solar activity. At the midand high-latitude region, the solar activity, geomagnetic activity and lower atmosphere perturbation all contribute to the TEC variability.

C1.1-0060-18 CLIMATOLOGY AND CHARACTERISTICS OF MEDIUM-SCALE F-REGION IONOSPHERIC PLASMA IRREGULARITIES OBSERVED BY COSMIC RADIO OCCULTATION RECEIVERS

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Medium-scale ionospheric plasma irregularities are a persistent global feature of the earth's Fregion ionosphere. Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) radio occultation measurements are well suited to address the incomplete global observational picture of irregularities, including the global climatology in both bottomside and topside F-region layers, as well as the irregularity structure in the vertical dimension. A climatological database of F-region ionospheric irregularities and their characteristics has been developed through detection of total electron content (TEC) perturbations by Global Positioning System (GPS) receivers onboard COSMIC satellites. Vertical scale sizes ranging from 2 to 50 km were resolved from 1 Hz TEC measurements. This paper presents the global occurrence and equatorial to mid-latitude characteristics of medium-scale irregularities under quiet geomagnetic conditions. The study covers four years, two during solar minimum (2008-2009) and two during the ascending phase of solar cycle 24 (2012-2013). Irregularities were commonly observed at high latitudes, and during nighttime in equatorial to mid-latitude regions in both bottom and topside F-region layers. Geographical and seasonal occurrence trends at equatorial and mid-latitudes are consistent with previous irregularity climatology, which reaffirms that localized irregularity occurrence is possibly linked to localized enhancements in plasma instability growth rates. Seasonal occurrence patterns also indicate a high occurrence of irregularities in regions corresponding to the solar terminator, confined primarily to altitudes below 300 km. The local time and altitude distributions of equatorial and mid-latitude irregularity occurrence, amplitude, and scale size provide further insight into irregularity generation mechanisms, and include features consistent with "spread-F" irregularities and travelling ionospheric disturbances (TIDs).

C1.1-0061-18 ANALYSIS OF THE IONOSPHERIC IRREGULARITY EVENTS OVER EAST ASIA LOW LATITUDE REGION BASED ON VARIOUS OBSERVATIONS

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Based on various ground-based and space-based observational instruments at Hainan station (19.5ºN, 109.1ºE, dip: 13.6ºN) and magnetic equatorial region, we analyzed the temporal and spatial variation and the relevant physical processes of low-latitude F region irregularity events observed during the night of November 20, 2011. The comprehensive observation of VHF radar, ionospheric scintillation and digisonde at Hainan station shows that the observed ionospheric irregularities mainly occurred near sunset and near midnight, and there were two distinctly different morphologies, which reflected that the different generation and development processes of low latitude ionospheric irregularities. Combined with the magnetic equatorial GPS and the C/NOFS satellite observations, it is found that the radar plume and strong scintillation over Hainan region near the sunset are obviously related to the primary EPB/ESF caused by the sudden increase of ionospheric velocity and height in the magnetic equatorial region of the South China Sea. The weak spread F and weak scintillation over Hainan region near midnight may associate with the secondary ESF/EPB caused by the lower ionospheric height in the magnetic equatorial region on the west of Hainan after sunset.

C1.1-0062-18 TEMPORAL AND SPATIAL CORRELATIONS OF THERMOSPHERIC VERTICAL DENSITY PROFILES IN QUIET AND STORMY CONDITIONS

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Modelling thermospheric density with high accuracy has proved to be a great challenge. With density predictions playing a crucial role in satellite tracking and orbital propagation calculations, there is a strong need to improve currently employed modelling techniques. In situ thermospheric density measurements are limited, leaving predictions reliant on the skill of density models developed with past observations, such as JB-2008 or DTM 2013.

Many density models demonstrate a reduction in skill in stormy conditions, including minor and moderate geomagnetic storms, which are frequent. Although improvements in density models are being made, the underlying reasons for this skill reduction can be difficult to diagnose from sparse observational density data. Parameterized vertical density profiles are commonly used in these models and are one known source of model uncertainty.

To develop a greater understanding of vertical density profiles we study quiet and stormy conditions in two thermosphere-ionosphere global circulation models: TIE-GCM and GITM. Thermospheric density profiles are examined under different conditions. To inform thermospheric density modelling we also examine spatial and temporal correlations of the profiles. The differences and similarities between TIE-GCM and GITM profiles are examined and the limitations of employing global circulation models for this work are discussed. The implications of this work to future modelling efforts of thermospheric density are highlighted.

C1.1-0063-18 RESPONSES OF GLOBAL OCEANIC EQUATORIAL/LOW-LATITUDE IONOSPHERIC IRREGULARITIES TO 2015 ST. PATRICK'S DAY AND SEPTEMBER, 2017 GEOMAGNETIC STORMS

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This study presents the responses of global oceanic equatorial/low-latitude ionospheric irregularities to 17th March, 2015 (St. Patrick's day) and 8th September, 2017 geomagnetic storms. We used total electron content (TEC) data from 15 International Global Navigation Satellite System (GNSS) Stations (IGS), distributed on the Pacific (7 stations), Atlantic (5 stations) and Indian (3 stations) Oceans. Rate of change index (ROTI) was used as the index to measure irregularities generation over the study sites. The study carefully diagnosed the interplanetary origins of the geomagnetic storms. The two storms, which occurred at the G4 and G3 levels, respectively were induced by corona mass ejection transients. We characterized the irregularities alongside with the geomagnetic storms, with five days before and after the days of occurrence of the two geomagnetic storms. During the main phases of the storms, an enhancement was observed on the irregularities generation over the Pacific Ocean, while irregularities were inhibited by the geomagnetic storms over the Indian and Atlantic Oceans. However, enhancement in irregularities occurrences were observed over the Atlantic Ocean during the Sudden Commencement phases of the geomagnetic storms.

C1.1-0064-18 ON THE ROLE OF IONOGRAM SIGNATURES OF LSWS (SATELLITE TRACES) AND LOW LATITUDE ESB LAYERS IN CAUSING THE VARIABILITIES OF ESF IRREGULARITIES OVER INDIAN SECTOR

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We investigate the role of ionogram signatures of LSWS (satellite traces) and low latitude Esb layers in causing the variabilities of ESF irregularities, in addition, to post-sunset vertical drift for the year 2015 using ground-based ionosondes located at Tirunelveli (8.71° N, 77.75°E, Geomag. Lat 0.21°N) and Hyderabad (17.38°N, 78.48°E, Geomag. Lat 8.74°N). Results show, statistically, that the presence/absence of STs is higher/lower than the absence/presence of Esb prior to occurrence/non-occurrence of ESF during all the seasons. This implies the importance of ST/LSWS in the ESF occurrence. Results of weak correlation of low latitude Esb layers with ESF possibly indicate its coupling to higher apex altitude than the base of the F-layer. Significant equinoctial asymmetry is also observed in both the ESF and ST occurrences wherein vernal is dominant than autumn equinox. Band-pass filtered h'F oscillations of 1-1.5 hour reveal significant wave amplification during the PRE on ESF than non-ESF days and also during vernal than autumn equinox. Further investigations suggest that the height oscillations of early ESF and delayed ESF are amplified according to their onset time of ESF. The study suggests that post-sunset height rise of F-layer together with the presence of LSWS provide suitable conditions for the ESF development. Further, the presence of downward phase propagation on ESF days than other days indicate the presence of upward propagating Gravity Waves (GWs) in the initiation of these wave structures

C1.1-0065-18 IONOSPHERIC DISTURBANCES DUE TO THE SOLAR FLARE WHICH OCCURRED ON SEPTEMBER 6, 2017, THE STRONGEST SPACE WEATHER EVENT IN A DECADE

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There is growing concern about the effect of solar flares and Coronal Mass ejections (CMEs) on the terrestrial ionosphere and upper atmosphere system mainly due to the possible deterioration or damage in our communication and navigation applications. The solar flares release a burst of radiation into interplanetary space, especially in the bands of X-ray, UV, and EUV. The X-ray and UV-EUV will be absorbed in lower ionosphere (D and E regions) and F-region, respectively. Therefore, there is a sudden increase of electron density in the D, E, and F regions, called sudden ionospheric disturbances (SIDs). The SIDs in the D region can cause a total or partial blackout of short radio-wave propagation through the ionospheric region. The equatorial electrojet (EEJ) increases its intensity (E region) and at the F region the Total Electron Content (TEC) increases as well. In addition, the ionograms recorded by ionosondes show total or partial black-out, which means that the radio wave pulses transmitted by ionosonde get absorbed by D-region and there is no echo traces during flare hours. On September 6, 2017 the solar active region AR 2673 emitted two solar flares and they were powerful enough to black-out high and low radio waves. The first flare took place at 09:10 (X2.2) and the second one at 12:02 UT (X9.2). The X9.2 was the strongest solar flare event in a decade and disturbed the ionosphere on the sunlit side of the Earth. In this study we will take advantage of these two extreme flare events X2.2 and X9.2 to investigate the effects

on ionosphere using ionosonde data and TEC inferred using GPS dual frequency receivers. During the solar flares events of X2.2 (09:00 UT) and X9.2 (12:00 UT) the European and African sectors and European, African, and Brazilian sectors were exposed to the solar flare radiation, respectively. It was noticed that during the X2.2 flare there was an ionosonde blackout duration of about 45 minutes and during the X2.9 flare there was an ionosonde blackout of about 1 hour and 30 minutes. In addition it was noticed that the GPS-TEC showed a positive phase during these events.

C1.1-0066-18 LONG TERM PARAMETERIZATION OF THE OCCURRENCE RATE OF HF BACKSCATTER AS A FUNCTION OF THE UPSTREAM DRIVERS AND MAGNETIC INDICES

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The study presents the statistical analysis of the impacts of the upstream solar wind drivers and magnetic indices on the occurrence of ionospheric backscatter from 1996-2016. The data used in our analysis were obtained from the two eastern-most Super Dual Auroral Network (SuperDARN) radars located at Hankasalmi (Finland) and Pykkvibaer (Iceland). We investigate the occurrence of ionospheric backscatter seen during the four seasons in four different sectors of magnetic local time. The solar cycle and local time variations of the occurrence of ionospheric scatter as a function of the drivers in the four sectors of the magnetic local time and during the four season's shows a remarkable result. The goal of the study is to identify which of the parameters, seasonal and local time for which such a parameterization can be used as a predictive tool for now-cast and forecast purposes of the occurrence of ionospheric scatter. The study shows that the occurrence of backscatter was low in summer than during winter which might be due to density gradients suppression by photo-ionization.

C1.1-0067-18 CHARACTERIZATION OF EQUATORIAL AND LOW-LATITUDE MAIN GEOMAGNETIC FIELD ELEMENTS IN AFRICA

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We use 3 ground-based magnetic observatories annual means time series of geomagnetic field elements, namely D (magnetic declination) and I (magnetic inclination), X (geographic northsouth), Y (geographic east-west), Z (vertically down-vertically up), H (horizontal), and F (total field intensity) to investigate regional features, long-term changes, and the dynamics of the main geomagnetic field over equatorial and low-latitude in Africa. The magnetometer observations were obtained from East Africa: Addis-Ababa, Ethiopia (AAE: 9.2oN, 38.46oE, +0.5o dip latitude) for the period 1958.5-1995.5; West Africa: Ibadan, Nigeria (IBD: 7.26oN, 3.54oE,

-4.38o dip latitude) for the interval 1956.5 to 1975.5; and North Africa: Tamanrasset, Algeria (TAM: 22.48oN, 5.32oE, +14.73o dip latitude) over the period 1951.5 to 2015.5. Our results indicate complicated spatial/temporal distribution of geomagnetic field elements. Addis-Ababa Yand Z-components exhibit reversal from the westward to the eastward direction and from upward to downward direction around 1972.5 and 1989.5, respectively. The observed variability of the magnetic field intensities at TAM is exceptionally larger in value than those seen at Addis-Ababa and Ibadan by a factor of up to 7 and 12, respectively. The trends of magnetic field intensities at Ibadan and Tamanrasset are predominately positive except for Z-component which indicates negative trend at both sites. The overall strength of the equatorial dipole field is found to be declining at a rate of 6.2 nT/year. Conversely, we found evidence of a positive trend of order 13.2 nT/year at Ibadan and 15.8 nT/year at Tamanrasset. The first-order, time derivative of X-, Yand Z-components follow similar behavior at each station apart from Tamanrasset north-south and east-west components. Prominent geomagnetic jerks observed in the secular variation (SV) seem to be apparent in all the three orthogonal components of Earth's magnetic field intensities for the three stations with higher occurrences in equatorial dipole field at Addis-Ababa. We found significantly larger magnetic declination mean drift rate of roughly 1.51 degree/year (eastward) for Addis-Ababa, 0.88 degree/year (eastward) for Ibadan, and -0.85 degree/year (westward) for Tamanrasset; whereas the magnitude of magnetic inclination average drift rate is approximately comparable at the three observatories with a value of 0.36 degree/year for Addis-Ababa, 0.43 degree/year for Ibadan, and -0.37 degree/year for Tamanrasset.

C1.1-0068-18 IONOSPHERIC RESPONSE TO NEAR-EARTH CONDITION OBSERVED OVER MAITRI STATION 70.76 DEGREE S, 11.74 DEGREE E: A PRELIMINARY STUDY

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Near-Earth space environment system is a major driving force which controls the Earth's ionospheric condition. The near earth space environment system is very complex where the dynamics of the electric and magnetic fields are influenced by the high energy particles associated with solar wind. The present study is an attempt to study the influence of the solar flux on the high latitudinal ionosphere and the plasma drift. The GPS data recorded at Indian permanent research base "Maitri", (70.76°S; 11.74°E) during astral summer and equinox disturbed days were considered. The results reveals that the high latitudinal background geophysical conditions are very much modulated by slight variation in the solar condition which further significantly affects the Phase and Amplitude of GPS signal due to change in the state of ionosphere. The results suggested that the high latitude ionospheric response to the adverse space weather condition are different for different seasons i.e. a positive effect for summer and negative effect has been observed for equinox. Such positive and negative effects are mainly depending upon the combination of high latitudinal electro-dynamic conditions and neutral wind direction. The combination of equator-ward plasma transportation along with ionospheric compositional changes causes a negative ionospheric impact during summer and equinox seasons. However, the combination of pole-ward contraction of the oval region along with particle precipitation may lead to exhibit positive ionospheric response. The overall results suggested that the changing near-earth space environmental condition modifies the high latitudinal electrodynamic processes. The modifications of electro-dynamic processes are mainly due to injection of high energy particle up to the lower ionospheric altitudes which further modifies the E x B drift velocity. The combined effect of E x B drift velocity and direction of neutral wind decides the nature of ionospheric response over the considered region.

C1.1-0069-18 APPLICATION OF HIGHAND LOW-ORBITING RADIO TOMOGRAPHY FOR EXPLORING THE IONOSPHERIC STRUCTURES ON DIFFERENT SCALES AND THE RT-BASED INDICES OF IONOSPHERIC PERTURBATION

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The ionospheric radio tomography methods (RT) are actively developing at present. These methods are suitable for reconstructing spatial distributions of electron density based on ra- dio signals transmitted from the navigational satellite systems and recorded by the receiv- ing networks on the ground. The RT systems working with the signals of low-orbiting (LO) (Parus/Transit) navigational systems have been in operation since the early 1990s. Recently, the RT methods employing the signals from the high-orbiting (HO) satellite navigational systems such as GPS/GLONASS have come into play. In our presentation, we discuss the accuracies, advantages, and limitations of LORT and HORT as well as the possibilities of their combined use for reconstructing the structure of the ionosphere in a studied region during a given time interval on the different spatiotemporal scales. LORT reconstructions provide practically instantaneous (spanning 5-10 min) 2D snapshots of the ionosphere within an interval of up to a few thousand km. Vertical resolution of LORT is 25-30 km and horizontal resolution is 15-25 km. HORT methods are capable of reconstructing the 4D structure of the ionosphere (three spatial coordinates and time). The spatial resolution of HORT is, generally, at best 100 km, and the interval between successive reconstructions is 30-60 min. In the regions with dense receiving networks, the spatial resolution can be increased to 30-50 km and time step reduced to 10-30 min. In California and Japan which are covered by extremely dense receiving networks, even higher spatial resolution (10-30 km) and shorter interval between the neighboring (up to 2 min) can be achieved. We discuss the LORT and HORT reconstructions of the ionosphere during different periods of the 23rd and 24th solar cycles in the different regions of the world. We analyze the spatiotemporal features and dynamics of the ionosphere depending on solar and geophysical conditions. Particular attention is focused on the periods of the strong geomagnetic disturbances. The storm-time ionosphere is characterized by extremely complicated rapidly varying structure. Under the action of a variety of the perturbing factors, the ionospheric parameters experience striking variations which can be traced by the RT methods. The RT reconstructions revealed multi-extremum plasma distributions, ionization troughs, steep wall-like gradients of electron density, spots of enhanced ionization, etc. A complicated structure of the main ionization trough with polar wall moving equatorwards was observed. The methods for constructing the RT indices of ionospheric perturbation which take into account the peculiar features of the HORT and LORT data are discussed. The results of comparing these RT indices to the indices of geomagnetic activity are presented. The work was supported by the Russian Foundation for Basic Research (projects nos. 16-05-01024 and 17-05-01250).

C1.1-0070-18 IRNSS SCINTILLATION STUDIES NEAR THE EIA CREST OF THE INDIAN ZONE

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Multifrequency and multi-satellite occurrences of scintillations of tranionospheric signals at unexplored S (2492.08 MHz) band and L5 (1176.45 MHz) band from satellite constellation of the Indian Regional Navigation Satellite System(IRNSS) along with scintillations at L1(1575.42 MHz) and VHF (250.650 MHz) bands are investigated in the context of failsafe navigation. Observation are made during April 2015 to April 2017 from Raja Peary Mohan College(22.660 N, 88.40 E) located near the northern crest of EIA. Analysis indicates occurrence of severe scintillations exceeding dynamic range in the VHF to lower microwave L bands during equinoctial months of high solar activity years but the S band scintillations are mostly limited to 6-10dB fluctuations.Fast fading 30 fade/minutes at VHF,6-18 fade/minute at L band distinguished slowest fading(5/6 fades/minutes) at S band.The most probable fade duration irrespective of depth and locations of IPSs is estimated 2-3 sec at L5 and S bands while 10dB fades at L5 are separated by 6-10sec. While multiple scattering, signatures of dual slope, lowest coherence length characterize the VHF to L band scintilations, single scattering dominates S band.A study of CDF leads to fade margin of 14dB at L5 and 6dB at S band for faithful navigation.There are periods when multi-satellite links located within the 10o span of IPPs (satellites stationed between 55oE (IRNSS) and 145oE (MTSAT)) exhibit scintillations simultaneously and different GNSS links are disturbed by losses of lock.During the period availability of GNSS links (GPS, GLONASS etc) attains a value of less than minimum requirement of 4 for faithful navigations. Analysis of TEC data on the various GNSS tracks reveals severe depletions along with high value of ROTI, evolution and shifting of wavelet pattern in detrended TEC during multisatellite scintillations.The result may be discussed in terms of post sunset evolution of cluster of equatorial plasma bubbles with embedded multi-scale irregularity structures and corresponding dynamics.

C1.1-0071-18 RELATIVE ROBUSTNESS OF TRIPLE FREQUENCY GPS SIGNALS OBSERVED FROM ANOMALY CREST LOCATIONS DURING PERIODS OF IONOSPHERIC SCINTILLATIONS

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GPS modernization program includes addition of new civilian frequencies, L2C and L5 (1176.45MHz) to augment the already existing L1 and semi-codeless L2 frequencies. The basic objective behind this exercise is to provide improved multi-frequency ionospheric corrections to the civilian user community. Relative robustness of these new signals during periods of deep signal fading frequently encountered at equatorial and low latitude regions need to be examined. A multi-frequency and multi-constellation GNSS receiver capable of tracking GPS, GLONASS and GALILEO signals at L1, L2C and L5 frequencies is operational at Institute of Radio Physics and Electronics, University of Calcutta (22.58N, 88.38E, magnetic dip: 32N) and Department of Physics, North Bengal University (88.26E, 26.42N, magnetic dip: 39.85N) around the northern crest of the Equatorial Ionization Anomaly (EIA) in the geophysically sensitive Indian longitude sector.

During the present solar cycle, frequent and intense amplitude scintillations at L-band were observed from Calcutta and Siliguri. Cycle slips were calculated at L1, L2C and L5 on the same satellite link to understand the effect of equatorial ionospheric scintillations at different frequencies. During March 2014, a number of cases of cycle slips with duration exceeding 10s were noted, these values being higher than that specified by International Civil Aviation Organization (ICAO) for aircraft approach with vertical guidance (APV). It is interesting to note that cycle slips were found to be more frequent at L5 compared to L1, and L2C compared to L5, the latter result indicating less robustness of L2C signal. This exercise was repeated during 2016-2017 from Calcutta and Siliguri. Differences in occurrence of cycle slips at Calcutta and Siliguri may indicate enhanced randomness in the medium of propagation during these periods of signal fades.

C1.1-0072-18 STUDY OF SOLAR ACTIVITY EFFECT ON TEC VARIATION AT LOW-LATITUDES

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The dual frequency signals from the GPS satellites recorded at Ile-Ife, Nigeria (Geomagnetic Lat 7.52oN and Long 4.28oE); Addis Ababa, Ethiopia (Geomagnetic Lat 9.04oN, Long 38.77oE) and Bangalore, India (Geomagnetic Lat 13.03oE, Long 77.57 oE) have been analysed to study the effects of geomagnetic and solar activities on Total Electron Content (TEC). In the study, we described the geomagnetic and solar activity dependence of TEC. TEC shows a positive ionospheric storm effect, with increased geomagnetic activity corresponding to higher TEC values. The variations of TEC at maximum and minimum solar radio flux (F10.7) and sunspot number (SSN) for the two years revealed that the magnitude of TEC are influenced by solar activity, with maximum solar indices corresponding to maximum TEC values and was dependent on season and geographic location. The best correlation was found between TEC and F10.7, with a highest value of 0.851 at Addis Ababa in 2011.

Keywords. Low latitude Ionosphere, Equatorial Ionisation Anomaly, Total Electron Content, Solar activity.

C1.1-0073-18 STUDYING THE REALISTIC IONOSPHERIC PRECURSORS FROM EARTHQUAKE

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Abstract: Spectral analysis as well as statistical analysis of total electron contents (TEC) derived from ground based GPS have been applied to study the earthquake's signature in the ionosphere. The anomalous perturbations in the TEC were observed from few days to few hours prior to the main shock of the earthquake. Perturbation depends on distance as well as direction of observation point from the epicenter. In addition to ionospheric perturbations, the wave-like features in detrended TEC (DTEC) were also identified. The spectral analysis of DTEC data showed an efficient tool to distinguish the perturbation between seismic induced perturbations from other sources. In addition to ionospheric perturbations, the wave-like features in DTEC were also identified. The wave like oscillation occurs few days to few hours before the main shock and associated periodicities in DTEC data varies from 20 min to more than 100 min. Keywords: Earthquake, GPS, Gravity Waves, Plasma Bubbles

Introduction: Earthquakes (EQs) are the most destructive phenomena which have killed thousands of people and destroyed several cities. Researchers around the world reported the seismic events and ionospheric perturbations anomalies observed in relation of EQs from almost two decades (Hayakawa et al, 1996; Pulinets 1998; Liu et al. 2000, 2001; Singh et al. 2004; Dutta et al. 2007; Hayakawa et al. 2010; Priyadarshi et al. 2011; Pulinets and Davidenko 2014; Kumar and Singh, 2017). These anomalies termed as seismo-ionospheric anomalies are detected through different ionospheric parameters as subionospheric fixed frequency transmitter signals, total electron content (TEC) etc. Gokhberg et al. (1989) reported first time the effect of the VLF radio sounding, and Molchonov and Hayakawa (2008) discussed in detail the electromagnetic phenomena associated with EQs.

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C1.1-0074-18 RESPONSE OF EQUATORIAL AND LOW LATITUDE IONOSPHERE OF INDIAN REGION TO A LONG DURATION NIGHT TIME M CLASS SOLAR FLARE

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Solar flare effect over Ionosphere has always fascinated ionosphere plasma physicists to understand the behavior of Ionosphere during the flare event. In the present study we are discussing the effect of M1.4 class long duration flare during night time over Indian region emanating from sunspot region 0808 during 7th September 2005. Ionosphere response due to this flare can be observed in terms of reduction of Equatorial Electro-jet strength, maximum height of F2 layer (hmF2) and Total electron content derived by Global Navigation Satellite System over equatorial station (Trivandrum) and at low latitude station, Hyderabad and Equatorial Ionization Anomaly zone, Bhopal. Since Equatorial Ionization anomaly (EIA) is the unique phenomenon of equatorial ionosphere which lead to the diffusion of plasma from equatorial region to low latitude region under the effect of pressure gradient and gravity. EIA proxy has been calculated to confirm the flare induced EIA inhibition during the event day. In order to address the reason for the suppression of EEJ electric field, the observations are compared with quasi two dimensional first principle Ionospheric model calculations. The electron density profile are calculated at non flare and flare conditions. Hall and Pederson conductivities are calculated from these electron density profiles under two conditions and was able to explain the observed variation in the EEJ, hmF2 and TEC over different stations. Since during flare time, Ionosonde measurements are hampered because of enhanced electron density, we are no longer dependent over these observations as the electron density simulated by our model is to the close approximation of real time electron density measurements in Ionosphere.

C1.1-0075-18 ESTIMATION OF THE HEIGHT OF IONOSPHERIC INHOMOGENEITIES BASED ON TEC VARIATIONS MAPS OBTAINED FROM GPS OBSERVATIONS

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Regional maps of total electron content (TEC) variations, obtained from the near zenith satellites observations of global navigation satellite systems (GNSS), make it possible to classify ionospheric heterogeneities and to evaluate their parameters. The analysis of the characteristic features of the spatial autocorrelation function allows to detect moving ionospheric inhomogeneities associated with atmospheric gravity waves and thermospheric winds. The direction of motion, speed, period and spatial distribution, as well as the lifetime, describe the characteristics of inhomogeneities in 3D space - latitude, longitude and time. In this presentation, we focus on the determination of the height of heterogeneity to create their 4D models. To calculate the height of the localization of ionospheric irregularities, the TEC variations maps, obtained from the signals of two or more GNSS satellites observed near zenith by the dual-frequency receivers of a dense regional network are used. Our research shows that the network area should not be less than 500x500 km with an average distance between stations about 50 km or less. The principle of determining the height is similar to the principle of determining the distance to the subject for focusing on the sharpness in modern photo cameras. The authors proposed and verified two techniques of the height estimation. Firstly, the sequence of the TEC variation maps for different heights of the ionospheric layer is constructed using the data of two or more simultaneously observed satellites. The localization height of inhomogeneities corresponds to the map with the greatest contrast. Secondly, the sequences of TEC variation maps for different heights of the ionospheric layer are constructed for each satellite separately. For each height the cross correlation functions between maps corresponding to different satellites are calculated. The biggest cross-correlation coefficient value determines the height of ionospheric irregularities. Numerical experiments on model inhomogeneities made it possible to estimate the optimal parameters and correlation characteristics of inhomogeneities, the height of which can be determined by the proposed techniques. It turned out that these are isotropic inhomogeneities with characteristic dimensions of around 100 km. Isotropy is

desirable because the mutual angular position of satellites can be arbitrary. Consequently, the cross-correlation characteristics of the inhomogeneities in the direction perpendicular to the plane formed by the two satellites and the reception point are essential to determine the height. The proposed techniques were tested for several events that took place in March 2013 and 2015 during the week when powerful geomagnetic storm on St. Patrick's Day occurred. At first, the time intervals for observing of more than one GPS satellites near the zenith were determined. For each day examined this condition was satisfied only for two fragments during the day and two satellites, that demonstrate the potential limitation of the proposed method. Nevertheless, even in two fragments during a day it was possible to study the behavior of ionospheric inhomogeneities. It was founded that in quiet geomagnetic conditions the ionospheric irregularities are localized predominantly within the interval 180-220 km near the maximum of the ionospheric F2 layer. In disturbed geomagnetic conditions, the height of their localization increased up to several hundreds of kilometers. These estimations correspond to the result from previous research. During the initial phases, on March 15 2013 and March 16 2015, of two powerful geomagnetic storms, both the significant growth of the height of inhomogeneities and a modification of their structure were detected. Namely, the traces of horizontally elongated quasiwaves structures in the ionosphere associated with moving irregularities, on the maps have been replaced by striped traces of structures elongated in the vertical direction and localized at altitudes of up to several thousand kilometers. These structures may be associated with streams of energetic electrons, emanating from the radiation belt along the lines of the geomagnetic field - Birkeland currents.

C1.1-0076-18 DIFFERENT KIND OF NIGHTTIME TRAVELING IONOSPHERIC DISTURBANCES OBSERVED BY AIRGLOW IMAGES OVER SOUTH-SOUTHEAST OF BRAZIL

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Different type of MSTIDs has been observed at Cachoeira Paulista (22.4°S; 45.0°W), Brazil, from June 2013 to December 2015 using airglow OI 630.0 nm images. During the period, 58 MSTIDs were identified and classified as: MSTIDs dark band (around 10 events), and periodic MSTIDs (48 events). Dark band MSTIDs present phase velocity between 50 and 200 m/s and propagation direction to northwestward. On the other hand, periodic MSTIDs have a horizontal wavelength of 80 to 160 km, a period ranging between 5 and 45 minutes, the phase velocity of 50 to 200 m/s, and propagation directions are mainly north-northeastward. The waves parameters indicate that the periodic MSTIDs have different characteristics compared to the dark band MSTIDs, suggesting that the periodic MSTIDs are not generated through the well-known Perkins instability. In addition to it, the present study indicates that the spectral characteristics found in Brazil are different from other regions such as Japan and Indonesia. Therefore, we intend to investigate the generation mechanisms of the periodic MSTIDs. Furthermore, the anisotropy observed in the periodic MSTID propagation direction can be explained by the wind filtering mechanism.

C1.1-0077-18 EQUATORIAL IONOSPHERIC RESPONSE TO THE MAIN PHASE OF INTENSE GEOMAGNETIC ACTIVITIES AT ILE-IFE, NIGERIA

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The effect of the main phase of two intense geomagnetic storm events which occurred on August 5-6 and September 26-27, 2011 on the equatorial ionosphere have been investigated using Global Positioning System (GPS) data obtained from an Ile-Ife station (geomagnetic lat. 9.84N, long. 77.25E). Total Electron Content (TEC) profiles during the main phase of the two geomagnetically disturbed days were obtained and compared with quiet time average profiles to examine the response of the equatorial ionosphere. International Reference Ionosphere (IRI) 2012 TEC model was also obtained from Virtual Ionosphere, Thermosphere, Mesosphere Observatory (VITMO) and the extents of deviation from measured GPS-derived TEC were examined for the main phase of the storm events. The results showed that the intensity of both storm events during the main phase which occurred at night-time correlated well with a strong southward direction of the z-component of the Interplanetary Magnetic Field (IMF-Bz) and Solar Wind Speed (Vsw), with the Disturbance storm time (Dst) profile showing multiple step development. TEC depletion was observed during the main phase of the August 5-6, 2011 storm event with TEC recording a maximum value of 9.31 TECU. A maximum TEC value of 55.8 TECU was recorded during the main phase of the September 26-27, 2011 storm event depicting TEC enhancement. Significant scintillation index value of 0.57 was observed when the main phase started on August 5-6, 2011 followed by a prolonged suppression while there was less significant scintillation impact on September 26-27, 2011 with a maximum value of 0.33. The present study show that remarkable energy input from solar wind during geomagnetic storm events have remarkable impact on the equatorial ionosphere over Ile-Ife, Nigeria.

C1.1-0078-18 THE MORPHOLOGY AND DRIVER OF THE TROPICAL IONIZATION TROUGH

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A new type of ionization trough, the “tropical ionization trough”, is identified in the tropical F region from the satellite observations. The trough is formed around midnight near ±25° magnetic latitudes in the winter hemisphere. The formation of the trough in the winter hemisphere is explained in terms of the convergence of meridional winds in the tropics in the winter hemisphere. Troughs are pronounced around 330°E in the Southern Hemisphere during the June solstices and around 210°E in the Northern Hemisphere during the December solstices. This phenomenon is explained by the magnetic declination control of the zonal wind effect; an intense trough develops at the location where zonal winds enhance the poleward (or downward) plasma motion along with summer-to-winter winds. We investigate the variability of the trough morphology with height and solar cycle by analyzing the CHAMP and Swarm satellite observations. The physical processes underlying the trough formation are investigated using the ionosphere and thermosphere data provide by TIEGCM.

C1.1-0079-18 THE IMPORTANCE OF THE THREE-DIMENSIONAL GEOMETRY OF SOLAR ECLIPSES FOR ANALYSIS OF THE IMPACT ON THE IONOSPHERE

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Solar eclipses are well known to cause major disturbances in the ionosphere. Even an eclipse that does not reach totality anywhere can have a significant impact on the total electron density, the peak height and density, and other ionospheric characteristics all along its path. Additionally, travelling ionospheric disturbances can be generated in the path of the eclipse and travel well outside the region of obscuration. An extensive catalogue exist of all solar eclipses from 2000 BC to 3000 AD, with detailed information on the timing of the eclipse and the obscurations observable from different locations on the earth. However, investigations of the effects of the total eclipses visible in Europe in 2015 and in North-America in 2017 on the ionosphere have indicated that not only the latitude and longitude should be considered when calculating the obscuration levels and timing during a solar eclipse, but the altitude as well. Various effects have been observed that can only be explained by taking into account the three-dimensional nature of the shadow of the moon during an eclipse. We present theoretical calculations considering the full, three-dimensional geometry of solar eclipses, and show some examples of the importance of the height dependency of the eclipses' effects on the ionosphere.

C1.1-0080-18 DEVELOPMENT AND VALIDATION OF A NEURAL NETWORK BASED MODEL TO OBSERVE THE IMPACT OF GEOMAGNETIC STORM ON TEC AT LUCKNOW DURING 2015-2016

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The effects of strong geomagnetic storms over Total Electron Content (TEC) in Indian longitude sector have been reported in this paper. Geomagnetic storms during December 20-21, 2015; January 20-21, 2016; October 13-14, 2016 have been used to inspect the effects over TEC from Lucknow (26.91°N, 80.96°E, magnetic dip 41.90°). During December 20-21, 2015, an enhancement of TEC is observed over this station during and just after the storm period. The maximum enhancement observed during December 22, 2015 was 21.76 TEC Unit (TECU) during 11:02UT. TEC enhancement is also noticed before diurnal peak on December 21, 2015. The enhancement of TEC maximizes on December 22, 2015. Similar TEC enhancement during geomagnetic disturbed conditions are observed during January 20-21, 2016; October 13-14, 2016. An Artificial Neural Network (ANN) based TEC model is developed at Lucknow to predict Vertical TEC (VTEC) during geomagnetic quiet as well as disturbed conditions. The model is developed using International GNSS Service (IGS) TEC data from Lucknow. The model uses geomagnetic, solar indices as well as neutral wind inputs to generate VTEC by one minute resolution. The model is compared with standard ionospheric models such as International Reference Ionosphere (IRI) and Parameterized Ionospheric Model (PIM) to analyze its applicability in equatorial region.

C1.1-0081-18 VARIATIONS IN THE METEOR RADAR WINDS AT 22.7°S DURING GEOMAGNETIC STORMS ON JULY 2004

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The interactions between the solar wind and the magnetosphere-thermosphere-ionosphere system produce variations on upper atmospheric dynamic to different spatial and temporal scales. The episodic increases in energy during geomagnetic storms results in additional variations in dynamics, chemistry as well as in the composition of the atmosphere. In this paper we have used winds from meteor radar at Cachoeira Paulista (22.7°S, 45°W) to investigate a possible relationship between variations in the dynamics of the upper mesosphere and lower themosphere (MLT) region and geomagnetic storm events on July 2004. The wind behavior presented a different pattern from those observed before and after the period of the geomagnetic storms, mainly in the meridional component. The possible relationship between diurnal tide variations and the geomagnetic storm events are discussed.

C1.1-0082-18 MITIGATION OF SYSTEMATIC ERRORS FROM IONOSPHERIC DISTURBANCES IN GOCE GPS DATA FOR GRAVITY FIELD DETERMINATION

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The ESA Gravity field and steady-state Ocean Circulation Explorer (GOCE) mission was operated from 2009 until 2013 in a Low Earth Orbit at an altitude between ca. 280 and 225 km. It provided gravity fields of the Earth with an accuracy 1 mGal, and with a spatial resolution of less than 100 km, using its gradiometers. Kinematic precise orbits were also determined using the GPS-data of GOCE, especially for long-wavelength gravity field determination.

However, gravity fields based on the kinematic orbit determination suffer from systematic GPS data errors in two latitudinal zones north and south of the Earth's geomagnetic equator that are likely caused by equatorial ionospheric plasma bubbles, especially at high solar activity.

In this talk, we give an overview of the activities undertaken at AIUB for empirically reducing the anomaly in the gravity fields as determined from kinematic orbits. We demonstrate that using the second derivative of the geometry-free GPS carrier phase observations (plain difference of L1 minus L2) as a screening criterion leads to slightly improved gravity fields.

C1.1-0083-18 DEPENDENCE OF LUNAR TIDE OF THE EQUATORIAL ELECTROJET ON THE WINTERTIME POLAR VORTEX, SOLAR FLUX AND QBO

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The lower atmospheric forcing effects on the ionosphere are particularly evident during extreme meteorological events known as sudden stratospheric warmings (SSWs). During SSWs the polar stratosphere and ionosphere, two distant atmospheric regions, are coupled through the SSW induced modulation of atmospheric migrating and non-migrating tides. The changes in the migrating semidiurnal solar and lunar tides are the major source of ionospheric variations during SSWs. In this study, we use 55 years of ground-magnetometer observations at Huancayo, Peru to investigate the composite characteristics of the lunar tide of the equatorial electrojet (EEJ) during SSWs. These long-term observations allow us to capture the EEJ lunar tidal response to the SSWs in a statistical sense. We examine the EEJ lunar tidal response during vortex-split and vortex-displaced SSWs and find that larger lunar tidal enhancements are observed during the vortex-split events. Further, we examine the influence of solar flux conditions and the phases of Quasi-Biennial Oscillation (QBO) on the lunar tide and find that the QBO phases and solar flux conditions modulate the EEJ lunar tidal response during SSWs in a similar way as they modulate the wintertime Arctic polar vortex. This work provides first evidence of modulation of the EEJ lunar tide due to the QBO phase.

C1.1-0085-18 SEASONAL VARIATION OF GEOMAGNETIC FIELD AND TEC AT MID LATITUDES

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Our study is focused on the analysis of the geomagnetic variability of the H and Z components at different local times and at midlatitude during high solar activity. The variations of geomagnetic field can be from scale of seconds to millions of years and they can be periodic or random and its strength can vary from few to thousands of nT. It is divided in two main groups: long and short time variations. The first ones are mainly related with the dynamics of the Earth interior, primarily fluid motion in the core, and are on scale of few years to millions of years. The short time variations come predominantly from an external origin and are produced by currents in ionosphere and magnetosphere and by induced current in Earth's crust and ocean; they are on a scale of seconds up to a year. However these two types of variations could be overlapped particularly on the solar cycle effects and on secular variation impulses, known as jerks.

In this work, the data sample were carefully chosen, to isolate certain geomagnetic variabilities characteristic, which are clearly related to primary and secondary current systems of the magnetosphere and the ionospheric region. In this way, the overlap of the events that are not physically orthogonal, is minimized and a numerical technique based on principal component analysis (PCA's technique) will be useful to explain about the causes that produce these variabilities. In order to link these variabilities with the total electron (TEC) content and the thermospheric winds, the same numerical analysis was performed on vTEC obtained from observations of Global Navigation Satellite System network and thermostheric vertical wind from HWM07 model. Some remarkable results are the nighttime variation of the geomagnetic field measure from the ground that show an strong annual variation, with the superposition of a smaller semiannual component, the numerical technique applied over the selected sample, isolate the ring current variability as the main effect. From the Z component, the effect of the F layer currents variabilities could be identify. For midday variations (subtracting the nighttime period) a strong relationship between the TEC variability (spatial and temporal) and the magnetic field was found. The thermospheric wind describe a variability linked to the magnetic field variation. Therefore, in our analysis is clearly observed the effect of the variability in the conductivity and of the thermospheric wind that causes a current variation that finally induces the variability in the magnetic field.

C1.1-0086-18 QUIET-TIME MODERATE MIDLATITUDE L-BAND SCINTILLATION IN ASSOCIATION WITH PLASMA BUBBLES OVER NICOSIA

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Despite the fact that scintillation events are infrequent phenomena over mid-latitude regions moderate night time amplitude scintillation on the GPS L1C/A signal was recorded at the midlatitude station of Nicosia (35.18N, 33.38E ; geomagnetic latitude 31.79N), Cyprus, on a geomagnetically quiet day. Slant total electron content (STEC) variations and amplitude scintillation index (S4) on the night of June 12, 2014 indicated the presence of electron density depletions in conjunction to scintillation occurrence. The apparent horizontal drift velocity estimated by digisonde drift measurements and the propagation direction of the plasma depletions are consistent with those observed for the equatorial plasma bubbles, thus indicating that the moderate amplitude L-band scintillation observed over Nicosia may be associated with the extension of such plasma bubbles. The L-band scintillation occurrence was concurrent with the observations of range spread F (RSF) on Nicosia digisonde ionograms. The Height Time Intensity (HTI) plot generated using the ionogram data also showed features indicative of off-angle reflections from electron density depletions, therefore corroborating the STEC observations. This event suggests that the midlatitude ionosphere is more active even during geomagnetically quiet days than previously thought and that further studies are necessary. This is particularly relevant for the GNSS user community and related applications.

C1.1-0087-18 GPS TEC SCINTILLATIONS AND TEC DEPLETION AS SEEN FROM HETAUDA AND NAST, NEPAL FOR 2016

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We analyzed the data of TEC from two GPS stations Hetauda and NAST, Nepal which are a part of UNAVCO. We obtained the variation of ROTI and S4 index throughout the year 2016 for the two stations involved for the 32 all the PRN numbers barring PRN number 4 which was inactive throughout the year. We also correlated the value of ROTI index with ROTI index and S4 index with S4 index for the two stations and found that the ROTI index of Hetauda was well correlated with ROTI index of NAST with the highest being 94% for PRN 10 and the lowest being -13% for PRN 1. Extremely low correlation between S4 index of Hetauda and S4 index of NAST was observed with the highest correlation being 8% in PRN 3, 32 and the lowest correlation of -15% in PRN 12.

C1.1-0088-18 CHARACTERISTICS OF EQUATORIAL PLASMA BUBBLES OBSERVED BY TEC MAP OVER SOUTH AMERICA AND NUMERICAL SIMULATION OF ITS DEVELOPMENT

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Ground-based network of GNSS receivers have been used to monitor Equatorial Plasma Bubbles (EPBs) by mapping the Total Electron Content (TEC map). Large coverage of the TEC map allowed us to monitor several EPBs simultaneously and get characteristics of the dynamics, extension and longitudinal distributions of the EPBs from the onset time until their disappearance. These characteristics were obtained by using TEC map analysis and keogram technique by using the data obtained during the period between November/2012 and January/2016. The zonal drift velocities of the EPBs showed a clear latitudinal gradient varying from 123 m/s at the equator to 65 m/s for 35°S of latitude. Consequently, observed EPBs are inclined against the geomagnetic field lines. Both zonal drift velocity and the inclination of the EPBs were compared with the thermospheric neutral wind, which showed a good agreement. Moreover, large coverage of TEC maps permit to study periodic EPBs with a wide longitudinal distance. This averaged values observed for the inter-bubbles distances also presented a clear latitudinal gradient varying from 920 km at the equator to 640 km at 30°S. On several occasions, the distances reached more than 2000 km. Inter-bubbles distances greater than 1000 km have not been reported in literature. Numerical model calculations, using different latitudinal gradients in zonal wind, showed a good agreement with the latitudinal gradient in the EPBs zonal drift observed by TEC map. Comparison of the observational results with the theoretical model calculations confirms that the EPB inclination against the geomagnetic field lines and the latitudinal gradient of inter-bubbles distances were originated due to a latitudinal gradient in the

EPBs zonal drift.

C1.1-0089-18 THE EMBRACE MAGNETOMETER NETWORK FOR SOUTH AMERICA: FIRST SCIENTIFIC RESULTS

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Embrace MagNet

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The present work is the second of a two-part paper on the Embrace Magnetometer Network. In this part, we provide some of the first scientific findings that we have already achieved with this network. We identified the diurnal and the seasonal natural variations of the H component. We provided the precise determination of SSC and SI. We showed that the H amplitudes derived from the Embrace MagNet during intense magnetic storm are in very good agreement with the Dst index. We showed that it is possible to investigate of the effects of the Sq systems response to the X-class solar flares occurring during daytime under magnetically quiet conditions.

C1.1-0090-18 A STUDY ON THE METEORIC PERIODIC ACTIVITY ON THE TRIGGER OF INFRASOUND WAVE PRODUCTION IN THE EQUATORIAL REGION OF INDONESIA

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The infrasonic region of the sonic wave spectrum in the Earth's atmosphere is filled with a wide variety of natural sources. One of the more unusual, but constant, sources of natural infrasound is that of interplanetary debris, or meteoroids, colliding with the Earth's atmosphere at hypersonic velocities, in a process commonly referred to as a meteor. Many meteors can be detected by radio, generating shock waves during the lower transition flow regime and before their terminal stages in the Mesosphere-Lower Thermosphere (MLT) region of the atmosphere, at altitudes range between 75 km and 100 km. The shock wave strength generated by the meteor depends on meteoroid atmospheric velocities in a given region. However, practical detection and determination of the altitude of formation of these shock waves (i.e. over dense meteors) have not been possible up to this point. Moreover, a good estimate of the direction and speed of infrasound propagation in the atmosphere at equatorial latitudes, remains elusive. To solve this, we investigated the relevant meteor parameters observed by Meteor Wind Radar (MWR) in Kototabang (0.20o S, 100.32o E) and Biak (1.17o S, 136.10o E) in Indonesia. Here, we present the observed periods of meteors which generated infrasound as a function of observed meteor velocity as an initial investigation for further study. On the other side, we plan to install the infrasound sensor network around equatorial Indonesia that can be used as a reasonably accurate indicator of the infrasound sources.

C1.1-0091-18 GRAVITY WAVES PROPAGATION FROM TROPOSPHERE UP TO THERMOSPHERE OVER BRAZIL

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Gravity wave structures were observed in the troposphere in southern Brazil on September 16th, 2015. Temperature profiles were obtained from COSMIC radio occultation technique. On the same day, wave structures were observed on dTEC (detrended Total Electron Content) maps in the ionosphere over the southeast region of Brazil, with a horizontal wavelength of 345 km, a 26-minute period and a phase velocity of 221 m / s, propagating to North. Airglow observations in the same region also show several types of gravity waves with horizontal wavelengths ranging from 14 to 34 km and periods between 5 and 8 minutes spreading to northeast. Using the reverse and forward mode of the ray tracing technique we investigate the wave sources in the troposphere and the wave propagation up to the thermosphere

C1.1-0092-18 MORPHOLOGY OF THE IONOSPHERIC SCINTILLATIONS OVER LOW LATITUDE REGION DURING GEOMAGNETICALLY QUIET AND DISTURBED PERIODS

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This study aims look into the long-term ionospheric scintillations activities during quiet and disturbed geomagnetically periods over the low latitude region in the Brazilian sector. The research was carried out from single-frequency GPS receivers acquired during 17 years on the amplitude scintillation data through Global Positioning System satellite. At first, it was analyzed the climatology of ionospheric scintillations at Cachoeira Paulista site (22.4ºS, 45.0ºW) during quiet geomagnetically periods from 1997 to 2014. The results reveal that the nocturnal occurrence of scintillation follows the seasonal distribution of plasma bubble irregularities. In addition to the solar cycle dependence, the results suggested that the occurrence climatology of scintillations is also modulated by the secular variation in the dip latitude of Cachoeira Paulista. The analysis was complemented by an unpublished study of statistical characterization of scintillations using the - distribution model. The results show that for different levels of solar cycle activity the α-μ model fit quite well with the experimental data and with the temporal characteristics when the S4 < 0,8. Meanwhile, in terms of higher-order statistics the parameter did not vary along the solar cycle. Then, it was analyzed the morphology of scintillations owing to magnetosphere-ionosphere coupling for storm time disturbance electric field propagation to equatorial latitudes through the processes of direct penetration (PPEF) and disturbance wind dynamo (DDEF), so that caused drastic changes on the electrodynamics of the equatorial ionosphere, especially, in terms of their impact on plasma bubble irregularity development conditions. The scintillation activities during geomagnetically periods were analyzed from 303 events of geomagnetic storms (SYM-H -50 nT) since 2000 until 2014 over the equatorial station of São Luís (2.3°S; 44.2°W) and a low latitude station of São José dos Campos (23.1°S; 45.8°W), located under the southern crest of the EIA. The geomagnetic storm events were classified according to their diferente types, intensities and solar wind drivers, so that a statistical study of scintillations was noticed over the both stations. In general, the results reveal that the a progressive increase of magnetic activity resulted in inhibition of irregularities causing scintillations, especially for S4 > 0.5. In the end, five diferentt events of storm were selected with the aim study on the equatorial ionospheric scintillation response to the disturbance electric field, since the in two events, where the maximum SYM-H excursion occurred close to the dawn or dusk terminators the results diverge from what was expected. However, the results that emerge from these observations indicate that the effects the ring current and the local time when the ring curent changes from injection to recovery appears to play a leading role in establishing the conditions necessary for equatorial F layer irregularity generation and inhibition.

C1.1-0093-18 GRAVITY WAVE PARAMETERS AND THEIR SEASONAL VARIATIONS STUDY NEAR 120OE CHINA BASED ON NA LIDAR OBSERVATIONS

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Based on the newly established lidar chain at meridian 120oE China, the gravity wave (GW) activity between 80 and 105km and the seasonal behavior of temporal and spatial spectra at Beijing, Hefei and Hainan were studied with continue accumulated data based on the 3 years observations. The GW induced atmospheric density perturbations and their spectra were analyzed at the three observation site. The averaged RMS atmospheric density perturbations over three sites are near 6 %, which in summer are obviously larger than that in winter and the maxima occur near the solstice. Besides, as a disparity, the density perturbation of GW is still active considerably in winter of low latitude in China at Hainan. The spectra of vertical wave number (m) with special value as 2π/8 km, 2π/4 km, 2π/2 km 2π/1 km and observed frequency spectra as =2π/60min, 2π/25min, 2π/15min exhibit the similar seasonal behavior with the semiannual maxima emerging around the solstice. The m spectra and spectra show power law shapes, of which the average are near -3 and -1.7, respectively. The GW spectra seasonal variation shows the similar regulation as density perturbations at different latitudes. The wave source was calculated by LIDAR observation at a distance of about 1100km westward to the 120oE observing chain which are located at the bounder of Tibetan Plateau, and it could be concluded that this behavior may be caused by effect of Tibet Plateau wind shear.

C1.1-0094-18 STUDY OF EFFECTS OF SOLAR ZENITH ANGLE PROFILE ON SUB-IONOSPHERIC VLF RADIO WAVE PROPAGATION CHARACTERISTICS

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The ionization of the lowermost D-layer of the ionosphere highly depends on the solar zenith angle profile (). The electron density profile of D-layer plays the key role for modulation of Very Low Frequency (VLF) radio signal propagated through earth-ionosphere waveguide. This implies that the VLF signal characteristics strongly depends on the solar zenith angle profile over the entire propagation path. As for a particular location, the solar zenith angle variation depends upon the day of the year, the diurnal and seasonal signal profile will follow the same trend of if no extra ionization takes place due to other source. Depending upon the time of the day, the propagation path may be uniformly or non-uniformly illuminated. Here we compute the zenith angle profile over different VLF propagation paths for different times of the day. We use Wait's exponential model to compute the electron density profile of lower ionosphere and we assume a linear relationship between the Wait's parameters effective reflection height (h), steepness parameter (????), and solar zenith angle. We fed these parameters to Long Wavelength Propagation Capability (LWPC) code to simulate the signal amplitude profile for various propagation paths and compare them with observed signal.

C1.1-0095-18 EFFECT OF SOLAR ACTIVITY ON NIGHT-TIME F-LAYER HEIGHT PROFILE AT THE MAGNETIC EQUATOR IN WEST AFRICA DURING THE SOLAR MINIMUM PERIOD 1995 - 1997

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The night-time equatorial F-layer height behavior at Korhogo (9.2° N, 5° W; 2.4°S dip lat), Cote d'Ivoire, in west African sector is investigated in this paper. The focus of this paper is to study the effect of solar activity on the night-time F-layer height. The period of study take place during the solar minimum (1995 - 1997), where data from quarter-hourly ionogram of an Ionospheric Prediction Service (IPS) 42-type vertical sounder is available at the station of Korhogo. The statistical analysis of the occurrence of night-time F-layer profiles through-out the solar minimum period (1995 - 1997) recently evidenced at Korhogo by Tanoh et al. (2015) revealed two main F-layer height patterns with specific characteristics associated with seasons. The one with the post-sunset height peak (Type-1) due to the evening E×B drift, associated with the northern winter period and the other with the midnight height peak (Type-2), observed during the northern summer period. The transition process from the pattern Type-1 to the pattern Type-2 was found to last only a few weeks during the equinox period. In order to evaluate the effect of solar activity on night-time F-layer height profiles Type-1 and Type-2, the average value of the F-layer all the time, on the duration of every period is calculated and the variations of the temporal profiles of average height obtained, as a function of year, are analyzed. During the consecutive years, the same F-layer profile Type-1 appears in the winter period with a peak the amplitude of which grows. In summer, the profile changes morphology from one year to another, passing gradually from the pattern Type-1, in 1995 at the solar minimum to relatively modified pattern Type-2 as a function to the increasing solar activity. However the amplitude of the peak increases. These results show that an important effect of the solar activity on the F-layer height is to lift the peak when the solar activity increases. However on the seasonal morphology, there is no influence of solar activity on the winter pattern Type-1. But on summer pattern Type-2, the relative change in the profile can be due to the method of data processing. Thus other investigations turn out to be necessary. A quantitative study of the variations of the post-sunset peak height and the midnight peak height, as a function of solar activity during the various seasons finds that the height of the peak grows linearly with the solar activity. The post-sunset peak rises of 1 km when the number of sunspots increases by a unit whereas the midnight peak grows twice less fast for the same variation of the solar activity.

C1.1-0097-18 HIGHLIGHTS OF THE ARECIBO OBSERVATORY REMOTE OPTICAL FACILITY (AO-ROF) DATABASE AND FUTURE PROJECTS.

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The Arecibo Observatory Remote Optical Facility (AO-ROF) was established in the island of Culebra since November 2015 and has been successful on its operation.The AO-ROF is located 95miles East from AO (18,3°N; 65,3°W) in a recluse and secure area and provides an economical opportunity to offer a superior data product to our scientific clients and users. Given Culebra Island's favorable geographical and climatological characteristics as its low elevation and geographic location, it has more steady weather conditions than Arecibo, so therefore it provides more availability for optical observations. The AO-ROF instrumentation includes: all-sky imager systems, GPS, High Frequency receivers and cloud sensor. The capability of the optical instruments placed at AO-ROF in to observe the same thermospheric volume over AO sampled by the Incoherent Scatter Radar (ISR) is especially relevant during the High Frequency (HF) campaigns, which are ran by the AO new heating facility. This work presents highlights of the database acquired at the ROF, as well a discussion of the current status of the facility and future projects.

C1.1-0098-18 METEOR RADAR TEMPERATURES AT 7.4°S AND 22.7°S

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Mesospheric temperatures at 90 km height have been estimated from meteor radar measurements obtained at Cachoeira Paulista (22.7°S, 45°W) and São João do Cariri (7.4°S, 36.5°W). The temperatures were estimated using local models for temperature gradient and pressure and showed a good agreement with temperatures from Sounding of the Atmosphere by Broadband Emission Radiometry (SABER) over both sites. The temperatures by gradient technique show larger day to day variations than those estimated by pressure method and from SABER data. Spectral analysis have revealed the presence of annual (AO), semiannual (SAO) and quadrennial (QAO) periods on temperatures estimated by two techniques and from SABER data at both sites. The amplitude of the SAO over Cachoeira Paulista on temperatures by pressure method exceeds those estimated by gradient technique as well as the SABER temperatures. Over São João do Cariri, the SAO amplitude on temperature by pressure method also exceeds those derived by gradient technique and from SABER data. The SAO temperatures are in phase with each other, with maximums around equinoxes, just when the phase of SAO on mean zonal winds around 81 km is westward over both sites, however, the maximums in the westward winds happens before the maximum temperatures.

C1.1-0099-18 IONOSPHERIC DISTURBANCES: HYBRID SIMULATION OF KELVIN-HELMHOLTZ INSTABILITIES IN THE PRESENCE OF RADIALLY VARYING FLOW

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This paper summarizes the hybrid simulation results of plasma flow curvature effects on the growth of the Kelvin-Helmholtz instability (KHI). It is found that KHI growth rate is higher when the shear flow has a negative initial curvature than linearly sheared initial flow. The growth rate is lower when the initial shear flow has a positive curvature. The growth rate under positive curvature decreases with increasing positive curvature.

C1.1-0100-18 STUDY OF THE CHARACTERISTIC OF THE GROWTH OF MSTID OBSERVED BY GNSS

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Medium scale traveling ionospheric disturbance is one of phenomenon in ionosphere and has been long studied. Nighttime MSTID will be caused by Perkins instability, but linear growth time(e folding time) of Perkins instability is very slow as growth time from random thermal noise. For this problem, we could solve by the geomagnetic connection between E-region and Fregion, and inserting the sporadic E layer's polarized electric field as the energy source of growth. However, we have few examples of observational verification whether E-region is connected to Fregion when a disturbance occurred. And Perkins instability's growth rate is independent from wavelength, but we observe more MSTID events which wavelength is 200km - 400km. Sporadic E layer has less than 100km periodic structure, which contradicts observation. Therefore we think it is difficult to claim E-region and F-region connection as growth mechanism. To verify this idea, we studied the character of growth of nighttime MSTID. Using this method, we statistically estimated growth rates of nighttime MSTID in japan in summer 2014 observed by GNSS. We applied three-dimensional spectral method for total electron content grid data ,and estimated propagation velocity. Using this velocity, we tracked movement of one wavefront of MSTID, and estimated the fastest growth time of each event by using wavenumber spectra when tracking. As a result, growth time is slower than 16 minutes. Propagation direction when growth time is fastest is southwestward(205 deg - 245 deg). Growth time is even faster when 240 degrees. This time is too slow as growth time of MSTID, and is within the range of one perkins instability expects. We will show the detail about the relation between this growth time and both mechanisms, and also present the wavelength dependence of growth.

C1.1-0101-18 TRANSIENT ES-LAYERS PROPERTIES AT MID-LATITUDES OF NORTH HEMISPHERE.

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At present, there are many methods for studying the ionosphere: rocket, radar, satellite, optical, vertical and inclined soundings with ionosondes, etc. Therefore, in recent years, the number of phenomena occurring in the ionosphere is becoming more and more known and obtain theoretical explanations. With the development of methods for studying the ionosphere, the phenomena of the lower part of the ionosphere the sporadic E-layer (Es) gets increasing interest. The greatest information about these layers is collected using ionosondes. To study Es-layers, other methods of observation either have a weak sensitivity (for example, GPS) or short duration (radar methods). In addition, an important parameter is the time and speed of observation or sounding, therefore, in order to study the fast processes of the ionosphere in Kazan the ionosonde «Cyclone» was modernized. Modernization consisted in increasing the sounding period from 15 to 1 minute. This ionosonde mode allowed to finde statistical features and heights appearance range of transit sporadic Eslayers at mid-latitudes. Possible mechanisms of the transit Es-layer formation are discussed.

C1.1-0102-18 ANALYSIS OF THE LOW AND EQUATORIAL IONOSPHERIC RESPONSE TO A SUPER STORM – OBSERVATIONS AND NUMERICAL SIMULATIONS

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We present both observations and numerical simulations of the low and equatorial ionospheric response to a super magnetic storm during 9-10 Nov. 2004. Observations include GPS-TEC, E×B drift obtained by the Incoherent Scatter Radar at Jicamarca Radio Observatory (JRO), hmF2 and foF2 obtained by the ionosonde at JRO. Both observations and simulations show super plasma fountains during the daytime and nighttime respectivelycaused by the strong eastward penetrate electric field. And then the super fountains are suppressed by the westward disturbed dynamo electric filed occurring subsequently. During the daytime, the F3 appears as a result of the super plasma fountain. The simulation reproduces the generation, development, and suppression of the equatorial F3, which is well consistent with the ionogram. During the nighttime, because of the lack of photochemical effect, there appears huge depletion at the low and equatorial ionosphere after the lifting of the ionosphere. The numerical simulations are consistent with the observations without consideration of the neutral wind effect, which implies that the electrodynamic effects might play a major role in controlling the ionosphere for this storm event.

C1.1-0104-18 CLIMATOLOGY OF THE NIGHTTIME IONOSPHERIC TROUGH

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Global vertical Total Electron Content (vTEC) maps produced by the International Global Navigation Satellite System (GNSS) Service are used to study the seasonal variation of the mid-latitud ionospheric trough (MIT). MIT shows a structure in longitude and latitude in the F2 region. The shape and behavior of the trough is different and its related with the spatial-temporal ocurrence. Some authors showed that the trough prevail during evening and night-times hours. Several physical mechanisms have been proposed to explain it formation which include plasma stagnation, periods of increasing geomagnetic activity, enhanced of the electric field between others. Also, the horizontal neutral wind was proposed as a possible cause in deepest MIT formation.

By using the principal component analysis (PCA) numerical technique, this work studies the spatial and temporal variations of the MIT at nigth for the period 1999-2017 during differents hours: 22, 00 and 02 LT. The vTEC maps series are carefully choosen taken into account the Kp index to associate the MIT formation with the geomagnetic activity. Also, vTEC maps from the International Reference Ionosphere (IRI) 2012 and the Horizontal Wind Model 2007 (HWM07) are used to improve our climatology interpretation, by analyzing the relationship between vTEC and the horizontal neutral wind.

C1.1-0105-18 OCCURRENCE AND AMPLITUDES OF EQUATORIAL PLASMA DEPLETION AS OBSERVED BY SWARM SATELLITES

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An auto-detection technique is developed to find equatorial plasma depletions (EPDs) and their amplitudes base on the in situ electron density profiles measured by Swarm satellites, which can also be applied to the measurements of other spacecraft. For the first time, three different parameters derived from Swarm satellites, the GPS receiver signal loss events, the Ionospheric Bubble Index (IBI) of L2 product, and the occurrence and amplitudes of EPDs are taken in comparison. The EPDs are found with largest occurrence rate between 2200-0000 magnetic local time (MLT) and show a similar pattern with IBI but with a larger magnitude, while largest depletion amplitudes of EPDs appear earlier between 1900-2100 MLT correspond to higher background electron density and stronger effects on the Swarm GPS receivers. Similar features are also identified from a longitudinal perspective. The occurrence rate of post-midnight EPDs is generally reduced compare to pre-midnight; however, during June solstice months even more post-midnight EPDs are observed at African longitudes. CHAMP observations confirm this point regardless to high or low solar activity conditions. Besides, evidence also shows that solar minimum is preferred for the occurrence of post-midnight EPDs over Pacific region, especially for southeast Pacific during Dec. S. months. Further by comparing with the plasma vertical drift velocity from ROCSAT-1, we suggest that the F-region vertical plasma drift plays a key role in dominating the occurrence of EPDs during pre-midnight hours, while the postmidnight EPDs are the combined results from the continuing of former EPDs and newborn EPDs, especially during June solstice. And these newborn EPDs during post-midnight hours seem less related to the plasma vertical drift.

C1.1-0107-18 NIGHTTIME ENHANCEMENT OF MIDLATITUDE IONOSPHERE AND ITS CONNECTION TO THE PLASMASPHERE

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Midlatitude Arcs (MLA) have been found in the TIMED/GUVI OI 135.6nm nightglow observation previously. The glow arcs are supposed to be the phenomenon of nightside enhancements of the ionosphere at 20º-45º magnetic latitudes in both hemispheres. Using ionospheric observations we search for plasma enhancement structure counterpart to the nightglow MLA. The topside TEC observations from LEO satellites reveal longitudinal plasma distribution of the plasmasphere, interestingly showing some correlation with the ionospheric MLA structure. The plasmaspheric TEC concentrates near the equatorial plane, while the geomagnetic field lines connect the plasmasphere and midlatitude ionosphere. We therefore suggest that the plasmaspheric downward flux possibly feeds the midlatitude ionospheric structures during nighttime.

C1.1-0108-18 ANALYSIS OF GPS IONOSPHERIC SCINTILLATION FADING UNDER LOW LATITUDE REGIONS

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Global Navigation Satellite Systems are widely used by the aeronautic community to increase safety and reduce costs. These systems allow the use of procedures that increase airport efficiency, increasing flight availability, reducing flight delay, saving fuel and increasing safety. However, quick variations in the signal amplitude and carrier phase shift due to the ionosphere scintillation may cause the degradation or loss of the GNSS related services. Equatorial regions, such as most of the Brazilian territory, present great ionospheric scintillation because of the development of instabilities and the Equatorial Ionospheric Anomaly. The objective of this work is to perform a statistical analysis of the ionospheric effects on the GPS signals, with signal data from monitoring stations in the Brazilian territory to assess the fading in signal amplitude for the civilian GPS signals L1, L2C and L5. The analysis will include approximations for the amplitude fading for the GPS signals in similar geophysical conditions. The analysis of these equations will show how the new civil signals L2C and L5 perform in scenarios with ionospheric scintillation in comparison with the current L1 signal. The used amplitude distribution model used in this work is the α -μ distribution. The data used in this work belong to four different stations with dips of 8.86°, 16.01°, 19.28° and 22.32°. The stations belong to CIGALA/CALIBRA network. The data were collected from November 2014 to March 2015, during the summer equinox in the peak of the current solar cycle, period of great ionospheric scintillation occurrence. The results show that GPS users of new frequencies L2C and L5 are significantly more susceptible to the effects of ionospheric irregularities, in particular the stations located near the crest of Equatorial Ionospheric Anomaly.

C1.1-0109-18 EXTRACTION OF SOLAR RADIATION EFFECT FROM TEC BASED ON NONLINEAR DATA PROCESSING TECHNIQUE FOR SEISMO-IONOSPHERIC ANOMALY DURING THE PERIOD OF EARTHQUAKES

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The study of ionospheric precursors of the earthquake has gained interest among many researchers, especially the precursor obtained in terms of anomalous variation in total electron content (TEC). If an earthquake occurs during a period of moderate to high solar activity, the TEC derived using global positioning system (GPS) measurements requires the elimination of solar effect so as to identify the precursory signature. This paper includes multi-resolution time series technique to remove the nonlinear effect from solar radiation on GPS-based TEC. The technique is based on wavelet transform applicable to RINEX TEC data. This technique is used to remove nonlinear background solar effect from TEC prior to four different earthquakes (M > 6.0). Further, in order to evaluate the extracted TEC, we obtain the correlation between the decomposed TEC A6 and measured solar index (F10.7) and extreme ultraviolet (EUV). A good correlation is obtained between decomposed TEC A6 and EUV for all the cases. This suggests that this technique is useful for the removal of background solar effect for identifying earthquake precursor in TEC.

C1.1-0110-18 STUDY ON ZONAL DRIFT VELOCITIES OF THE IONOSPHERIC PLASMA BUBBLES USING A SINGLE GPS SCINTILLATION MONITOR

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Global Navigation Satellite Systems (GNSS) have been used over the years to provide precise information on time and positioning for several applications. For the aeronautical and aerospace community, the GNSS has been widely used to increase flight safety and also reduce operational costs. Avionic systems based on GPS technology have expanded aircraft routes, increased flight availability, airport efficiency and flight safety. These systems are highly dependent on signals transmitted by navigation satellite systems such as the American GPS and the Russian GLONASS. As these radio waves propagate through the ionosphere, they may suffer disruptions and signal losses due to ionospheric plasma and its structuring. Scintillation, characterized by rapid phase and amplitude fluctuations in the signal as it travels through the ionosphere is among the most common effect. Its consequences range from small precision and accuracy errors to a complete loss of signal lock and, ultimately, a complete failure of the system that may prove to be catastrophic. In equatorial and low-latitude regions that cover most of Brazilian territory the scintillations are more frequent and intense due to the presence of the Equatorial Ionization Anomaly characterized by a global maximum in plasma density. The objective of this work is to apply a methodology based on GPS ephemeris data and simple scintillation monitor parameters to characterize the plasma irregularities associated with the scintillation mainly thorough their drift velocity. Data from two monitoring stations in Brazil (Fortaleza and Porto Alegre) receiving information from GPS satellites at three frequencies (L1, L2 and L5) were used to investigate the applicability of the method for different latitudes inside Brazilian territory. The data analyzed is from Spring and Summer months of 2013-2016, a period of seasonal maximum in ionospheric scintillation occurrences.

C1.1-0111-18 A COMPARISON OF STATISTICAL FEATURES OF IONOSPHERIC SCINTILLATIONS AND CYCLE SLIPS IN THE MID-SOUTH REGION OF CHINA

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In this paper, the statistical features of scintillations and cycle slips of GPS (Global Positioning System) signals, as well as the effects of solar activity and geomagnetic activity on scintillations and cycle slips have been analyzed and compared by means of the observations from a scintillation observation network in the mid-south region of China during 2012-2015. Results show that the statistical features of scintillations and cycle slips. The results show that the variation features of cycle slip occurrence with local time, month, solar activity and geomagnetic activity are very similar to those of scintillation occurrence, and the occurring probability of cycle slip increases as the S4 index increases, suggesting that cycle slips are closely related to scintillations and scintillations are a key factor which can cause cycle slips. Scintillations and cycle slips occur mainly during the night, most frequently before midnight and seldom in the daytime. It is found that scintillations and cycle slips occur mainly in equinox months but seldom in solstice months at the ionization anomaly crest and its adjacent regions, and an equinoctial asymmetry that scintillations and cycle slips occur more frequently in Spring than in Autumn is also found. The occurrence of scintillations and cycle slips shows a strong dependence on the solar activity, it increases as the solar activity increases. However, the occurrence of scintillations and cycle slips shows a negative correlation with geomagnetic activity. The geomagnetic disturbances inhibit scintillations and cycle slips as a whole. On average, the closer to the magnetic equator, the more frequently and the earlier scintillations occur, indicating that the scintillations are caused by ionospheric irregularities which originate at the magnetic equator. In addition, there is a good consistency between the spatial distributions of scintillations and cycle slips. They mainly occur in the area with elevation angle between 35º and 55º and azimuth angle between 150º and 240º.

C1.1-0112-18 OBSERVATIONAL STUDY OF LOW LATITUDE IONOSPHERIC IRREGULARITIES OVER CHINA

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In recent years, a multi instrument observational network which including VHF coherent scatter radar, ionosonde, GNSS scintillation/TEC receiver and all-sky airglow imager, has been built in low latitude of China. By using this network, the occurrence characteristics of low latitude ionospheric irregularities have been investigated. In this report, some of the recent progress made in understanding the ionospheric irregularities, F region plasma bubbles over the Chinese longitude sector will be introduced. This involves results obtained mainly from the multi-beam Sanya (18.3°N, 109.6°E) VHF radar (pre-sunset bottom-type scattering layer, bubble onset, bubble zonal structure), the Fuke (19.3°N, 109.1°E) VHF radar and all-sky airglow imager (bubble onset and evolution, F layer bottomside large-scale wave structure LSWS, and small-scale wave structure SSWS), and the ground-based GNSS TEC/scintillation receivers (morphological aspects of EPB). Moreover, attempts were made with simultaneous Kototabang (0.2°S, 100.3°E) and Sanya radar multi-beam steering measurements to investigate the longitudinal variation in equatorial plasma bubble generation. The results obtained from the two stations closely located in longitude will be discussed. Finally, a brief introduction on our future efforts in equatorial plasma bubble observation will also be given.

C1.1-0113-18 STRONG IONOSPHERIC DISTURBANCES OVER THE BRAZILIAN SECTOR ASSOCIATED WITH THE GEOMAGNETIC STORM DURING THE SEPTEMBER 27 - 30, 2017

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Study of the strong ionospheric disturbances due to geomagnetic storm occurred on September 27-30, 2017 (low solar activity) has been carried out using a network of 130 GPS-TEC stations over the Brazilian sector. During this event the Dst reached a minimum value of -76 nT, the Kp reached maximum value of 7-, the solar wind velocity (Vp) was about 300 km/s before the storm and reached the maximum value of about 720 km/s during the main phase, and the proton density (Np) reached about 60 #/cm3 during the main phase. The IMF Bz during the main phase had multiple reversals, turning 3 times southward and twice northward. It is noted that the vertical total electron content (VTEC) showed a positive phase during the main and recovery phases. It is observed that the equatorial and low latitude regions are most disturbed while the region beyond the EIA crest is less disturbed. The disturbances took place almost the same time in both regions, indicating the prompt penetration of electric field (PPEF). In addition the EIA was severely disturbed due to this PPEF. This study shows that the ionosphere can be strongly disturbed by geomagnetic storm even during the low solar activity (F10.7= 80 sfu) conditions.

C1.1-0114-18 IONOSPHERIC SPACE WEATHER RESPONSE DUE TO THE GEOMAGNETIC STORM OF MAY 2017, IN THE BRAZILIAN SECTOR

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We investigated the response of the F-region in the Brazilian sector during the geomagnetic storm of May 27-30, 2017 using multisite and multi-instrument observations over the Brazilian sector. This study was carried out using a network of 129 GPS-TEC receivers, 3 ionosondes, and 4 all-sky imaging systems (OI 630 mm emission). During this event the geomagnetic indices (Dst and Kp) and interplanetary parameters of the solar wind (Bz, Vp and Np) were significantly disturbed; the Dst reached a maximum value of 43 nT (initial phase) and a minimum value of -125 nT (main phase) with the Kp index reaching a value of 6+. The solar wind during the quiet period was about 300 km/s and increased to 380 km/s during disturbed period.

The proton density reached the maximum values close to 60 #/cm−3. The IMF-Bz reversed south during the main and recovery phases of the storm. The vertical total electron content (VTEC), during the main phase, had a similar magnitude and variation as compared with quiet days. However, during the first day of the recovery phase, an oscillatory positive ionospheric disturbance was noted, probably due to simultaneous perturbations caused by the disturbed dynamo and TID propagation. The equatorial ionization anomaly (EIA) was investigated using a chain of GPS-TEC receivers and it is noted that during the first day of the recovery phase there was an intensification of the EIA followed by a decrease in its intensity on the second day of the recovery phase.

C1.1-0115-18 PLASMA BLOBS OBSERVED BY GROUND-BASED OPTICAL AND SATELLITE DMSP THE F-REGION

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Discrete increase in plasma electron density by a factor of two or more was observed in the F region of the nocturnal ionosphere in the Brazilian sector, in the Manaus-AM region (MAN; 2,59°S; 60,22°O; dip. latitude 12,1°N; region near the magnetic equator). This increase was observed through the imaging photometer data and measured by the DMSP F15 satellite. Plasma density irregularities in the nighttime equatorial ionosphere were first observed by Booker and Wells in 1938, when they discovered spread-F in the ionogram of backscattered signals of ionosonde in Huancayo, Peru. The increase in plasma electron density was reported for the first time by Oya et al. in 1986, and they named this irregularity as plasma blobs. The plasma blobs that we observed on the MAN region were events that occurred independently, that is, without the presence of plasma bubbles. Cases of independent plasma blobs are rare events to observe, with more frequent occurrence with the simultaneous presence of plasma bubbles. In this work we present results of 4 nights of occurrence of independent plasma blobs in the period from October to November 2015, calculations of zonal and latitudinal drift of these blobs, besides measuring the north/ south and east / west dimensions that they reached, during all the time they were visible on the lens of the imaging photometer.

C1.1-0116-18 ON THE RESPONSE OF EQUATORIAL IONOSPHERIC ANOMALY DURING GEOMAGNETIC STORM EVENTS AND COMPARISONS WITH IRI MODEL PREDICTIONS

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This paper discuses variability of electron density of F2 ionospheric region (NmF2) using ionosonde observations from stations in the region of equatorial ionization anomaly (EIA), during geomagnetic storm periods. Data based on availability during periods of high solar activity and different seasons from each station considered were used to carry out our stud- ies. The results obtained were used to evaluate the performance of the International Reference Ionosphere (IRI-2012) model predictions in the EIA region of the ionosphere. These results showed that the model predictions have agreement with the observed values in terms of the pattern of variations but there are number of cases where either the model overestimates and underestimates the observed values. Results from this study will be of help to improving prediction ability of the IRI model, most especially in this region of the ionosphere where there is paucity of data. Details of the statistical analysis of the results and the accuracy of the IRI model predictions are presented.

C1.1-0117-18 IRREGULARITIES AND SCINTILLATION, END TO END FROM SWARM TO THE GROUND

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This study focused on observations of irregularity structures using Swarm Langmuir Probe (LP) measurements in comparison with amplitude scintillation events recorded by the Global Positioning System-Scintillation Network and Decision Aid (GPS-SCINDA) receiver installed in Mbarara (Geog. lat = -0.60°, Geog. lon = 30.74°, Mag. lat = -10.2°). For some Swarm satellite passes, there was a good agreement between the increase in level of amplitude scintillation index (S4) and the depth of electron density perturbations. Cases where scintillation was seen without clear variation in density suggests that irregularities can be effective quite locally, horizontally or in height. Also, irregularities with no associated scintillation event were noted and this was attributed to a low background electron density. Initial results from this study indicate the capability of in situ density fluctuations observed by Swarm satellite passes over Mbarara of being used as indicators of ionospheric radio wave scintillation at that site. This is true even when the measurements are made at horizontal ranges of over 1000 km away from the ground site as long as the field line apex altitudes are less than 500 km. An attempt was made to model amplitude scintillation from Swarm LP electron density measurements using the power law phase screen model developed by Rino (1979). A spectral analysis procedure carried out to aid the modelling of amplitude scintillation for the Swarm satellite electron density revealed that the power spectrum follows a power law with spectral index ranging between -1.8 and

-2.2. The results also indicate that the Swarm satellite in situ measurements of electron density fluctuations may be used to model scintillation over the low latitude.

C1.1-0118-18 STUDY OF THE F3 AND STF4 LAYERS NEAR THE SOUTHERN CREST OF THE EIA ON THE WESTERN AND EASTERN SOUTH AMERICAN SECTOR

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This investigation presents the seasonal and solar cycle variations of the daytime F-layer multiple stratification (F3 and StF4 layers) near the southern crest of the EIA on the western and eastern South American sector. The ionograms recorded by a CADI digital ionosonde installed at Sao Jose dos Campos (SJC eastern sector; 23.21°S, 45.97°O; dip latitude 17.6°S) Brazil, from 2002 to 2006, and the ionograms recorded by an AIS-INGV ionosonde installed at Tucumán (TUC western sector; 26.9ºS, 65.4ºW; dip latitude 13.9°S) Argentina, from 2007 to 2015, are used for this study. Both stations are localized near the EIA southern crest in the South American sector. The F3 layer occurrence shows an annual variation with maximum during summertime and minimum during wintertime, in both stations (SJC and TUC). Concerning the StF4 occurrence at SJC and TUC, the results have shown a maximum during summertime, and no occurrence during wintertime. At SJC, a total of 1477 days were analyzed and the results shown that the F3 layer was found in 382 days (25.9%), while the StF4 layer was found in 5 days (0.3%), indicating that the StF4 is seen during 1.3% of F3 layer days. At TUC 1812 days were analyzed, and the F3 layer was found in 370 days (20.4%), while the StF4 layer was found in 41 days (2.3%) indicating that the StF4 layer is seen during 11% of F3 layer days. Moreover, at TUC, the F3 and StF4 layers occurrences show a solar activity dependence with maximum during high solar activity. On the other hand, at SJC, the F3 and StF4 layers do not show a clear solar activity dependence. Furthermore, a significant connection between StF4 and F3 has been noticed in both stations, since the StF4 layer is always preceded and followed by a F3 layer appearance.

C1.1-0119-18 TOWARD AN INTEGRATED VIEW OF IONOSPHERIC PLASMA INSTABILITIES

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The Earth's ionosphere is filled with irregularities in the electron density generated by electrostatic plasma instabilities including the Farley-Buneman instability (FBI) and the gradientdrift instability (GDI). In this study, a general analytic expression is derived for the FBI/GDI growth rate using a recently developed cubic dispersion relation that is valid in the broad range of ionospheric altitudes. It is demonstrated that the previously considered limiting cases of FBI/GDI in the E region and GDI in the F region are successfully reproduced using the more general expression. The obtained analytic expressions provide a unified theoretical framework for considering plasma irregularity generation in the lower ionosphere including the previously unexplored transitional region between the E and F layers. A number of specific applications are presented, with a particular focus on critical density gradient scales sufficient for irregularity generation in the GDI linear regime and their dependence on the irregularity wavelength.

C1.1-0120-18 FORMATION MECHANISMS OF THE SEMI-ANNUAL ANOMALY OF NMF2 AT MIDDLE LATITUDES DURING DAYTIME GEOMAGNETICALLY QUIET CONDITIONS AT LOW SOLAR ACTIVITY

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The ionosonde and radar observations and theoretical calculations of the F2-layer peak altitude and peak number density, NmF2, over Millstone Hill during geomagnetically daytime quiet conditions on 22 January 2008, 8 April 1997, 12 July 1986, 26 October 1995, 29 January 2008, 2 April 1986, 11 July 2008, and 5 October 2010 at low solar activity are used to study the formation mechanisms of the observed daytime semi-annual anomaly of NmF2. The onedimensional time-dependent model of the mid-latitudinal ionosphere and plasmasphere is used to calculate number densities and temperatures of electrons and ions. The study shows that the semi-annual anomaly of NmF2 is mainly cased by seasonal variations of the following atmospheric parameters: (1) the plasma drift along geomagnetic field lines due to corresponding changes in neutral wind components, (2) temperature and number densities of the neutral atmosphere, and (3) an optical thickness of the atmosphere caused by the dependence of the solar zenith angle on the day of the year for the same altitude and solar local time. Seasonal variations of the production rate of unexcited O+ ions due to chemical reactions involving electronically excited O+ ions and the reactions of unexcited O+ ions with vibrationally excited N2 and O2 cannot produce a significant impact on the formation of the semi-annual anomaly of NmF2.

C1.1-0121-18 LATITUDE DEPENDENT DELAY IN THE RESPONSES OF THE EQUATORIAL ELECTROJET AND SQ CURRENTS TO X-CLASS SOLAR FLARES.

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We have analyzed low latitude ionospheric current responses to two intense (X-class) solar flares that occurred on 13-May-2013 and 11-March-2015. Sudden intensifications, in response to solar flare radiation impulses, in the Sqand Equatorial electrojet (EEJ) currents, as detected by magnetometers over equatorial and low latitude sites in South America are studied. In particular we show for the first time 5 to 8 minutes time delay is present in the peak effect in the EEJ, with respect that of Sq current outside the magnetic equator, in response to the flare radiation enhancement. The Sq current intensification peaks close to the flare X-ray peak, while the EEJ peak occurs 5 to 8 minutes later. We have used the Sheffield University Plasmasphere-Ionosphere Model at National Institute for Space Research (SUPIM-INPE) to simulate the E-region conductivity enhancement as caused by the flare enhanced solar EUV and soft X-rays flux. We propose that the flare induced enhancement in neutral wind occurring with a time delay (with respect to the flare radiations) could be responsible for a delayed zonal electric field disturbance driving the EEJ, in which the Cowling conductivity offers enhanced sensitivity to the driving zonal electric field.

C1.1-0122-18 CAUSES OF THE SPRING-AUTUMN ASYMMETRY OF NMF2 AT MIDDLE LATITUDES DURING DAYTIME GEOMAGNETICALLY QUIET CONDITIONS AT LOW SOLAR ACTIVITY

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The ionosonde and radar observations and theoretical calculations of the F2-layer peak altitude and peak number density, NmF2, over Millstone Hill during geomagnetically daytime quiet conditions on 3 March 2007, 29 March 2007, 12 September 2007, and 18 September 1984 at low solar activity are used to study the causes of the observed daytime spring-autumn asymmetry of NmF2. The one-dimensional time-dependent model of the mid-latitudinal ionosphere and plasmasphere is used to calculate number densities and temperatures of electrons and ions. The study shows that the spring-autumn asymmetry of NmF2 occurs mainly due to seasonal variations of the plasma drift along geomagnetic field lines caused by corresponding changes in neutral wind components and seasonal variations of temperature and number densities of the neutral atmosphere at the same altitude and solar local time. Seasonal variations of the production rate of unexcited O+ ions due to chemical reactions involving electronically excited O+ ions and the reactions of unexcited O+ ions with vibrationally excited N2 and O2 cannot produce a significant influence on the formation of the spring-autumn asymmetry of NmF2.

C1.1-0123-18 ESTIMATION OF GPS-TEC USING DIFFERENT TECHNIQUES AND COMPARISON WITH VALUES FROM IRI-2012, NEQUICK-2 AND IRI-PLAS 2015 MODELS DURING GEOMAGNETIC STORMS

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Total Electron Content (TEC) is an important element for effective satellite communication and it constitutes one of the key parameters for observing the variable structure of the ionosphere. This work, which is divided into two parts, compared Vertical Total Electron Content (VTEC) obtained from seven different sources, namely: estimation from method developed by the IONOLAB group (www.ionolab.org), estimation from GPS TEC application software developed by Dr Gopi Seemala (GOPI-VTEC), IRI2012 model (using three different options: IRI2001, IRI01cor and NeQuick), NeQuick-2 model and IRI-Plas model, during geomagnetic storm and non-storm days. The first part compared between GPS-VTEC computed using the estimation method developed by the IONOLAB group and that developed by Dr Gopi Seemala. The second part compared the performance of different model based VTECs with these estimations (IONOLAB-VTEC and GOPI-VTEC). It is observed that IONOLAB-VTEC is in good agreement with the estimates from the GOPI-VTEC for all ionospheric states and regions. All the models followed the diurnal pattern of the observed values of VTEC. Our result shows that IRI-Plas model did not predict observed VTEC better than existing models, as expected.

C1.1-0125-18 FORECASTING TOTAL ELECTRON CONTENT OVER ARGENTINA

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Global Navigation Satellite Systems (GNSS) positioning are affected by the ionosphere refraction causing serious propagation errors. The forecast of ionospheric parameters is useful to predict the possible degradation of the performance of these systems for warning purposes. Total Electron Content (TEC) is an important parameter for monitoring the behavior of the ionosphere and indeed a magnitude of interest to understand the properties and behavior of the Sun-Earth System. This work presents the simulation of a framework to forecast the Vertical Total Electron Content (vTEC) using GNSS data (Global Navigation Satellite System) and geospheric information. The GNSS observations were processed with the Bernese V5.2 software to obtain a regional vTEC model. The geospheric data such as Solar Flux F10.7, DST, Kp, among others, were obtained from different repository and processing centers. To perform the vTEC forecast, a Neuro Fuzzy Inference System (NFIS) was implemented, using a 5-layer Neural Network architecture with fuzzy input. The input data in the NFIS model are those that are directly related to the temporal variation of the vTEC and the geospheric information. In order to analyze the spatial and temporal performance of the model different scenarios were proposed. Three specific sectors were selected: near the equatorial anomaly, mid-latitude and sub-auroral regions. Finally, different geospheric conditions were analyzed for each sector

C1.1-0126-18 CORRELATION BETWEEN THE NUMBER OF LIGHTNING STRIKES AND TOTAL ELECTRON CONTENT (TEC) OVER THE STATE OF PARANA, BRAZIL

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The total electron content measured by a station using global positioning system (GPS) receiver and the number of lightning strikes (cloud to ground) recorded by the National Integrated Network for the Detection of Atmospheric Discharges (RINDAT) in the State of Parana, Brazil, were examined to determine the correlation between the occurrence of lightning storms and variations in TEC. The length of both of lightning strike and TEC times series was 120 days. Lightning strike counts were accumulated over one-hour intervals, and TEC values were averaged also over one-hour intervals. Data were collected from September 1 to December 31, 2014. Time series analysis techniques were used to analyze the TEC and lightning strike data sets. Results show a clear correlation between the occurrence and number of lightning strikes and variations in TEC. Increases of up to 80% in TEC were measured during lightning storms.

C1.1-0127-18 ERROR ANALYSIS ON NMF2 AND HMF2 OF IRI-2016 MODEL DURING MAGNETICALLY QUIET AND STORM PERIODS

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The international reference ionosphere (IRI) model is an empirical ionosphere model, which is based on worldwide available data of ground-based and satellite observations. In this paper, the precision of the latest IRI-2016 model is validated through the comparison of NmF2 and HmF2 data between IRI-2016 and ionosondes during geomagnetic quiet periods in 2014 and geomagnetic storm periods in 2015, respectively. The NmF2 and HmF2 data of five ionosonde stations(Juliusruh:68.54°, Okinawa:37.26°, Jicamarca:-0.26°, Port Stanley:-51.24°, Hermanus:

-64.24°), which are available in different geomagnetic dip zones are compared with those of IRI-2016, since the variations of NmF2 during day and night can reach more than an order of magnitude, so we utilized the standard deviation (std) of relative error to show its error characteristics, and using std of absolute error to show that of HmF2. The results indicate that

IRI predictions have good agreements with ionosonde data for both NmF2 and HmF2, and are higher than the measured data during most time of the two years. In 2014 which geomagnetic quiet period (Kp<4) accounts for 98% of the year, IRI-2016 showed the worst correlation with Port Stanley station (std=83.54%) and Okinawa station(std=45.72km) in NmF2 and HmF2, respectively. The highest correlations were held by Juliusruh station(std=34.69%,20.28km) for both NmF2 and HmF2. Analysis on local time and seasonal characteristics at Juliusruh indicate that the error in daytime was lower than that in nighttime, the model in sum- mer season has a better accuracy. In 2015 which geomagnetic disturbance period (Kp>=4) accounts for 15.3% of the year, IRI-2016 showed the worst correlations with Juliusruh station(std=100.18%,68.79km) in both NmF2 and HmF2, while the highest correlations were held by Jicamarca(std=40.38%,26.83km) in both NmF2 and HmF2. Analysis on local time at Jicamarca indicate that the error in daytime was lower than that at nighttime. The above analyses initially obtained the statistical error characteristics of the IRI-2016, thus providing the priori error information for the application of the IRI model and laying a foundation for the further improvement of it. Due to the limited quantity and quality of ionosonde data, this study is not statistically perfect, we can see the big error especially in the geomagnetic storm period. Our next step is to acquire more ionosonde data (such as the data of "meridian project" of China), evaluating the controlling the quality of ionosonde efficiently, so we can obtain more statistically significant error characteristics of the IRI model.

C1.1-0128-18 SEASONAL VARIATION OF OI 630.0 NM NIGHTGLOW EMISSION: MODELING AND OBSERVATIONS

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The OI 630.0 nm nightglow was observed at Cachoeira Paulista (22.7°S, 45°W) by multichannel photometer during the year 2015. The seasonal variation of OI 630.0 nm nightglow is studied using the data. It is found that the temporal variation of OI 630.0 nm nightglow intensity shows a peak at post-midnight hours (01:00hrs) during the summer. During autumn, this peak is shifted towards pre-midnight hours (22:00hrs). It is noticed that this peak again shifted towards post-midnight hours, 02:30hrs and 01:50hrs, during winter and spring, respectively. The intensity values increase a factor of 4 in summer than compare to other three seasons.

We have developed a model to compute excitation, loss, emission rates and intensity of OI

630.0 nm nightglow during four seasons. The dissociative recombination of O2+ with electron is considered as major production source of O(1D) atoms during night time. All possible loss processes of O(1D) are incorporated in the model. The measured electron density by the ionosonde at Cachoeira Paulista (22.7°S, 45°W) is used in the calculations. The neutral parameters are adopted from NRLMSISE-00 model. We have calculated O2+ density within the model by considering its production and loss processes. The excitation, loss and emission rates of O(1D) are calculated at different local times during four seasons. By integrating the emission rate profile, we obtained the intensity of OI630.0 nm at a particular local time. The model intensities are compared with the measured intensities. It has been found that the model intensities are reasonably in good agreement with the measurement for all four seasons and model reproduces the features of peak intensities very well. It can be noted that a detailed OI630.0 nm nightglow model is developed for the first time which can explain the temporal variation of OI630.0 nm nightglow during all four seasons.

C1.1-0129-18 PERFORMANCE OF NEQUICK-2 MODEL AND IRI-PLAS 2017 MODEL DURING SOLAR MAXIMUM YEAR IN 2013-2014 OVER GLOBAL EQUATORIAL AND LOW LATITUDE REGIONS

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This paper inspect the prediction Capability of Nequick-2 model and the latest version of International Reference ionosphere IRI Extended to the Plasmasphere (IRI-Plas 2017) model in predicting the Total electron content (TEC) over eight different equatorial and low latitude regions across the globe during solar maximum year 2013-2014. In all, the diurnal and the seasonal variations agree fairly well with GPS-TEC in all the station although with some upward and downward offsets. The observed GPS-TEC shows the presence of winter anomaly which is high in December (DecSol) and Low in June solstices (June sol).The monthly and seasonal variations of the NeQuick-2 model TEC with IRI-Plas 2017 model has been compared with the GPS-TEC. From the prediction errors, it shows that the monthly and seasonal variation of the IRI-Plas 2017 Overestimate GPS-TEC in all the regions when compared with NeQuick -2 models except in Addis Ababa station where there is a good agreement with the GPS-TEC. The NeQuick -2 model, in general performed better when compared with IRI-Plas 2017 in months and in season. These models exhibit latitudinal variation and showed a seasonal trend. The main problem of the NeQuick-2 model TEC representation is not situated in the Plasmaspheric part, its absence in NeQuick-2 model or its presence in IRI Plas 2017 model, the main source of the resulted discrepancies is still in the IRI topside ionosphere representation.

C1.1-0130-18 VISCOSITY OF THE MULTICOMPONENT NEUTRAL ATMOSPHERE

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Approximate expressions for the viscosity coefficient of the multicomponent neutral atmosphere are analyzed and evaluated by comparing them with that given by the rigorous hydrodynamic theory. These approximations are tested for the atmosphere consisting of N2, O2, O, He, and H during geomagnetically quiet and disturbed spring conditions at low, moderate, and high solar activity in the altitude range of 100-500 km for different values of the universal time, latitude, and longitude. Two new approximate expressions for the viscosity coefficient of the multicomponent atmosphere are proposed. Their differences from the viscosity coefficient given by the rigorous hydrodynamic theory do not exceed 3.4% and 4.8%. These differences are significantly smaller than the maximum differences (from 11.8% to 15.1%) of the viscosity coefficient approximations used in atmospheric studies from the viscosity coefficient given by the rigorous hydrodynamic theory. The new approximate expressions for the viscosity coefficient of the multicomponent atmosphere are recommended for use in atmospheric studies to reduce errors of calculations of atmospheric parameters.

C1.1-0131-18 VALIDATION RESULTS OF NMF2 DERIVED FROM GLOBAL NAVIGATION SATELLITE SYSTEM RADIO OCCULTATION OBSERVED BY GNOS ON FY3C SATELLITE

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The first Global Navigation Satellite System (GNSS) Occultation Sounder (GNOS) which is compatible with both BeiDou Navigation Satellite System (BDS) and Global Positioning System (GPS) was successfully launched into orbit onboard the FengYun3C satellite (FY3C) on September 23, 2013, and it has already gathered a large amount of ionospheric radio occultation data so far, including the GPS radio occultation (GPSRO) data and BDS radio occultation (BDSRO) data. In this work, we discuss the configuration of the FY3C/GNOS firstly, then we define matching principles of NmF2 data between GNOS-GPSRO/GNOS-BDSRO and ionosondes to match them into data pairs, thus the quality analysis of the GPSRO and BDSRO products can be carried out. We get that between NmF2 data of GNOS-GPSRO and ionosondes during October 1, 2013 and September 30, 2014, their correlation coefficient, bias and standard deviation (std) are 0.96, 6.71% and 18.03%, respectively, and between NmF2 data of GNOS-BDSRO and ionosondes during October 1, 2013 and October 10, 2015, their correlation coefficient, bias and std are 0.96, 10.21%, 19.61%, respectively. Not hard to see the NmF2 data of GPSRO and BDSRO observed by the same GNOS payload have very similar precision, they are also consistent to precision of other international radio occultation products, like those of CHAMP and COSMIC. That way

the precision consistency between GNOS-GPSRO and GNOS-BDSRO, GPSRO/BDSRO and ionosondes, GPSRO/BDSRO and other international radio occultation products are verified. The NmF2 quality analysis between GNOS-GPSRO/GNOS-BDSRO and ionosondes in different latitudes, local times, seasons, orbits are also included. The precision consistency of the ionospheric radio occultation products of different GNSS is significant to the ionospheric research and space weather forecasting based on the GNSS occultation sounding data. By comprehensively analyzing and utilizing its ionospheric occultation data with those of other GNSS, it is possible to improve the coverage and temporal-spatial resolution of occultation events, which is conducive to the real-time monitoring of ionospheric weather and the research and development of ionospheric climate models. And the enhancement of BDS and the continuous launches of FY3 series satellites in the future will greatly increase the number of ionospheric occultation events, which will enable GNOS to provide more occultation data for the world.

C1.1-0132-18 THE THERMAL CONDUCTIVITY COEFFICIENT OF THE MULTICOMPONENT NEUTRAL ATMOSPHERE

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Approximate expressions for the thermal conductivity coefficient of the multicomponent neutral atmosphere are analyzed and evaluated by comparing them with that given by the rigorous hydrodynamic theory. These approximations are tested for the atmosphere consisting of N2, O2, O, He, and H during geomagnetically quiet and disturbed winter, spring and summer conditions at low, moderate, and high solar activity in the altitude range of 100-400 km for different values of the universal time, latitude, and longitude. The new approximations of the thermal conductivity coefficients of simple gases N2, O2, O, He, and H are derived and used. The approximation for the thermal conductivity coefficient of a multicomponent mixture of neutral gases given by Mason and Saxena is modified, and it is found that this modified approximation is more accurate in reproducing the atmospheric values of the rigorous hydrodynamic thermal conductivity coefficient in comparison with those that are generally accepted in atmospheric studies. The found approximation for the thermal conductivity coefficient of the multicomponent neutral atmosphere is recommended for use in calculations of the neutral temperature of the atmosphere.

C1.3-0001-18 THE ROLE OF ATMOSPHERIC “COLLISIONAL MACHINE” IN THE FORMATION OF ELECTRON PRECIPITATED FLUXES IN THE AURORA

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It is shown that wave particle interaction processes that drive precipitating fluxes in the region of diffuse aurora from the magnetospheric altitudes are only the first step in the formation of electron precipitation at ionospheric altitudes, and they cannot be separated from the atmospheric “collisional machine” that redistributes and transfers their energy inside the magnetosphereionosphere-atmosphere coupling system. We discuss the consequences of such interactions and coupling on the ionospheric conductivity and ultimate “absorbed” precipitating fluxes into the upper atmosphere. The ionospheric conductivity is a critical parameter for MagnetosphereIonosphere coupling as it regulates the amount of energy that can flow between magnetosphere and upper atmosphere. Having an accurate account of the ultimate precipitating electron flux allows us to accurately forecast the impact to upper atmosphere chemistry.

C1.3-0002-18 ASSESSING THE ROLE OF OUTFLOWING IONOSPHERIC HEAVY IONS IN THE DYNAMICS OF THE NEAR-EARTH ENVIRONMENT

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Changes in the ion composition throughout the Earth's magnetosphere can have profound implications on plasma structures and dynamics, since it can modify the temperature and the magnetic field configuration, altering the convection patterns inside the magnetosphere. The ratio of hydrogen to oxygen ions has been shown to be highly dependent of geomagnetic activity, with the O+ content increasing with increasing activity. This suggest that ions of ionospheric origin can become the dominant species in the inner magnetosphere during disturbed times. Therefore, numerous studies focused on the transport and energization of O+ through the ionosphere-magnetosphere system; however, relatively few have considered the contribution of N+, in addition to that of O+ to the near-Earth plasma dynamics, even though past observations have established that N+ is a significant ion species in the ionosphere and its presence in the magnetosphere is significant. Ring current observations from the Active Magnetospheric Particle Tracer Explorer (AMPTE) spacecraft show that high energy N+ fluxes are comparable to those of O+ during disturbed times, confirming the substantial presence of N+ ions in the inner magnetosphere. In spite of only 12% mass difference, N+ and O+ have different ionization potentials, scale heights and charge exchange cross sections. The latter, together with the geocoronal density distribution, plays a key role in the formation of ENAs, which in turn controls the energy budget of the inner magnetosphere and the decay of the ring current. We present here numerical simulations using the Hot Electron and Ion Drift Integrator (HEIDI) model, which suggest that the contribution of N+ to the ring current dynamics is significant, as the presence of N+, in addition to that of O+, alters the development and the decay rate of the ring current. Electron transfer collisions are far more efficient at removing N+ the system, compared with O+ ions. These findings suggest that differentiating the N+ loss and transport from those of O+ in the near-Earth environment has a profound impact on global magnetosphere dynamics, as plasma composition affect both the local and the global properties of the plasma.

C1.3-0003-18 TEMPORAL AND SPATIAL DEVELOPMENT OF TEC ENHANCEMENTS DURING SUBSTORMS

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Total electron count (TEC) enhancements due to space weather are a threat to communications and global positioning systems (GPS). It is known that TEC enhancements occur during magnetic storms and can cover large areas for many hours, but it is also not uncommon for TEC enhancements as large as 10 TEC units to occur during substorms. Although much is known about storm-associated TECs, the temporal and spatial characteristics of substorm-associated TECs are not well established. By combining two dimensional maps of TECs over North America and Greenland and with maps of ionospheric currents derived with the spherical elementary current method [Weygand et al., 2011], we investigate the temporal and spatial changes of TEC enhancements events for both a single substorm and for multiple substorms combined using a two dimensional superposed epoch analysis. Both the single event analysis and the statistical analysis show an increase of TECs during the expansion phase. Substorm values of the TEC enhancements peak within 10 min after auroral onset and recover to nominal levels after about 40 min. TEC enhancements occur mainly within the night side Region 1 downward current system and cover millions of square kilometers. Furthermore, these enhancements appear to be associated with enhanced precipitating particle fluxes. These results address one of goals of the Space Weather Action Plan, which are to establish benchmarks for space weather events and improve modeling and prediction of their impacts on infrastructure.

C1.3-0004-18 PHYSICAL PROCESSES ASSOCIATED WITH HEATING, PLASMA CONVECTION AND FIELD ALIGNED CURRENTS IN THE HIGH LATITUDE IONOSPHERE

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Field aligned currents (FACs) flowing between the magnetosphere and ionosphere, across a wide range of temporal and spatial scales, have been a major focus of magnetosphere-ionosphere coupling and its effects on the high latitude ionosphere. At the same time, theoretical treatment of MI coupling processes using magnetohydrodynamic frameworks reveal an important role played by neutral species. An example is Ohm's law, which clearly shows the dependence of high latitude currents on the neutral wind in an Earth-fixed frame. Another example is heating at high latitudes during geomagnetic storms, which has been associated with the term "Joule heating". However, such heating can occur in the absence of an electric field and is more properly interpreted as frictional heating between ions and neutral species near ionospheric E-region altitudes. Since the 1970s and the theoretical work of Vasyliunas, magnetospheric convection appears intimately related to FACs such that they appear to be manifestations of the same phenomenon: specifying FACs allows one to calculate magnetospheric convection, or specifying magnetospheric convection permits the calculation of FACs (certain boundary conditions must be assumed). We will discuss how including neutral species in MI coupling alters this picture. Finally, we describe how neutral wind divergence due to local auroral heating of the thermosphere may lead to measurable field aligned currents originating in the ionosphere.

C1.3-0005-18 DRIVING AF STRONG NIGHTSIDE GEOMAGNETIC ACTIVITY ACTIVITY BY MULTIPLE MEOS-SCALE POALR CAP FLOW ENHANCEMENTS

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It is now known that meso-scale flows within the polar cap often cross the magnetic separatrix into the plasma sheet, leading to plasma sheet flow bursts, auroral poleward boundary intensifications (PBIs), streamers, and poleward motion of the polar cap boundary from reconnection. At times, these flows can enhance in magnitude and there can be several approaching the nightside polar cap boundary over a broad longitude range and for a prolonged period (several to tens of minute). We will show evidence that such enhancements in meso-scale flows can lead to strong auroral nightside activity and concurrent poleward expansion under several different circumstances. These include immediately following impacts of large increases in solar wind dynamic pressure as can occur at a storm sudden commence, enhancing substorm occurrence rate during storms, controlling the poleward expansion and duration of post-substorm-onset auroral activity, and leading to explosions of activity from the auroral poleward boundary. This strong effect with its several important manifestations has not yet been the subject of through investigations, but is accessible for future study using available observations from ground-based auroral imagers and radars and from low-altitude satellites.

C1.3-0006-18 THE EFFECT OF PRECIPITATING ELECTRONS ON THE INNER MAGNETOSPHERIC ELECTRIC FIELD AND THE THERMOSPHERE DURING THE MARCH 17, 2013 STORM

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Diffuse auroral electrons are important for magnetosphere-ionosphere-thermosphere coupling because they are a major energy source to the auroral ionosphere. We investigate how the precipitating electrons modify the ionospheric conductivity, ionospheric electric potentials, and thermospheric density and wind profiles during the large 17 March 2013 magnetic storm. Our approach is to couple (1) the magnetically and electrically self-consistent Rice Convection Model - Equilibrium (RCM-E) of the inner magnetosphere, (2) the B3C transport model for electron-proton-hydrogen atom aurora in the ionosphere, and (3) the Thermosphere-IonosphereElectrodynamics General Circulation Model (TIEGCM) for the ionosphere and thermosphere. We use parameterized rates of whistler-generated electron pitch-angle scattering from Orlova and Shprits [JGR, 2014] that depend on equatorial radial distance, magnetic activity (Kp), and magnetic local time (MLT) outside the simulated plasmasphere. Inside the plasmasphere, parameterized scattering rates due to hiss [Orlova et al., GRL, 2014] are used. Spectral properties of the RCM-E precipitating electrons at 500 km are used as the upper boundary input to the B3C transport model for calculating height-integrated conductance and to the TIEGCM as the source of auroral heating. We compare simulated trapped, precipitating electron flux distributions, electric field properties, and thermospheric densities with measurements from the Van Allen Probes/MagEIS, Defense Meteorological Satellite Program (DMSP), and the Gravity field and steady-state Ocean Circulation Explorer (GOCE) satellites for the March 17, 2013 event.

C1.3-0007-18 GLOBAL MODELLING OF MAGNETOSPHERE-IONOSPHERE COUPLING: EPOP-SWARM OBSERVATIONS

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We present first results from a comprehensive three-dimensional model of magnetosphereionosphere coupling. The model describes plasma flow produced by global scale (Volland-Stern) convection electric fields that are coupled with a physical model of the ionosphere. The initial magnetospheric plasma density is specified using the Global Core Plasma Model (GCPM), while initial density and temperature profiles of electrons and various species of ions and neutrals are taken from the IRI and MSIS models, respectively. The interaction of magnetospheric plasma with the ionosphere is self-consistent and includes effects of sunlight, ionization and recombination, heating and cooling processes, Hall and Pedersen conductivity altitude dependence, and chemistry. The model has already been used to study the development and erosion of plasmaspheric plumes that exert influence over energetic particle dynamics in the inner magnetosphere. It also describes plasma flow over the entire polar cap, which, when combined with data-assimilation of, for example, SuperDARN data, will eventually lead to improved accuracy of space weather forecasting. The main application of the new model is focused on interpreting measurements from the ePOP/CASSIOPE and SWARM satellite missions, which have combined their operations. First modelling results utilizing observations from this new ESA-Canada joint mission will be presented. The novel Yin-Yang overset grid and flexibility of the model to describe non-dipolar magnetic fields will be briefly described, as well as methodology needed to combine the model with more global models such as the LFM MHD model.

C1.3-0008-18 STATISTICAL ANALYSIS OF THE AKR-LIKE EMISSIONS OBSERVED BY RELEC MISSION DURING AUGUST-DECEMBER 2014

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AKR-like emissions are phenomena similar to the typical Auroral Kilometric Radiation (AKR) events, but observed by satellites at lower altitudes, as well as by the ground-based instruments. The typical Auroral Kilometric Radiation (AKR) consists of intense electromagnetic emissions generated by energetic electron beams in the Electron Cyclotron Maser process at heights over 2000 km in the auroral region, whereas the exact nature of AKR-like emissions observed in the ionosphere as well as on the ground is still not well understood.

In this work, we selected observations of AKR-like emissions from the RELEC (Relativistic Electron) mission, in the time period from August to December 2014. The statistical analysis of AKR-like events observed for different invariant latitudes, magnetic local times and altitudes (in the range of 600-850 km, well below AKR sources lower height limit) will be presented. The selected events have also been divided due to the observed features that might shed light on the physical processes responsible for their origin.

C1.3-0009-18 EQUATORIAL ELECTRODYNAMICS PERTURBATION DURING THE GEOMAGNETIC STORMS DURING THE MAXIMUM PHASE OF THE CURRENT SOLAR CYCLE 24

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This paper investigates the geomagnetic pulsation in Pc5 band associated with the enhancement of the Equatorial Electrojet EEJ current and its ionospheric response detected at the equatorial region during the maximum phase of the current solar cycle 24. We used several techniques of ground-based and satellite instrument to perform this study. The day side vertical E×B drift velocity is estimated at the equator using data from a pair of magnetometers based on the technique described by (Anderson et al., 2004). We found a good correlation between the EEJ disturbances revealed by Pc5 pulsation and the interplanetary electric field (IEF). This correlation was noticeable in the day time response of H, Pc5 and IEF. Our results show that Pc5 oscillation can penetrate to the equatorial region and modulate the equatorial electrodynamics through the E×B drift which can be estimated from ground-based magnetometer data. This was verified by the signature of Pc5 oscillation in H data. The time-response (Tr) between the Dst triggering and the Total Electron Content (TEC) disturbance was estimated during the day-time of the most energetic geomagnetic storms which have been detected. The relation between Tr and the Dst values showed a good correlation with a correlation factor of 0.85. This time-response parameter can be considered as an important feature that could improve our understanding of the equatorial ionospheric phenomena. Key Words: Equatorial Electrodynamics - Geomagnetic storm - Geomagnetic pulsations - Total Electron Content - Equatorial Electrojet - interplanetary electric field.

C1.3-0010-18 DYNAMICS OF THE UPPER THERMOSPHERIC WINDS DURING MAGNETOSPHERIC SUBSTORMS

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Thermospheric winds play a key role in momentum and energy transfer between the magnetosphere and the high-latitude ionosphere-thermosphere system. We use the Fabry-Perot Interferometer (FPI) at Tromsø, the collocated EISCAT incoherent scatter radar, and the IMAGE magnetometer chain over Scandinavia to investigate the upper thermospheric wind dynamics during non-stormtime substorms. Based on the simultaneous measurements, we can assess the effect of local ion-drag force and Joule heating on the wind dynamics.

The upper thermospheric winds have different responses during substorm growth, expansion, and recovery phases. During the growth phase, the wind generally accelerates slowly in the direction of background plasma convection, which increases due to increased dayside merging between the IMF and the terrestrial magnetosphere. Hence, the ion drag force is the dominant factor. In addition, mesoscale wind disturbances are found in the vicinity of growth phase arcs.

During the expansion phase, the horizontal winds are accelerated in the eastward and southward directions within the substorm current wedge. The eastward acceleration takes place when the ionospheric westward electrojet expands over Tromsø, and therefore we suggest that even though ion drag may provide a part of the eastward acceleration, Joule heating is the dominant force. Acceleration often continues in the early part of the recovery phase. During the late recovery phase, the winds decay to pre-substorm conditions.

During substorms, atmospheric gravity waves (AGWs) may be generated centered at the onset region. The propagation of the AGWs causes periodic perturbations (20-40 min) in the vertical and horizontal winds. The perturbations are predominant during the recovery phase.

C1.3-0011-18 GENERATION, DYNAMICS, AND DECAY OF A POLAR CAP PATCH AND ASSOCIATED GPS SIGNAL SCINTILLATION

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The polar cap ionosphere, an important part of the solar wind-magnetosphere-ionosphere system, is formed by ionization of the neutral atmosphere by solar radiation and particle precipitation under internal transportation and chemical processes. The polar ionosphere is primarily driven by magnetospheric convection and neutral circulation, and undergoes structuring over a wide range of temporal and spatial scale sizes. This structuring is due to the interplay of mechanical forces, electrodynamics, and ionization chemistry. The most prominent and frequent structure of the polar cap ionosphere is the polar patch, which is defined as a region of enhanced F layer ionization distinguishable from the background electron density. Several theories, observations, and hypotheses on the generation and dynamics of these patches are available in the literature. However, a coherent understanding of patch formation is still lacking, mainly due to the lack of high spatial and temporal resolution observations. This is also compounded by our attention to more dramatic patch events. This presentation will focus on a less-dramatic patch event using observations from the Canadian High Arctic Ionospheric Network (CHAIN), in order to provide a coherent view of formation, dynamics, and decay of polar patches. We also present the role of this patch in the generation of GPS amplitude and phase scintillation.

C1.3-0013-18 SWARM SATELLITE AND EISCAT RADAR OBSERVATIONS OF A PLASMA FLOW CHANNEL IN THE AURORAL OVAL NEAR MAGNETIC MIDNIGHT

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We present a multi-instrument case study of ionospheric electrodynamics in the midnight sector at high latitudes, showing an existence of a plasma flow channel with high eastward flow velocities. The flow channel is 1.5° wide in latitude and contains southward electric field of 150

mV/m, corresponding to eastward plasma velocities of 3300 m/s in the F-region ionosphere. The flow channel measured by both the Swarm satellite and the EISCAT incoherent scatter radar is located equatorward of the polar cap boundary within the dawn convection cell.

While the poleward part of the auroral oval in this event is electric field dominant with low conductivity and the flow channel, the equatorward part is conductivity dominant with at least five auroral arcs. The main part of the westward electrojet flows in the conductivity dominant part. According to Kamide and Kokubun [1996], the whole oval is expected to be conductivity dominant in the post-midnight sector, so the studied event challenges the traditional view.

The flow channel is observed after a substorm onset. We suggest that the observed flow channel, which is associated with a 13-kV horizontal potential difference, accommodates increased nightside ionospheric plasma flows during the substorm expansion phase as a result of reconnection in the near-Earth magnetotail.

C1.3-0014-18 IN-SITU OBSERVATIONS OF REDUCED TOPSIDE PLASMA DENSITY AND ASYMMETRIC INTER-HEMISPHERIC ION FLOW AND RESULTING TRAVELING IONOSPHERIC DISTURBANCES DURING THE 2017 ECLIPSE

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During the August 21, 2017 solar eclipse over North America, the Enhanced Polar Outflow Probe (e-POP) traversed the path of totality at 640 km altitude over Idaho at 17:37 UT within 10 minutes of totality, which provided a unique vantage point for observing several significant effects of the eclipse on the topside ionosphere. We present observations from the imaging ion mass spectrometer (IRM) and GPS receiver-based attitude, positioning and profiling experiment (GAP) onboard showing that during the eclipse: (1) the topside plasma density decreased by a factor of two; (2) the light H+ ions exhibited a concurrent and significant (50%) drop in only the upward ion flux that was not accompanied by a corresponding drop in downward flux from the conjugate hemisphere; and (3) the resulting traveling ionospheric disturbances (TID) resulting from the eclipse had an apparent spatial scale of about 200 km and an amplitude of about 0.2 TECU (total electron content unit). In addition, observations from the radio receiver instrument (RRI) in conjunction with ground radio transmitters reveal a distinct reduction in radio absorption in the eclipsed ionosphere relative to non-eclipse ionosphere. These observations are attributed to the temporary cessation or reduction of photoionization in the F-region over the umbra and penumbra regions as the moon's shadow and the resulting maximum solar obscuration moves at supersonic speed across the continent.

C1.3-0015-18 IMPACT OF LOWER ATMOSPHERIC FORCING ON STORM TIME RESPONSE OF THE IONOSPHERE-PLASMASPHERE-MAGNETOSPHERE COUPLING

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This study aims to evaluate the impact of whole atmospheric coupling on storm time response in the ionosphere and plasmasphere during geomagnetically disturbed periods. The influence of coupling to terrestrial weather during storm time has drawn little attention. There are some unresolved questions: Whether or not the geo-effectiveness of magnetic storms could be changed when the upper atmosphere has been pre-conditioned by the lower atmospheric forcing; How does the lower atmospheric forcing modulate the recovery to a quiet level from a disturbed level? Recently, we have coupled the Ionosphere-Plasmasphere-Electrodynamics (IPE) model with the Whole Atmosphere Model (WAM) to investigate the connection between terrestrial and space weather. This presentation focuses on how some typical storm time phenomena in the ionosphere and plasmasphere are affected by the inclusion of forcing from below during geomagnetically active periods in simulations performed using the coupled WAM-IPE model. The presentation focuses on such phenomena as (1) temporal and spatial evolution of the Storm Enhanced Density (SED) plumes/Tongue of Ionizations (TOIs); (2) hemispheric asymmetry in SED plumes/TOIs; (3) Ionosphere-Plasmasphere-Magnetosphere Coupling via plumes and refilling, for the two St. Patricks' day storms in 2013 and 2015. The impact of lower atmospheric forcing is evaluated by comparing results with and without including forcing from below. Furthermore, the presentation discusses how the lower atmospheric forcing can influence the differences in storm time response in the ionosphere and plasmasphere.

C1.3-0016-18 IONOSPHERIC POLAR CAP PATCHES OBSERVED IN ANTARCTIC SUMMER USING SWARM

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Dense, fast-moving regions of ionization called patches are known to occur in the highlatitude F-region ionosphere. Patches are widely believed to be caused by convection of dense, sunlit plasma into a dark and therefore low-density polar cap. Therefore patches are not expected to be found in summer. Counter to previous reports, a long-term analysis of Swarm ionospheric measurements shows that patches typically occur in the same calendar months across both hemispheres, with very few around June in either hemisphere. This finding is surprising because it means there are many patches in southern hemisphere summer, and very few in southern hemisphere winter. Therefore current patch formation theories are incomplete and the physical cause of this annual variability remains unknown.

C1.3-0017-18 STORM-TIME IONOSPHERIC CONVECTION IN THE CENTRAL POLAR CAP

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Observations of the ionospheric convection during a storm main phase on 9th September 2011 were examined. Measurements were obtained by three SuperDARN radars (ZHO, SYE and MCM) located in the southern hemisphere, the conjunction of these 3 radars plays an important role in revealing the dynamic process in magnetosphere-ionosphere coupling system. During the storm period, MCM radar scanning polar cap ionosphere monitored sequential strong antisunward large-scale plasma irregularities, which clearly presents the highly structured polar cap patches moving across the pole to the nightside and eventually into the the nightside auroral oval in quasi-periodical variation. While the ZHO radar recorded intense ionospheric backscatter echo power and moderate Doppler negative velocity in the poleward boundary of the nightside auroral oval, and simultaneous observation by the optical auroral imager did not get aurora data. In the duskside sector, Doppler velocity monitored by the SYE showed irregular plasma structures towards or away from the radar site. Furthermore, ionospheric digisonde at Zhongshan station observed strong spread F during the storm main phase. Concerning this event, coordinated observations suggest that the ionospheric convection dominates the periodical plasma transportation during typical disturbed geomagnetic environment.

C1.3-0018-18 A STUDY OF COUPLED SOLAR WIND-MAGNETOSPHERE-IONOSPHERE DYNAMICS AND THEIR SPACE WEATHER IMPLICATIONS

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The solar wind is the principal medium through which the activity of the sun is communicated to the region of the Earth. The variability and interaction of the solar wind with the Earth's magnetosphere drives dynamic and variable conditions in the geo-space environment. The coupling effects of such perturbations on the ionosphere results in adverse conditions that can affect the performance and reliability of spaceand ground-based systems, and services that rely on them. In this study we investigate the effects of solar (and geomagnetic) induced variations in high-latitude ionosphere via the critical frequencies and virtual heights of radio sounding. We analyse solar wind speed (Vsw) and associated particle density (PD), geomagnetic Ap, disturbance storm time (Dst) index, and X-ray flux output, in association with ionospheric parameters (e.g. foF2, h'F2, foF1, h'f1, foEs, h'Es, foE, h'E) during 1-31 July 2000 and 1-31 July 2006. The periods represent intervals of high and low solar activity. We also simulate the orbital decay rate (ODR) of low Earth orbiting satellites (LEOSs) during these regimes, to infer the resultant effects of solar-induced ionospheric variations on satellites trajectory. Bulk of the effects of solar-driven ionospheric variations on LEOSs' ODR are mainly due to solar EUV and geomagnetic field-induced Joule heating, and consequent density increase. In modeling the ODR for two hypothetical LEOSs (having different ballistic coefficients), we show a strong connection between solar and geomagnetic activity, associated ionospheric disturbances and changes in ODR of the satellites.

C1.3-0019-18 MULTISCALE FIELD-ALIGNED CURRENTS: CHARACTERISTICS, CONTROLLING PARAMETERS, RELATIONSHIPS, AND CONNECTION TO IRREGULAR SPACE WEATHER ACTIVITY

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The magnetosphere, ionosphere and thermosphere (MIT) act as a coherently integrated system, driven in part by solar influences and space weather disturbances. It is now recognized that studying these regions under a 'system science' framework is a key path forward for advancing our understanding of space weather to the point of prediction. Fundamental to the success of system science in the MIT is the ability to describe coupling phenomena, especially in the highlatitude region where the effects are most direct. Field-aligned currents (FACs), or the system of currents flowing along Earth's magnetic field lines, are the dominant form of energy and momentum exchange between the magnetosphere and ionosphere. FACs are ubiquitous across the high-latitude regime and have unique characteristics depending on the magnetospheric or solar wind source mechanism, and, therefore, mapping location in the ionosphere (i.e. auroral zone, polar cap, cusp). Further complicating the picture, FACs also exhibit a large range of spatial and temporal scales. In order to create new understanding of FAC spatial and temporal scales, their cross-scale effects, and the impact on the polar region, new data analysis approaches are required.

We explore the characteristics, controlling parameters, and relationships of multiscale FACs using a rigorous, comprehensive, and cross-platform analysis. We present the repeatable behavior of FACs across scales (i.e., the characteristics), the dependence on the interplanetary magnetic field orientation, and the degree to which each scale "departs" from nominal large-scale specification. We find that the relationships between scales are complex and reveal new information about the connection between multiscale FACs and irregular space weather activity.

C1.3-0020-18 GLOBAL IONOSPHERIC RESPONSES TO SPACE WEATHER DISTURBANCES

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Solar coronal mass ejections and high-speed solar wind streams can cause geomagnetic storms, which have significant impact on Earth's magnetosphere, ionosphere, and thermosphere (M-IT). Coupling effects within the M-I-T system can dramatically and globally disturb the ionospheric state. We will present our research investigating ionospheric responses to space weather disturbances on global scales. Using ionospheric total electron content (TEC) measurements derived from GPS data, and Global Ionospheric Maps constructed using GPS data, we inspect the responses from high to low latitudes and at various local times and longitude sectors, according to different phases of space weather perturbations. Several approaches to characterizing the resulting disturbance patterns will be presented. These patterns could become essential to distinguishing major dynamical and chemical effects in the ionosphere in different regions, and to supporting the effort of forecasting space weather effects. Analyses of the responses to several storms, including the 2013 and 2015 St. Patrick's Day storms, using these approaches will be presented.

C1.3-0021-18 MIDDLE AND LOW-LATITUDE IONOSPHERE-THERMOSPHERE RESPONSES TO SOLAR WIND DRIVING DURING CME-TYPE STORMS

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We analyze ionosphere-thermosphere (IT) responses to driving by complex solar wind structures during strong storms at 15 minutes to about hourly time scales. We focus on lowand middlelatitude total electron content (TEC), global thermospheric infrared nitric oxide emission, composition ratio and locations of the auroral boundary obtained from multiple satellite platforms and ground-based measurements (GPS, TIMED/SABER, TIMED/GUVI, DMSP/SSUSI). We analyze IT storm dynamics in relation to the efficiency of solar wind-magnetosphere coupling and driving by particular solar wind structures. The impacts of direct external driving and of IT pre-conditioning in these storms are discussed. We identify IT effects that can be important for long-lasting strong storms.

C1.3-0022-18 FEBRUARY 2, 2017 OBSERVATION OF MAGNETIC IMPULSIVE EVENT (MIE) BY AUTUMNX AND VAN ALLEN PROBES

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Transient magnetic impulse events (MIE), lasting for 5-15 min have been frequently recorded by high-latitude ground-based magnetometers [Lanzerotti et al., 1991, Sibeck and Korotova, 1996]. Multiple theories of the cause and drivers of these events have been proposed for the dayside such as bursty reconnection (Glassmeier et al., 1984; Lanzerotti et al., 1986) and magnetic motion by pressure pulses due to abrupt changes in the Interplanetary Magnetic Field (IMF) (FriisChristensen et al., 1988; Sibeck et al., 1989); and for the nightside Field Aligned Currents (FAC) associated with plasmapause transients [Lanzerotti et al., 1991, Sibeck and Korotova, 1996]. In this work, we report on the simultaneous observation of a Magnetic Impulsive Event (MIE) on the nightside by ground based (Connors et al., 2017) and orbital detectors. On February 2, 2017, Canadian AUTUMNX ground stations on the east bank of the Hudson Bay in Quebec Canada and the MACCS CDRT ground station in Cape Dorset on Baffin Island, Nunavet, Canada recorded a large MIE with a negative surface z component of the induced magnetic field of -1,200 nT at the INUK station and a positive 500 nT at the CDRT station which is 647 km north. At the same time, the Van Allen Probes A spacecraft using the Radiation Belt Storm Probes Ion Composition Experiment (RBSPICE) and the Electric and Magnetic Field Instrument suite and Integrated Science (EMFISIS) DC magnetometer observed a magnetic pulse and associated changes in the energetic proton and electron particle distributions. We provide details of these observations as reported by the ground stations and the as well as the simultaneous changes to the magnetosphere as observed by the Van Allen Probes A and B instruments. Connors, M., D. Braun, Mark J. Engebretson, J. L. Posch, M. Kaur, S. Guillon,

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C1.3-0023-18 STATISTICAL STUDY OF IONOSPHERIC CONDUCTIVITY DEPENDENCE OF THE SUBAURORAL POLARIZATION STREAMS USING THE SUPERDARN HOKKAIDO EAST HF RADAR

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In this study, we investigate characteristics of the subauroral polarization streams (SAPS), focusing on ionospheric conductivity dependence, especially the solar zenith angle(SZA) dependence, using the Super Dual Auroral Radar Network (SuperDARN) Hokkaido East radar, National Oceanic and Atmospheric Administration (NOAA) Polar Operational Environmental Satellites (POES) system and Meteorological Operational Satellite Program of Europe (MetOp) system data. The time span for the present study is from 2008/1/10 to 2016/12/31, which contains over 3180 days, and we limited the time range of the analysis to 3-8 UT (12-17 LT). We found 60 SAPS events over seasons except for summer, and for each event we examined the SZA and the peak Line-of-sight velocity observed in the SAPS, in order to identify the threshold of the possible SZA and illuminated ionospheric altitude for SAPS to be generated. We have determined location of the echo region based on the straight ray path geometry with empirical offset value for multiple-hop paths, whereas in order to investigate the effect of HF propagation geometry and achieve a more precise mapping of scattering locations, we are trying to apply a new empirical virtual height model to the SuperDARN Hokkaido East radar, which uses different coefficients in the model when mapping backscatter targets propagate via different propagation paths. We also took into account the effect of EUV absorption in the atmosphere. As a result of the statistical study, we find that SAPS tend to appear when the SZA is larger than 98.5 degrees, and that the minimal threshold of illuminated ionospheric altitude for SAPS occurrence is estimated to be about 138 km, which is just above the altitude of the peak of Pedersen conductivity. This result suggests that the low background Pedersen conductivity plays an important role in the generation of SAPS through a positive feedback in which the enhanced electric filed drives frictional heating of the neutral atmosphere and thereby lowers the conductivity further. To the best of our knowledge, this is the first detailed study of

SAPS-associated SZA, and shows quantitatively the importance of Pedersen conductivity for SAPS generation.

C1.3-0024-18 PERFORMANCE OF IRI-PLAS MODEL WITH GIM-TEC INPUT DURING 2017 EQUINOX MONTHS

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International Reference Ionosphere (IRI) extended to Plasmasphere (IRI-Plas) is one of the most acclaimed climatic models of ionosphere that is used to obtain various parameters of ionosphere and plasmasphere such as electron density distribution, critical layer plasma frequency, maximum ionization height and ion and electron temperatures. IRI-Plas uses CCIR or URSI background hourly-monthly median model coefficients in determination of F2 layer critical frequency, foF2. All the other parameters are computed using this model foF2, foF2model. The two major drawback of all standard deterministic climatic models is that the hourly-monthly median values typically do not represent the current state of the ionosphere and the coupling of solar and geomagnetic activities into the ionosphere are represented by basic 12 month running averages of solar and ionospheric indices such as Sun Spot Number (SSN) and F10.7. As opposed to these standard models, IRI-Plas has two very important advantages. The first one is the input of GPS-TEC and the second one is user defined choice of 9 solar/ionospheric indices such as SSN1, SSN2, F10.7, Lyman-α, Mg II, IG, TEC, GEC, GECRZ. IRI-Plas can be downloaded from http://ftp.izmiran.ru/pub/izmiran /SPIM/ as a FORTRAN code. IONOLAB group provides user friendly online computation of IRI-Plas at www.ionolab.org with a choice of automatic input of all ionosonde station locations and, IGS and EUREF GPS receiver locations along with GIM-TEC values for all IGS Analysis Centers for the user defined location, date and time. In this study, IRI-Plas model F2 layer critical frequency, foF2model, is compared with ionosonde foF2, foF2iono, in Root Mean Square (RMS) and Normalized RMS (NRMS) sense for the equinox months of 2017, March and September. All available ionosondes are grouped into global, high-latitude, midlatitude and equatorial regions and northern and southern hemispheres are also considered as separate groups. It has been observed that URSI and CCIR models provide the same background globally both in March and September 2017.

The input of TEC is very successful in lowering the error fit to ionosonde foF2 if JPL GIMTEC input with IG index and Mg II are used in March and September 2017, respectively. For the overall midlatitude, high-latitude and equatorial best fitting choices are JPL GIM-TEC input with IG index (March) and Mg II or TEC

(September), IG or Lyman-α (March) and GECRZ (September), IG (March) and no input GEC and Lyman-α(September), respectively. This study is supported by TUBITAK 115E915.

C1.3-0025-18 IMPACT OF GEOMAGNETIC VARIATION OVER SUB-AURORAL IONOSPHERIC REGION DURING HIGH SOLAR ACTIVITY YEAR 2014

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The present work is an attempt to evaluate the sub-auroral ionospheric behavior under changing space weather conditions especially during high solar activity year 2014. In view of this, the GPS TEC along with Ionosonde data over Indian permanent scientific base "Maitri", Antarctica (70°4600 S, 11°4356 E) has been utilized. The results suggested that the nature of ionospheric responses to the geomagnetic disturbances mainly depended upon the status of high latitudinal electro-dynamic processes along with season of occurrence. Fortunately, in this study, both negative and positive ionospheric impact to the geomagnetic disturbances has been observed in a single year but in different seasons. The study revels that the combination of equatorward plasma transportation along with ionospheric compositional changes causes a negative ionospheric impact during summer and equinox seasons. However, the combination of poleward contraction of oval region along with particle precipitation may leads to exhibits positive ionospheric response during winter season. Other than this, some Ionosonde based new experimental evidences also provided clear evidence of particle precipitation deep up to the low altitudinal ionospheric heights i.e. up to E-layer by sudden and strong appearance of E-layer at 100 km altitudes. The sudden appearance of E-layer along with decrease in F-layer electron density suggested the dominance of NO+ over O+ at considered region under geomagnetic disturbed condition. The strengthening of E-layer is responsible for modification of auroral electrojet and field aligned current system. The present study provided a good scientific insight on sub-auroral ionospheric to the changing space weather condition.

C1.3-0026-18 CLASSIFICATION AND QUANTIFICATION OF SOLAR WIND DRIVER GASES LEADING TO INTENSE GEOMAGNETIC STORMS

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Classification and quantification of the interplanetary structures causing intense geomagnetic storms (Dst -100 nT) that occurred during 1997-2016 are studied. The subject of this consists of solar wind parameters of seventy-three intense storms that are associated with the southward interplanetary magnetic field. About 30.14% of the storms were driven by a combination of the sheath and ejecta (S+E), magnetic clouds (MC) and sheath field (S) are 26% each, 10.96% by combined sheath and MCs (S+C), while 5.48% of the storms were driven by ejecta (E) alone. Therefore, we want to aver that for storms driven by: (1) S+E. The Bz is high (10 nT), high density () (> 10 N/cm3), high plasma beta () (> 0.8), and unspecified (i.e. high or low) structure of the plasma temperature (T) and the flow speed (V); (2) MC. The Bz is 10 nT, low temperature (T 400000°K), low (10 N/cm3), high V (450 km), and low (0.8); (3) The structures of S+C are similar to that of MC except that the V is low (V 450 km); (4) S. The Bz is high, low T, high, unspecified V, and low ; and (5) E. Is when the structures are directly opposite of the one driven by MCs except for high V. Although, westward ring current indicates intense storms, but the large intensity of geomagnetic storms is determined by the intense nature of the electric field strength and the Bz. Therefore, great storms (i.e. Dst -200 nT) are manifestation of high electric field strength (13 mV/m).

C1.3-0027-18 OBSERVATION OF INTERMITTENCY-INDUCED CRITICAL DYNAMICS IN GEOMAGNETIC FIELD TIME SERIES PRIOR TO THE INTENSE MAGNETIC STORMS OF MARCH, JUNE AND DECEMBER 2015

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Criticality has been proposed as a suitable framework to study the nonlinear system of the Earth's magnetosphere. The magnetic field variations observed by the mid-latitude HellENIc GeoMagnetic Array (ENIGMA) with respect to the most intense magnetic storms (Dst < 150 nT) of the current solar cycle (i.e. 17 March, 23 June and 20 December 2015) are analyzed using the method of critical fluctuations (MCF). We show that the application of MCF to the ENIGMA time series reveals the existence of intermittency induced criticality in the range of 6 to 45 hours prior to the onset of these events. The results suggest that the underlying dynamical processes in the magnetosphere prior to intense magnetic storms present dynamics analogous to those of thermal systems undergoing second order phase transition.

C1.3-0028-18 THE TURBULENT PLASMASPHERE BOUNDARY LAYER

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We present multisatellite observations of enhanced plasma turbulence caused by substorminjected plasma jets penetrating into the plasmasphere and creating the turbulent plasmasphere boundary layer between the plasma sheet boundary at the pre-substorm plasmapause and the drop in the injected ion flux. A number of plasma instabilities develops during this highly dynamic process via interaction of the overlapping hot and cold plasma populations. The outcomes of the excited turbulence for the subauroral geospace, such as precipitation of the radiation belt electrons and collisionless heating and acceleration of plasma particles to suprathermal energies, which enhances the downward heat flux and concomitant heating of the ionospheric electrons, are described.

C1.3-0029-18 MID-LATITUDE IMPACT OF THE MEMORIAL DAY STORM 2017

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A slow-moving CME hit the earth on May 27-28, 2017 causing Kp to reach 7 and sparking largescale impact. This impact was widely observed at mid-latitudes, specifically in the F-region. We present here the observed impact of this storm at F-region altitudes using the Mid-latitude All-sky-imaging Network for Geospace Observations (MANGO), which is a network of 630nm imagers covering the continental United States, and detrended GPS total electron content data from the same region. The observations suggest that impact at sub and mid-latitudes was not limited to auroral enhancements at these latitudes, but also modulated wave propagation and airglow enhancements.

C1.3-0030-18 INTERMEDIATE SCALE IRREGULARITIES OBSERVED USING GPS SCINTILLATION DURING THE HALLOWEEN STORM OF 2003

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Superstorms are unusually strong storms where the Dst index reaches below -300 nT and understanding the effects of such space weather events is a key component of the National Space Weather Action Plan. Magnetospheric-Ionospheric coupling during extreme events can be very complex as compared to the more typical geomagnetic activity, thus the associated ionospheric irregularities (which are basically density structures in the ionosphere) can be different for superstorms. Ionospheric irregularities can cause rapid variations in amplitude and phase of radio waves (such as a satellite signal from global navigation satellite systems (GNSS)), referred to as amplitude and phase scintillation. Scintillation are due to diffraction and delays within ionospheric irregularities with scale sizes on the order of 0.1-100 km (intermediate-medium scales). We study the superstorm on Oct. 2003 (with Dst index below -300 nT), known as the Halloween event using GNSS scintillation observations, ground-based optical and incoherent scatter radar data. To complement the proposed data analysis efforts, we will use our physics based model of ionospheric plasma instabilities (GEMINI) and the EM wave propagation model (SIGMA) to propagate the GNSS signals through turbulent media to simulate scintillation on ground before and during the extreme event. Our models will be initialized with conditions consistent with available ISR and optical data during the time of interest. Based on our investigation, we predict the type of instability (Gradient Drift or Kelvin-Helmholtz) responsible for scintillation.

C1.3-0031-18 SIMULATIONS OF IONOSPHERIC DYNAMICS DURING A SUBSTORM

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We present numerical simulations of the coupled ionosphere-inner magnetosphere during a substorm interval on March 1, 2017. Simulation results of the chosen event intervals are obtained with the SAMI3-RCM ionosphere-magnetosphere coupled model. The latest version of the model includes a self-consistent 3-dimensional ionosphere responding to dynamic electric fields of magnetospheric origin as well as enhanced structured auroral electron precipitation. We compare these simulation results with co-incidental high precision GNSS receiver data providing local overhead total electron content (TEC) measurements at Poker Flat and Venetie (Alaska). Additional comparison will be presented with the Poker Flat Incoherent Scatter radar measurements of the rapid ionization enhancement in the 100-200 km region across multiple beams looking in the auroral region. The available SuperDARN data from this time period will also be used to determine the regional pattern of ionospheric flows. We will discuss these initial results to provide physical interpretation observed ionospheric dynamics during a substorm.

C1.3-0032-18 RECONSTRUCT SMALL-SCALE ELECTRIC FIELD IN THE HIGH LATITUDES USING DIFFERENT METHODS

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In the high latitudes, in addition to the large-scale background electric field there is a significant component of small-scale electric field or electric field variability. Its contribution to the Joule heating can be comparable to or even larger than the background electric field. While the significance of electric field variability to the Joule heating has been recognized, we still face a big challenge to describe it precisely and implement it in the GCMs appropriately. To improve our capability to specify the high-latitude electrodynamics, both traditional and machine-learning methods have been applied to the DE-2 and SWARM satellite measured electric field data. The reconstruction of small-scale electric field will be compared with empirical model and DMSP satellite observations. The influence on the upper atmosphere will be simulated through coupling with Global Ionosphere-Thermosphere Model (GITM).

C1.3-0033-18 HEMISPHERIC ASYMMETRIES IN IONOSPHERIC HORIZONTAL AND FIELDALIGNED CURRENTS FROM THE SWARM SATELLITE MEASUREMENTS

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The Swarm mission by ESA is the first ionospheric multi-satellite mission. Each of the three Swarm satellites carries magnetometers and other instruments that make e.g. measurements of plasma density and electric field. Analysis of the magnetic measurements by these satellites allow the determination of ionospheric horizontal and field-aligned currents (FAC) more accurately than ever before. In combination with the plasma and electric field measurements on the same satellite, these data can provide detailed information about electrodynamics of the ionosphere and the ionosphere-magnetosphere coupling processes. In this study, we use the spherical elementary current system (SECS) method for the analysis of the vector magnetic field measurements by the two parallel-flying Swarm satellites [Amm et al., 2015]. This method allows us to estimate the field-aligned currents, and the curl-free (cf) and divergencefree (df) components of the horizontal current. We will present statistical investigation of the high-latitude current systems based on 3 years of Swarm data on the Northern and Southern hemisphere at geomagnetic latitudes greater than 50o. The results show that generally the currents are more intense in the Northern hemisphere, but the difference has seasonal dependence. We have carried out model calculations to find possible reasons behind the observations.

C1.3-0034-18 FIRST RESULTS ON CLIMATOLOGICAL RESPONSE OF INDIAN LOW LATITUDE IONOSPHERE TO GEOMAGNETIC STORMS DURING SOLAR CYCLE 23 AND 24

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For the first time, a climatological response of low latitude ionosphere to geomagnetic storms is presented using long term global ionospheric maps (GIM) data from June 1998 to June 2015 covering two solar cycles 23 and 24. The results are not only the first from Indian region but also the first around the globe to bring latitudinal character of daytime ionospheric storms with use of newly defined criteria. The results are presented for daytime forenoon and afternoon sectors under minor, moderate and major ionospheric storm categories based on minimum Dst index criterion. For the first time the effectiveness of storms is identified using monthly standard deviation as an indicator of the day-to-day variability in equatorial and low latitude ionosphere. Thus results on climatology are definitive and form a data base that would be comparable to statistical results from any other longitude and time. Seasonal statistics for total storms, effective positive and negative storms, and amplitude of mean seasonal perturbation in total electron content are obtained. Total and effective storms are found to be higher in solar cycle 23 than in 24 and only couple of effective storms occurred during low solar activity 2007- 2009 that also in minor category. Afternoon sector is found to be favourable for occurrence of maximum number of effective positive storms. A latitudinal preference is found for a given storm to be effective in either time sectors. Equinoctial asymmetry in ionospheric response both in terms of occurrence and perturbation amplitude is found. September equinoxes are found to bear maximum total, effective positive and negative storms. Winters are found more prone to negative storms whereas summers have recorded minimum number of either of storms and minimum perturbation amplitudes.

C1.3-0035-18 POLAR CAP STRUCTURES AND DYNAMICS REVEALED BY TEC KEOGRAMS EXTRACTED FROM TEC MAPS

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Total Electron Content (TEC) keograms constructed from TEC maps used to study various polar cap structures and their dynamics. The TEC keongrams along various meridians from dayside lower latitudes to nightside lower latitudes in two cases studies revealed several interesting structures and their dynamics associated with corresponding Interplanetary Magnetic Field (IMF). Some of the structures such as polar patches were simultaneously identified by using SuperDARN radars as well. During the talk, we will discuss these results and their implications in Solar-Terrestrial coupling research as well as the use of TEC keograms in surveying polar cap structures.

C1.3-0037-18 PLASMAPAUSE DYNAMICS OBSERVED DURING THE 17 MARCH AND 28 JUNE 2013 STORMS

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Earth's plasmasphere is a region of cold (T 1 eV), dense (n 101 to 104 cm-3) plasma located in the inner magnetosphere and coincident with a portion of the ionosphere that co-rotates with the planet in the geomagnetic field. Plasmaspheric plasma originates in the ionosphere and fills the magnetic flux tubes on which the corotation electric field dominates over the convection electric field. The corotation electric field results from Earth's spinning magnetic field while the convection electric field results from the solar wind driving of global plasma convection within the magnetosphere. The outer boundary of the plasmasphere is the plasmapause, and it corresponds to the transition region between corotation-driven vs. convection-driven plasmas. When the convection electric field is enhanced during active solar wind periods, such as magnetic storms, the plasmasphere can rapidly erode to L 2.5 or less. During subsequent quiet periods of low solar wind speed and weak interplanetary magnetic field (IMF), ionospheric outflow from lower altitudes refills the plasmasphere over the course of several days or more, with the plasmapause expanding to higher L-shells. The combination of convection, corotation, and ionospheric plasma outflow during and after a storm leads to characteristic features such as plasmaspheric shoulders, notches, and plumes.

In this presentation, we focus on the dynamics of the plasmapause during two storms in 2013: March 17 and June 28. The minimum Dst for the two storms were -139 and -98 nT, respectively. We examine plasmapause dynamics utilizing data from an extensive global network of groundbased scientific GPS receivers (4000) and line-of-sight observations from the GPS receivers on the COSMIC and C/NOFS satellites, along with data from THEMIS and van Allen Probes, and Millstone Hill Incoherent Scatter Radar. Using the various datasets, we will compare the prestorm and storm-time plasmasphere. We will also examine the location, evolution, and erosion time scales of the plasmapause during the active portion of the storm using a combination of the observational data, the assimilative PDA model, and the RCM-E model.

C1.3-0038-18 FAILURES IN ELECTRICAL GRIDS IN SOUTHERN POLAND IN 2010 AND 2014 IN RELATION TO SPACE WEATHER EFFECTS

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The impact of space weather events on energy infrastructure via geomagnetically induced currents is very well known and widely studied since at least Quebec blackout on 13rd of March 1989. Those effects are not very extensively studied in relation to Polish energy infrastructure. Pulkkinen and coauthors (2005), describing the Halloween Storm's (October/November 2003) aftermath mentioned two episodes on SwePol Link cable (SwePol Link connects, under the Baltic Sea, Polish and Swedish energy infrastructure, by the 450 kV high voltage direct current).

Taking into account the conductances map of Europe (Viljanen et al., 2014) we consider the data of failures in electrical grids in the south part of Poland. Here we analyze two years during the ongoing solar activity cycle 24: 2010 (an early ascending phase of the cycle, near to solar minimum) and 2014 (solar maximum). We consider 228 failures in 2010 and 186 in the first half of 2014, which might be connected with space weather effects. We analyze data of unexplained breakdowns which occurred during the periods of an increased geomagnetic activity. Based on the data from The Institute of Meteorology and Water Management -National Research Institute (IMGW-PIB) we exclude from the consideration those failures which had meteorological causes.

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C1.3-0039-18 EFFECTS OF THERMOSPHERIC DENSITY AND COMPOSITION CHANGES DURING GEOMAGNETIC STORMS ON ION OUTFLOW

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The mass loading of the magnetosphere by ionospheric ion outflow has substantial effects on the evolution of geomagnetic storms, and methods for including this ion outflow in global geospace models are still under development. Most of the ion outflow models currently in existence use empirical specifications of the neutral thermosphere. Nonetheless, it is well established that the high-latitude energy dissipation during geomagnetic storms causes significant changes to thermospheric density and composition. We explore the effects of these changes on ion outflow using coupled geospace models. We model the thermospheric changes during storms using the Coupled Magnetosphere Ionosphere Thermosphere (CMIT) model, which combines the Thermosphere Ionosphere Electrodynamics General Circulation Model (TIEGCM) with the Lyon-Fedder-Mobarry (LFM) global magnetospheric magnetohydrodynamics model. We use TIEGCM thermospheric state variables from CMIT runs as inputs to the Ionosphere/Polar Wind Model (IPWM) to quantify the changes in ion outflow associated with changes in the thermosphere.

C1.3-0040-18 LOFAR SCINTILLATION MEASUREMENT AS A TOOL FOR PLASMA DIAGNOSTIC

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As a part of the The Low Frequency Array (LOFAR) network, the Polish station PL610 in Borówiec provides observational data useful for studying distant radio sources in a frequency range between 10-270 MHz. It can also be used to investigate weak scintillation regimes commonly found in mid-latitude ionosphere. Strong radio sources (such as Cassiopea A and Cygnus

A) and bright quasars have been observed in the local mode of the station to study ionospheric and interplanetary scintillations. As an EM wave propagates through a medium where electron density fluctuations are present, variations in the refractive index of this medium occur. Such density irregularities of interplanetary medium cause signal diffraction, producing diffraction patterns that can be used to obtain estimates on the local speed of solar wind. Moreover, since observations carried out in low frequency range are more sensitive to ionospheric disturbances than in higher frequencies, they can provide information on irregular structure of this layer that influences f.e. low frequency radioastronomy and radio communication. By using raw amplitude measurements over full bandwidth of LOFAR, daily statistics of ionospheric scintillation index S4 have been determined, which is a common parameter describing ionosperic disturbances. Very good frequency and time resolution of LOFAR observations enable studying dynamical changes of the S4 index, through which changing conditions of ionospheric layer can be monitored. We present examples of analysis of LOFAR observational data, including theoretical background of such analyses and scattering properties of solar wind and ionospheric disturbances.

C1.3-0041-18 GNSS AS A GLOBAL OBSERVING SYSTEM FOR DISTURBED IONOSPHERE STUDY

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Techniques based on the transionospheric radio waves propagation, in particular Global Navigation Satellite Systems (GNSS), has been effectively used during several decades for ionospheric climatology research as well as for monitoring and study of main parameters of ionospheric plasma disturbances. The number of the ground-based receivers within the global and regional GNSS networks grew significantly from several hundred worldwide in the 1990s to more than 6000 stations today. Many of operated Low-Earth-Orbit satellites are also equipped with dualfrequency GNSS receivers and give possibilities to estimate ionosphere plasma density above and below LEO orbit and to detect ionospheric irregularities signatures at high altitudes. The proven and most informative in a global scale Radio Occultation (RO) technique also based on GNSS signal parameters analysis. Ground-based GNSS networks, COSMIC RO constellations and LEO GPS provide continuous measurements of navigation signals parameters, that allows to consider these facilities as a global observatory for permanent monitoring of ionospheric plasma density spatial distribution and its dynamics. We present results demonstrating advantages of using dense ground-based GNSS networks, COSMIC RO data and products as well as LEO GPS observations for investigation of ionospheric responses on Space Weather drivers and focus on representative case studies during the 2015 severe geomagnetic storms. In this study, we investigate signatures of the large-scale traveling ionospheric disturbances (LSTIDs) recognized in the ground-based total electron content (TEC) and storm-induced ionospheric plasma density irregularities caused by auroral particles precipitations, plasma gradients associated with SED/TOI (storm-enhanced density / tongue of ionization) formation and storm time plasma bubbles development. Also, we present recent results of GNSS TEC analysis of the ionosphere's response to the 21 August 2017 solar eclipse.

C1.3-0042-18 EFFECT OF GEOMAGNETIC STORM CONDITIONS ON THE EQUATORIAL IONIZATION ANOMALY AND EQUATORIAL TEMPERATURE ANOMALY

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The effect of the geomagnetic storm on the equatorial ionization anomaly (EIA) and equatorial temperature anomaly (ETA) has been studied using the atomic oxygen dayglow emissions at 577.7 nm (OI 557.7 nm) and 732.0 nm (OII 732.0 nm). For the purpose of this study, four intense geomagnetic storms during the ascending phase of solar cycle 24 have been considered. This study is primarily based on the results obtained using photochemical models with necessary inputs from theoretical studies and experimental observations. The latest reaction rate coefficients, quantum yields, and the corresponding cross-sections have also been incorporated in these models. The volume emission rate of airglow emissions has been calculated using the neutral densities from NRLMSISE-00 and charged densities from the IRI-2012 model. The modeled volume emission rate (VER) for OI 557.7 nm shows a positive correlation with the Dst index at 150 km and negative correlation with Dst at 250 and 280 km altitudes. Latitudinal profile of the green line emission rate at different altitudes shows a distinct behavior similar to what has been observed in EIA with crests on either side of the equator. The EIA crests are found to show poleward movement in the higher altitude regions. The volume emission rate of 732.0 nm emission shows a strong enhancement during the main phase of the storm. The changes observed in the airglow emission rates are explained with the help of variations induced in neutral densities and parameters related to EIA and ETA. The latitudinal variation of 732.0 nm emission rate is correlated to the variability in EIA during the storm period.

C1.3-0043-18 EQUATORIAL SATELLITE DRAG EFFECTS DURING SUPER MAGNETIC STORMS

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Prompt penetration electric fields (PPEFs) associated with intense magnetic storms have been found to uplift the dayside ionosphere through E×B forces near the magnetic equator. This effect is known as the “dayside superfountain effect”. The upward moving O+ (oxygen ions) will elevate the oxygen atoms to higher altitudes via the ion-neutral drag forces between the two particle species. The uplifted oxygen ions and neutrals could produce extra drag on low orbiting satellites. This paper presents a linear calculation on the satellite drag effect during a 1859- type (Carrington) superstorm. The analysis shows that uplifted oxygen neutral densities at low-Earth-orbiting (LEO) satellite altitudes may be sufficiently high to present severe satellite drag. It is estimated that with a prompt penetrating electric field of 20 mV m-1 turned on for 20 min, the O atoms and O+ ions are uplifted to 850 km where they produce about 40 times greater satellite drag per unit mass than normal. Stronger electric fields will presumably lead to greater uplifted mass.

C1.3-0046-18 SWARM DUAL SATELLITE OBSERVATION OF LONGITUDINAL VARIATION OF FIELD-ALIGNED CURRENTS

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In this study we investigated the longitudinal variations in the mean densities of field-aligned currents (FACs) at high latitudes in different seasons, by using magnetic field data from SWARM A and C satellites. There appears a wave-1 longitudinal structure in FACs in both hemispheres. Longitudinal variations are about a factor of 1.2-3.2 larger in the Southern Hemisphere than in the Northern. Variations in solar illumination can explain certain longitudinal variations in FACs, with more solar illumination and stronger FACs at near pole longitudes than at far-from-pole longitudes. On the nightside in the local winter a higher value of FACs is generally associated with more intense auroral precipitation in the same area. The theoretical study from the global ionosphere and thermosphere model revealed that the role of neutral wind is comparable to that of electric field in the longitudinal modulation of FACs. A tidal analysis was applied to both FACs and cos0.5(SZA) (SZA= solar zenith angle). FACs contain a large DW2 component, in particular during summer and equinox, which is absent for cos0.5(SZA). Factors like the geomagnetic field strength, conductivity gradient, and dipole tilt angle might contribute to the observed DW2 features in FACs.

C1.3-0047-18 ON GEOMAGNETIC STORMS AND IONOSPHERIC RADIO WAVE ABSORPTION IN THE EQUATORIAL REGION: A PHILOSOPHICAL REINFORCEMENT

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Investigations using radio waves reflected from the ionosphere, at high-and mid-latitudes indicate that ionospheric absorption can strongly increase following geomagnetic storms; which appears to suggest some definite relationship between ionospheric radio wave absorption and geomagnetic storms at these latitudes. However, corresponding earlier studies in the equatorial region did not appear to show any explicit relationship between ionospheric radio wave absorption and geomagnetic storm activity. This position appeared acceptable to the existing scientific paradigm, until in an act of paradigm shift, by a change of storm selection criteria, some more recent space weather investigations in the low latitudes showed that ionospheric radio wave absorption in the equatorial region clearly increases after intense storms. Given that these results in the equatorial region stood against the earlier results, this paper presently attempts to highlight their philosophical underpinning and posit that they constitute a scientific statement.

Keywords: Geomagnetic storm, A3 method, Ionosphere, Radio wave absorption, Equatorial Region, Popper’s Demarcation Rule.

C1.3-0048-18 ON IONOSPHERIC PHENOMENA DURING PRE-STORM AND MAIN PHASE OF A VERY INTENSE GEOMAGNETIC STORM

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An investigation to elucidate the mechanisms responsible for the pre-storm and main phase ionospheric phenomena during November 20-21, 2003, is presented using heliophysical, interplanetary, geomagnetic, and global ionospheric data. The results show that the ionospheric responses in the main phase do not indicate prompt penetration electric fields as the main ionospheric driver. The results also show that the prestorm phenomena do not originate from a local time effect. The simultaneous occurrence of foF2 enhancements at two widely separated longitudinal zones appeared to suggest a role played by the magnetospheric electric field. However, the analysis of hmF2 at the stations could not confirm the notion that these fields are the main drivers of pre-storm phenomena. An investigation of flare effects on the pre-storm phenomena also revealed that solar flares are not the main drivers. The present results appear to suggest that the pre-storm ionospheric phenomena could be a result of some underlying mechanisms that are working together with varying degree of importance.

Keywords: geomagnetic storm, solar X-rays, solar wind, shock gas, ionosphere, pre-storm phenomena.

C1.3-0049-18 UNEXPECTED SOUTHERN HEMISPHERE IONOSPHERIC RESPONSE TO GEOMAGNETIC STORM OF 15 AUGUST 2015

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When studying the ionospheric response to a geomagnetic storm of 15 August 2015, an unexpected phenomenon was observed at higher middle latitudes of the Southern Hemisphere. This phenomenon was a localized TEC enhancement (LTE) in the form of two separated plumes, which peaked southward of South Africa. The plumes were first observed at 5 UT near the southwestern coast of Australia. The southern plume was associated with local time slightly after noontime (1-2 hours after local noon). The plumes moved with the Sun. They peaked near 13 UT southward of South Africa. The southern plume kept constant geomagnetic latitude (63-64oS); it persisted for about 10 hours, whereas the northern plume persisted by about two hours more. Both plumes disappeared over the South Atlantic Ocean. No similar LTE event was observed during the prolonged solar activity minimum period of 2006-2009. In 2012-2016 we detected altogether 26 LTEs and all of them were associated with the southward excursion of Bz. The negative Bz excursion seems to be necessary but not sufficient condition for the LTE occurrence.

C1.3-0050-18 SELF-CONSISTENT MODELING OF ELECTRON PRECIPITATION AND RESPONSES IN THE IONOSPHERE: APPLICATION TO LOW-ALTITUDE ENERGIZATION DURING SUBSTORMS

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We report a new modeling effort that self-consistently couples the physics-based magnetospheric electron precipitation to its impact on the ionosphere, representing significant improvement over previous modeling capabilities, in which the ionosphere is either treated as a 2D spherical boundary of the magnetosphere, or is driven by empirical precipitation models that are incapable of capturing small-scale, transient variations. In specific, we two-way couple a kinetic ring current model RAM-SCBE with a two-stream electron transport code GLOW. The newly coupled model allows us to examine the impact of substorm-associated, short-lived energetic electron precipitation on the 3D ionosphere. It is found that during substorms, precipitating energetic electrons (10<E<100 keV) resonantly scattered by whistler-mode waves exhibit as a high-energy tail in the spectra at the top of the ionosphere. Subsequently, an ionospheric sub-layer characterized by enhanced Pedersen conductivity arises at unusually low altitude (85 km) at auroral latitudes in the midnight-to-noon sector. The intermittent occurrence of the sub-layer is strongly correlated with recurrent substorm injections. This layer structure, which often appears transient in observations, propagates eastward in accordance with the drift path of source electrons in the magnetosphere, resulting in a global impact within the ionosphere. Such a global structure may provide insights on the large-scale current closure in the coupled magnetosphere-ionosphere system during substorms, and further indicates the necessity of using a self-consistent modeling capability for studies of a fully coupled system.

C1.3-0051-18 THE STUDY OF CORONAL HOLES FROM 2015 TO 2017 YEARS

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The systematic study of coronal holes began in the late 1970s with the coordinated scientific program of observations of the SkyLab orbital observatory and ground-based observations in the HeI 1083nm line (Kitt Peak Observatory, USA). In the Soviet Union began to study coronal holes employees of the Laboratory of Sun Physics of the Crimea Astrophysical Observatory since the late 80's under the leadership of N.N. Stepanian on the spectral heliograms data of the universal spectrophotometer of the BST-2 telescope in the HeI 1083nm line. The analysis of the observations obtained from the data of the spacecraft ACE / SWEPAM showed that coronal holes are the only sources of fast solar wind (> 450 km / s) on the quiet Sun. Thus, the previously obtained results were confirmed [1]. The SDO / AIA 19.3 nm, CRAO / TST2 HeI 1083 nm data and calculate PFSS models (for more accurate coronal hole detection) were analyzed on the quiet Sun from 2015 to 2017 years. A direct relationship between the change in the area of coronal holes single polarity and the speed of the solar wind for whole visible disk was obtained. With the growth of the coronal hole area, the speed of the solar wind increases and vice versa. A correlation coefficient of 0.7 is obtained. The connection between a giant coronal hole and space weather phenomena was analyzed.

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C1.3-0052-18 VARIATION OF RADIATIVE COOLING AND NITRIC OXIDE ABUNDANCE DURING INTENSE GEOMAGNETIC STORMS AS OBSERVED BY TIMEDSABER AND GUVI

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The variation of O/N2 (reference to N2 column density 1017 cm−2) and nitric oxide radiative emission flux exiting the thermosphere have been studied over the northern hemisphere during the super-storm event of November 7-12, 2004. The data have been obtained from GUVI and SABER onboard the NASA's TIMED satellite. The NO radiative flux is observed to show an anti-correlation with O/N2 on a global scale. Both NO radiative flux and O/N2 ratio show equatorward motion with maximum penetration in western longitude sectors. A local variation of O, O2 and N2 densities have been calculated using NRLMSISE-00 model over a mid latitude location (55°N,180°E). On a local scale, model calculated O/O2 and O/N2 ratios are found to follow the observations made by GUVI. The collisional excitation of NO with atomic oxygen is the most dominant process for the total cooling rate. The SABER retrieved NO cooling rate (CR) at a local site suggests an enhancement during the storm period with the peak emission rate closely correlated to the progression of the storm. The peak emission altitude of NO CR moves upward during the main phase of the storm. The NO abundance has been calculated by using cooling rate and Nitric Oxide Empirical Model (NOEM) model. Both these suggest a vary large (3-15 times) increase in NO density during the storm which is required to account the changes in NO radiative flux. A similar kind of enhancement in NO abundance is also noticed in Student Nitric Oxide Explorer observations during intense geomagnetic storms.

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C1.3-0053-18 A STUDY OF FOF2 ANOMALY DURING INTENSE GEOMAGNETIC STORMS OF THE 24TH CYCLE

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The foF2 is an important ionospheric parameter and any change in foF2 during geomagnetic storms reveals important aspects of M-I coupling .15 intense (Dst<-nT) geomagnetic storms of the 24th cycle were identified by observing the dst indices. In order to study the effect of these geomagnetic storms on the ionosphere foF2, ionosonde data for stations in the latitudinal range 30°N to 30°S and three different longitudinal ranges (-149 to-159.8) ,(72.6 to -88) and (142.3 to 152.4) were recorded.The effect of geomagnetic storms on the F2 region was studied by calculating the deviation foF2 of foF2 during storm time .Though Negative phase of foF2 was predominant Positive phase were also observed for a few events at a few stations.

C1.3-0054-18 MAGNETOSPHERIC-IONOSPHERIC COUPLING DURING THUNDERSTORM LIGHTNING AS OBSERVED FROM ENERGETIC PARTICLE BURST (C3.2)

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Lightning discharge originates electromagnetic waves propagating in all directions through the earth-ionosphere waveguide. A small component of such wave enters into the earth magnetosphere and propagates along the magnetic field lines as a whistler mode wave. During this propagation, they interact with radiation belt electrons and due to this some of the electrons get trapped or precipitated in the ionosphere as a sporadic patch of excess ionization. The trapping electrons increase the count rate in the inner radiation belt and this particle count rate can be measured through satellite observation. Low Earth Orbital (LEO) satellite observes count rate of energetic particle burst in Van Allen Radiation Belt. We mainly use data from Medium Energy Proton and Electron Detector (MEPED) instrument associated with NOAA 15 satellite for this study. We use WWLLN network and global lightning data to get the lightning information. A significant increase of count rate is observed in MEPED data. We also corroborate our findings by the excess ionization due to lightning as observed from amplitude modulation of Very Low Frequency radio signal.

C1.4-0001-18 REGIONAL DIFFERENCES IN CLIMATE CHANGE OF THE IONOSPHERE

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The increasing concentration of greenhouse gases, particularly carbon dioxide CO2, in the atmosphere affects not only the troposphere and surface climate, it affects the whole atmosphereionosphere system and it induces long-term trends and/or climate change in the ionosphere. The geographic distribution of CO2 in the upper atmosphere/ionosphere is relatively homogeneous and the long-term increase of CO2 concentration in the atmosphere is known to be stable. However, there are some other secondary drivers of long-term trends in the upper atmosphere/ionosphere, whose long-term behavior and/or effects either are not spatially homogeneous or are not stable in time (or both). Geomagnetic activity, solar activity, secular change of the Earth's magnetic field, long-term evolution of stratospheric ozone concentration and atmospheric wave activity are such trend drivers. They are responsible for regional differences in trends and also for their temporal non-stability. Regions of strong trends as a consequence of regional differences of trends represent a specific kind of risk from the point of view of space/ionospheric climate. These features of ionospheric trends will briefly be treated in this presentation.

C1.4-0002-18 THE IMPACT OF SPACE WEATHER ON THE IONOSPHERE

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Space Weather is not only an up-to-date but also an interesting research topic and has a significant importance for modern society. As a matter of course, technical progress also means an increasing vulnerability of technical systems. Space weather events, i.e. solar superstorms like the prominent Carrington event from 1859, will have an enormous impact on our technical systems and infrastructure and can even lead to their collapse. In recent years some solar storms have happened, like the Halloween storm in 2003 or the St. Patrick's storm in 2015, but there was no event in a dimension like the Carrington event. Therefore it remains unclear which effects in numbers a solar superstorm would have for ionosphere, Earth and society. The IAGICCT Joint Study Group 0.20 (JSG0.20) is exactly working on this subject, i.e. the JSG 0.20 investigates the impact of a solar superstorm on different technical systems. For this purpose, it is necessary to simulate such an extreme event and to produce data representing the storm. Based on this, the effect of a solar superstorm on different technical issues can be examined. This presentation describes the basic considerations and thoughts, serving as a guide to simulate datasets for, e.g., the planetary K-index, the F10.7 index and the ionosphere in the case of an occurring solar superstorm. In this contribution we regard to the mutual relations of the above mentioned parameters. Furthermore, the ionosphere requires a detailed investigation w.r.t. its temporal and spatial behaviour during a superstorm as well as the strength of ionisation. The methods and computations to study ionospheric storm-time characteristics will be represented.

C1.4-0003-18 WIDE SENSE STATIONARITY PERIOD OF SLANT AND VERTICAL TOTAL ELECTRON CONTENT IN DETERMINATION OF TEMPORAL CORRELATION OF MIDLATITUDE IONOSPHERE

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The temporal correlation of ionosphere as observed by Total Electron Content (TEC) estimated from ground based dual-frequency GPS receivers plays an integral role in monitoring the structural variability. Wide Sense Stationarity (WSS) indicates the period where the first and second moment of a random process (ie mean and autocorrelation functions) stay constant. In modeling spatio-temporal variability of TEC as a random field, the WSS can represent the optimum duration where the statistical structure can be tracked to reduce the near-real time computational load. In this study, WSS periods of Slant TEC (STEC) and Vertical TEC (VTEC) are investigated over regional networks of Czech Republic and Turkey for the years of 2010 to 2012. The TEC values are estimated as IONOLAB-STEC and IONOLAB-TEC. The novel algorithm which is developed to determine the WSS period of TEC data is named as IONOLAB-WSS. All the GPS stations that were active in the Permanent GPS Networks of EUREF, TNPGN and TNPGN-Active are incorporated. The GPS stations are classified into subregional sections of 20x30 in latitude and longitude, respectively. The satellites are grouped into east, west, north and over directions according to their IPP tracks of each subregion. The day is divided into five periods according to solar diurnal movement. The year is divided into seasons reflecting ionospheric trend structure. It has been observed that the WSS of midlatitude ionosphere has a median value of 7.5 to 11 min, independent of region, subregion, satellite track, time of the day, and seasonal variation. The WSS reduces to 3 to 5 min during severe geomagnetic storms or ionospheric disturbances. For quiet and non-disturbed periods, the WSS can be as long as 13 to 15 min. The results indicate the importance of optimum temporal update periods of near-real time monitoring systems that are under heavy computational burden. This study is supported by TUBITAK 115E915 and joint TUBITAK 114E092 and AS CR 14/001.

C1.4-0004-18 MID-LATITUDE TROUGH RESPONSE TO THE GEOMAGNETIC ACTIVITY

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Mid-latitude trough is characteristic structure of the ionosphere, that is observed in great majority during the nighttime. The phenomenon manifests itself as a significant depletion in the electron density, which can be found in the sub-auroral region of the top side ionosphere. In favorable conditions when insolation is limited at higher latitudes (e.g. during local winter), the main ionospheric trough can occur extended for almost whole range of the geomagnetic longitudes. It is well known that trough is highly sensitive to dynamic geomagnetic conditions. Especially distinct feature is that the trough properties change accordingly to the geomagnetic storm phase. In particular it moves equatorward with the storm onset, and as the storm develops it narrows and deepens. This paper provides the qualitative and quantitative answer for the question how the geomagnetic activity impacts the mid-latitude trough characteristics. The studies are based on the data set provided by DEMETER mission in 2005-2010.

C1.4-0005-18 LATITUDINAL ASYMMETRY DURING THE LARGEST IONOSPHERIC STORMS OF THE SOLAR CYCLE 23.

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Latitudinal asymmetry has been observed in NmF2 variation during the largest ionospheric storms. Five (5) storms have been analyzed individually to unravel succinct information about the flow of plasma across the F layer of the atmosphere during positive ionospheric storms. Ionosonde records from four (4) stations in the northern hemisphere were employed. The ionospheric NmF2 profile was obtained after removing quiet-time variations such that only the strongest positive ionospheric storms that could clearly be identified from their profiles were considered. Analysis of the Time series of these ionospheric storms showed clear latitudinal dependence. These positive ionospheric storm variations are discussed in view of composition changes and the role played by asymmetric geomagnetic field.

C1.4-0006-18 VARIABILITY OF THE SUN AND ITS TERRESTRIAL IMPACT (VARSITI): RESEARCH ACTIVITIES ON SPACE WEATHER AND SOLAR EFFECTS ON CLIMATE

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The Scientific Committee On Solar-TErrestrial Physics (SCOSTEP) operates the scientific program "Variability of the Sun and Its Terrestrial Impact" (VarSITI, http://www.varsiti.org/) in 2014-2018 to focus on the recent and expected future solar activity and its consequences for the Earth, for various time scales from the order of thousands years to milliseconds, and for various locations and their connections from the solar interior to the Earth's atmosphere. During the last solar minimum in 2008-2009, solar activity was extremely low for an extended period, and the maximum of sunspot cycle 24 is the lowest in the last 100 years. It is not clear how this long-term solar activity variations influences the geospace and global climate change. It is also not clear how the short-term solar activity variations, such as solar flare and CME influences the geospace and the Earth's atmosphere. In order to elucidate these various Sun-Earth connections, we encourage close communication between solar scientists (solar interior, atmosphere, and heliosphere) and geospace scientists (magnetosphere, ionosphere, and atmosphere). Four scientific projects are carried out under the VarSITI program: (1) Solar Evolution and Extrema (SEE), (2) International Study of Earth-Affecting Solar Transients (ISEST/MiniMax24), (3) Specification and Prediction of the Coupled Inner-Magnetospheric Environment (SPeCIMEN), and (4) Role Of the Sun and the Middle atmosphere/thermosphere/ionosphere In Climate (ROSMIC). In this presentation, we review recent scientific results related to the VarSITI activities on the space weather researches and solar influence on climate change.

C1.4-0007-18 VARIATIONS OF REGIONAL VTEC MODEL DUE TO IONOSPHERIC SCINTILLATION OCCURRENCE

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Global Navigation Satellite Systems (GNSS) which are extensively used for various purposes such as navigation, surveying, remote sensing and telecommunication, are strongly affected by the Earth's upper atmosphere, the ionosphere. Ionosphere is a very complex medium that is ionized by the radiation of high energy particles from Sun and cosmic rays. When a GNSS electromagnetic signal passes through this region, it may experience rapid amplitude fluctuations or an unexpected phase change, which is referred to as ionospheric scintillation. Ionospheric scintillation is caused by small scale irregularities in the electron density and is one of the dominant propagation disturbances for microwave signals. These irregularities severely affect the accuracy and reliability of GNSS measurements; therefore it is necessary to investigate ionospheric scintillation and its effects on GNSS observations. The focus of this paper is to detect ionospheric scintillation effects on GPS observations and also on regional Vertical Total Electron Content (VTEC) models over Iran's region, during different periods of solar activity. The results show that effectiveness of this phenomenon depends on geographic location, local time, and global geomagnetic storm index (kp index). The required data for this study are the ground-based measurements of permanent GPS stations over Iran (IPGN), established by the National Cartographic Center of Iran (NCC).

C1.4-0008-18 CLASSIFICATION OF IONOSPHERIC IRREGULARITIES OVER TURKEY IN 2012 USING DROT ON STEC

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Ionosphere causes variable time delays on GPS signals. Variable time delays affect both timing and positioning of GPS receivers. GPS position errors are mainly originate from satellite clocks, orbit errors, receiver noise, multipath, troposphere, and ionosphere. Consequently, the ionosphere is the largest source of error in GPS receivers. General values of position errors due to ionosphere are approximately 5 m and 30 m for ionospheric quiet and disturbed days, respectively. Therefore, detection and estimation of ionospheric irregularities are very important for precise positioning. Most of ionospheric disturbances are modeled as wave-like oscillations which have constant velocity, direction, wave front slope, and frequency. One of the most important ionospheric parameter is Slant Total Electron Content (STEC) for investigating the ionospheric disturbances. STEC is defined as total number of electrons along a ray path from satellite to receiver. Wave-like ionospheric disturbances cause oscillations on STEC values. Differential Rate Of TEC (DROT) is a new algorithm for automatic detection of wave-like oscillations on STEC and TEC. It is defined as intensity of difference between ROT and its trend. In order to detect wave-like disturbances over Turkey, STEC estimates obtained from Turkish Permanent GPS Network Active (TNPGN-Active) by using IONOLAB-STEC method. DROT values are computed by using STEC estimates for each receiver-satellite pair and each day. Subsequently, DROT values are classified into three categories as higher than %70 (Category 3), between %50 and %70 (Category 2), less than %50 (Category 1). Category 3 DROT values indicate that there might be Large Scale Ionospheric Disturbances (LSTIDs) or some strong TIDs. For the purpose of detection of time and direction of disturbance, Category 3 DROT values are classified into four groups according to satellite tracks as north, east, west and over. Occurrence percentage of category 3 DROT values observed daily for each direction during 2012. It is observed that Category 3 occurrence percentage decreases in summer whereas percentages get high values in winter for all directions. For east direction and in spring, category 3 DROT occurrence percentages are less than other directions. It is observed that, the most affected direction from the wave-like disturbances is west for all seasons. This study is supported by TUBITAK 115E915 and joint TUBITAK 114E092 and AS CR 14/001.

C1.4-0009-18 EFFECT OF IONOSPHERE AND PLASMASPHERE ON GEOSTATIONARY COMMUNICATION SATELLITE SIGNALS

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Geostationary orbit (GEO) communications satellites allow radio, television, and telephone transmissions to be sent live anywhere on Earth. They are extremely important in daily life and also for military applications. Since, satellite communication is an expensive technology addressing crowd of people, it is critical to improve its performance. Radio frequency ranges C, X, Ku, Ka and V-band are used in satellite communications. Satellite signals are disturbed by atmospheric effects on the path between the satellite and the receiver antenna. These effects are mostly cloud, rain and gaseous attenuation. It is expected that ionosphere and plasmasphere have a minor effect on the satellite signals when the ionosphere is quiet. But there are anomalies and perturbations on the structure of ionosphere with respect to geomagnetic field and solar activity and these conditions may cause further affects on the satellite signals. In this study IONOLAB-RAY algorithm is adopted to examine the effect of ionosphere and plasmasphere on satellite signals. IONOLAB-RAY is developed to calculate propagation path and wave parameters of high frequency signals. The algorithm does not have any frequency limitation and models ionosphere and plasmasphere up to 20,200 km altitude, so that propagation between a GEO satellite and antenna on Earth can be simulated. The algorithm models inhomogeneous, anisotropic and time dependent structure of the ionosphere with a 3-D spherical grid geometry and calculates physical parameters of the ionosphere using IRI-Plas software. One of the outstanding features of IONOLAB-RAY is the opportunity of Total Electron Content (TEC) assimilation. This feature enables more realistic representation of ionosphere, especially for the times when ionosphere deviates from the generalized models, such as during geomagnetic storms. This feature is critical to examine the effect of ionosphere and plasmasphere on satellite signals under ionospheric storm conditions. In this study the effect of ionosphere and plasmasphere on the signal propagating from Earth to GEO satellite by comparing the attenuation and time delay calculated by IONOLAB-RAY for the scenarios of calm date and time with respect to storm date and time. This study is supported by TUBITAK 115E915 and joint TUBITAK 114E092 and AS CR 14/001. Keywords: Ionosphere, IRI-Plas, GEO Satellite, Satellite Communication, IONOLAB.

C1.4-0011-18 GEOSPACE STORM INDUCED SUBAURORAL AND MIDLATITUDE IONOSPHERIC DENSITY DISTURBANCES BASED ON GNSS AND INCOHERENT SCATTER RADAR OBSERVATIONS

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Large plasma density gradients have severe impact on modern radio communication and technology applications in general. Particularly for midlatitudes where the dense population resides, the geospace storm induced significant gradients, Storm Enhanced Density (SED) plumes, for instance, have been a main concern for its space weather consequences, and also a research topic of strong scientific interest. With the use of dense networks of GNSS receivers for total electron content (TEC) observations, SED structures are getting readily visualized with unprecedented details. It is generally believed that SED plumes are generated through a very dynamical process where the zonal (westward) ion drift — in the form of either Sub-Auroral Polarization Stream (SAPS) and expansion of polar convection — and northward (upward) ion drift associated the meridional component of ion convection (perpendicular to the magnetic field line) or penetration electron field induced upward ion drift, work jointly to transport plasma to high altitudes as well as poleward and westward into the dayside cusp region. In this study, using GNSS TEC and incoherent scatter radar observations at Millstone Hill and elsewhere, we discuss some stormtime subauroral and high latitude plasma dynamical processes that link SED, tongue of ionization (TOI) in the polar region and polar cap patches. We discuss also evolution of these plasma density gradients during the geospace storm. We focus on the 2015 St Patrick's Day event.

C1.4-0012-18 REGIONS OF INTEREST FOR CHARGED DRAG ON SMALL SATELLITES USING GITM DATA

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Recent research has indicated that the contribution of charged drag to total atmospheric drag on satellites in low-earth orbit (LEO) may be more significant than is usually assumed. The research presented here suggests these forces may be as strong as 25% of the drag force due to the neutral atmosphere at some times and locations. This work utilises data from the Global Ionosphere-Thermosphere Model (GITM), along with recent analytical work used to quantify LEO plasma-body interactions, to identify regions of Earth's upper atmosphere where spacecraft experience higher forces due to charged drag. The space weather conditions that lead to the formation of these regions are also described. In order to quantify the effect of the charged environment on satellites, the forces over a variety of simple orbits are integrated to show the work done by charged drag on these satellites. The implications of these regions of enhanced drag to the problems of satellite drag calculations, maneuvers by charged spacecraft, and the broader field of space situational awareness will be discussed.

C1.4-0013-18 COMPARISON OF IRI-PLAS MODEL WITH EQUATORIAL IONOSONDES DURING SUMMER AND WINTER SEASONS OF 2011 AND 2015

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Equatorial ionosphere is a very special region that offers various challenges in modeling and monitoring of the anomalies and disturbances that are geomagnetic, solar or seismic in origin. In addition to the spatial sparsity of ionosondes that are located in this region (about 7 or 8 ionosondes compared to 50 in midlatitude), the average monthly temporal data samples hardly exceed 500 as opposed to 3500 in midlatitude regions. Therefore, a reliable ionospheric model is a very important asset in representation of both trend and spatio-temporal variability. International Reference Ionosphere (IRI) extended to Plasmasphere (IRI-Plas) is one of the most acclaimed climatic models of ionosphere that is used to obtain various parameters of ionosphere and plasmasphere such as electron density distribution, critical layer plasma frequency, maximum ionization height and ion and electron temperatures. IRI-Plas uses CCIR or URSI background hourly-monthly median model coefficients in determination of F2 layer critical frequency, foF2. As opposed to the standard models, IRI-Plas has two very important advantages. The first one is the input of GPS-TEC and the second one is user defined choice of 9 solar/ionospheric indices such as SSN1, SSN2, F10.7, Lyman-α, Mg II, IG, TEC, GEC, GECRZ. IRI-Plas can be downloaded from http://ftp.izmiran.ru/pub/izmiran/SPIM/ as a FORTRAN code. IONOLAB group provides user friendly online computation of IRI-Plas at www.ionolab.org with a choice of automatic input of all ionosonde station locations and, IGS and EUREF GPS receiver locations along with GIM-TEC values for all IGS Analysis Centers for the user defined location, date and time. In this study, IRI-Plas model F2 layer critical frequency is compared with ionosonde foF2, in Root Mean Square (RMS) and Normalized RMS (NRMS) sense for the winter (January) and summer (June) months of 2011 and 2015. All available ionosondes in equatorial region are included in the analysis. It has been observed that URSI and CCIR models provide the same background. The input of TEC is very successful in lowering the error fit to ionosonde foF2 if JPL, CODE or IGS GIM-TEC inputs with TEC index in 2011 and SSN2 index in 2015 are used. The overall RMS (NRMS%) differences are 1.4 MHz (20.8%) in January 2011, 1.32 MHz (19.1%) in June 2011, 1.38 MHz (15.1%) in January 2015 and 1.07 MHz (13.6%) in June 2015. Overall fit error is slightly lower for June as compared to January in both 2011 and 2015. This may be an indicator of increased seasonal variability during winter months in equatorial region. This study is supported by TUBITAK 115E915.

C1.4-0014-18 ENHANCEMENT OF HF COMMUNICATION LINK BY USING NEAR REALTIME UPDATED BACKGROUND IONOSPHERIC MODEL

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Ionosphere plays very important role in HF (3-30 MHz) communications as the primary propagation environment. Ionospheric plasma layer structures depend on a wide variety of forcing from above and below such as solar, geomagnetic and seismic activities. The spatio-temporal variability of ionosphere causes many effects on radio signals such as dispersion, attenuation, and delay. These effects are observed not only on HF signals but also on radionavigation and satellite signals. Total Electron Content (TEC), which is obtained from Global Positioning System (GPS) measurements, critical layer parameters such as F2 layer maximum plasma frequency foF2 and maximum ionization height hmF2 which are obtained from ionosondes are the main observable parameters for investigating the ionosphere. International Reference Ionosphere extended to plasmasphere (IRI-Plas) is one of the most acclaimed climatic models of ionosphere and plasmasphere. IRI-Plas provides hourly, monthly median values of critical layer parameters which may not reflect the current state of the ionosphere for a desired location, date and time. IRI-Plas can use GPS-TEC as input and extends the Electron Density Profiles (EDP) up to GPS satellite orbit altitude. In IRI-Plas, the ionospheric slab thickness is defined as the ratio of TEC to the maximum electron density of the F-region, NmF2. Since IRI-Plas model is a background model, hourly median values of slab thickness and instant slab thickness values are assumed to equal in the algorithm. The update of ionospheric state using instant GPS-TEC cannot be possible and it may not match to instant ionosonde foF2. Therefore, in this study, a new statistical update parameter K is proposed for modification of the instant model foF2 value using instant GPS-TEC and median slab thickness. Using proposed K parameter, the background model can be updated by using GPS-TEC as inputs which can be obtained from both dense networks of GPS receivers and high resolution in time. For initial investigations, Pruhonice Digisonde (Czech Republic) and gope station GPS-TEC values are used for year 2012. It is observed that update of background ionospheric model using parameter K reduced the fit error between the model foF2 and the ionosonde foF2 more than %40. By using updated background model in ionospheric ray tracing algorithm IONOLAB-RAY, HF communication parameters, operating frequency, azimuth and elevation angles of radio signal

direction, delay, and attenuation, can be obtained. This study is supported by TUBITAK 115E915 and joint TUBITAK 114E092 and AS CR 14/001.

C1.4-0015-18 IONOSPHERIC TEC DISTURBANCES DURING MAJOR GEOMAGNETIC STORMS IN 24TH SOLAR CYCLE AND PERFORMANCE ANALYSIS OF IRI2016 AND SPIM MODELS OVER THE INDIAN LOW LATITUDES

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The present study investigates the response of ionospheric Total Electron Content (TEC) over the Indian low latitude station, Bangalore during 10 major geomagnetic storms in 24th Solar Cycle. Further, we compared the Global Positioning System derived TEC during the geomagnetically quiet and storm days with the newest versions of International Reference Ionosphere (IRI) and Standard Plasmasphere Ionosphere Model (SPIM) to evaluate their reliability over the low latitude zone across Indian region. As the SPIM model is an extended edition of IRI model capable of predicting up to the plasmasphere height at the GPS orbit, it enabled us to discriminate the characteristic response signatures in the topside, bottomside as well as plasmasphere electron content (PEC) during the disturbed periods. Selecting various solar proxy parameters, such as Sun Spot Number (SSN1), SSN2, F10.7, Global Electron Content (GEC), TEC, IG, Mg II, Lyman-α and GEC_RZ in the SPIM model, the effectiveness of solar proxies over the region realized.

C1.4-0016-18 MACHINE LEARNING BASED DETECTION OF EARTHQUAKE PRECURSORS USING IONOSPHERIC DATA

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Prediction of strong earthquakes is one of the challenging research areas that has the potential of saving significant loss of lives. In the last decade, it has been shown that strong earthquakes affect the electron distribution in the regional ionosphere that can be detected in GPS signals. Especially the Total Electron Content (TEC) estimated from GPS data can be used in the prediction of strong earthquakes. Unlike commonly used ground based seismic activity sensor networks, GPS based predictions can be a week or more earlier than the occurance of the earthquake. This is mainly because of the different mechanisms that generates the spatio-temporal anomalies that these sensors are sensitive to. The anomalies that leads to earlier prediction on TEC data is of pre-seismic in nature, whereas, seismic networks are most sensitive to co-seismic activities. In this study, a novel machine-learning based technique is proposed for detection of earthquake precursors in near-real time GPS-TEC data. The proposed algorithm utilizes an SVM classifier to decide whether an observed spatio-temporal anomaly is an earthquake precursor or not. The data fed to the classifier are composed of spatio-temporal variability map of a region. Also, the classifier has access to the daily solar and geomagnetic indices. Performance of the proposed approach is demonstrated in a case study over a region covering Italy between Jan. 1, 2014 and Sept. 30, 2016. The data in this time interval is partitioned into three non-overlapping time periods, that are used for training, validation and test of detecting precursors of earthquakes with magnitudes above 4 in Richter scale. It is observed that the proposed technique is able to predict 17 out of 21 earthquakes while generating 6 false alarms during the validation period of 266 days, and 23 out of 24 earthquakes while generating 13 false alarms during the test period of 282 days. As a future work, cost-sensitive supervised machine learning techniques will be implemented to provide about the same probability of false alarms on both the validation and test periods. This study is supported by TUBITAK 115E915 and Joint TUBITAK 114E092 and AS CR 14/001 projects.

C1.4-0017-18 COMPARATIVE STUDY OF THE POSSIBLE ANOMALIES IN D-REGION ELECTRON DENSITY PROFILE AS COMPUTED FROM UNUSUAL TERMINATOR SHIFTS IN SUB-IONOSPHERIC VERY LOW FREQUENCY (VLF) SIGNAL DURING HONSHU, 2011 AND NEPAL, 2015 EARTHQUAKES

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We present the perturbations and anomalies in the propagation characteristics of Very Low Frequency (VLF) signals received at Ionospheric Earthquake Research Centre (IERC) (Lat.

22.50 N, Long. 87.48 E) during and prior to the two devastating earthquakes in Honshu on 11th March 2011 at 11:16:24 a.m. local time (05:46:24 UTC) with magnitude of M=9 and depth 29 km at the Pacific coast of Honsu, Japan and another in Nepal on 12 May 2015 at 12:35:19 pm local time (07:05:19 UTC) with magnitude of M=7.3 and depth 18 km at south-east of Kodari. The VLF signal emitted from JJI/22.2KHz in Japan (Lat. 32.05 N, Long. 131.51 E) shows strong shift in VLF-sunrise terminator times towards nighttime starting from a few days prior to the earthquake. We chose these two earthquakes to check the effectiveness of terminator time shift method on this particular propagation path as these two earthquakes have taken place near the VLF transmitter-end (JJI) and near the VLF receiver-end (IERC) respectively. In this work, we have utilized the situation and simulated the VLF sunrise terminator shifts using the RANGE model and EXPONENTIAL sub-program of Long Wavelength Propagation Capability (LWPC) code. To represent the D-region ionospheric variabilities clearly, we assumed a mean dynamic perturbation over the path and presented them with a set of effective Wait's parameters (eff, heff). We have also reproduced the temporal trend of the normalized VLF signal amplitude at VLF sunrise terminators for a few days around both the earthquakes. Then, we used Wait's two-component exponential ionospheric model for estimating the altitude profile of D-region electron density (Ne(h)) at VLF sunrise terminator

times on all those days around both the earthquakes. Hence, we have studied quantitative changes of those Ne(h) profiles during and prior to the seismic events.

C1.4-0018-18 STUDY OF A STRONG EARTHQUAKE OF MAGNITUDE M=8.5 OCCURRED IN SUMATRAN REGION USING GROUND AND IONOSPHERIC OBSERVATIONS AT A LOW LATITUDE STATION AGRA, INDIA

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In the present study, we have analyzed GPS based total electron content (GPS-TEC) data using a statistical technique over Agra in relation to an strong earthquake of magnitude M

= 8.5 which occurred in Sumatran region on 11 April, 2012. To strengthen our results, we have also analyzed the ground based ULF magnetic field data over Agra. We have found the enhancements and depletions in TEC data few days before and after the occurrence of the earthquake. In ULF data, we have found a burst on the day of earthquake which varies from

-1 to 1 (nT) and -2 to 2 (nT) in X and Y component respectively. We have also checked the other possible causes (magnetic storm, solar activity, and lightning etc.) of these disturbances in both sets and found that earthquake is only the possible cause of these disturbances. These perturbations are explained in terms of different mechanisms available in the literature. While the mechanisms of the ULF and TEC anomalies are not well known, it is expected that the ULF bursts occurred due to micro fracturing of the earth's crust during stress accumulation and that the TEC anomalies occurred as a result of the electric field induced in the ionosphere during such processes.

C1.4-0019-18 INFLUENCE OF SOURCE GEOMETRY IN DETERMINING THE CHARACTERISTICS OF TSUNAMI-INDUCED TIDS

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Acoustic-Gravity Waves (AGW) generated by tsunamis propagating in the open ocean perturb the ionosphere and generate Traveling Ionospheric Disturbances (TID). Recent investigations show that continuous monitoring of tsunamigenic TIDs can be used as a tsunami early warning system, provided such TIDs are properly characterized in order to differentiate it from the TIDs of other origins. The characteristics of tsunamigenic TIDs are primarily derived with a point source approximation and thus assuming the wavefronts of the tsunamis are circular. However, in reality, the wavefronts of the tsunamis generated by the submarine earthquakes mimic the shape of the rupturing faults. Hence, such simple approximations while studying the tsunamis generated by rupture of the fault with a length of 1200-1300 km in the case of 26th December 2004 Sumatra-Andaman tsunami and 500 km in the case of 11th March 2011 Tohoku tsunami will severely undermine the characteristics of the resultant TIDs. In this work, we present characteristics of TIDs induced by the 26th December 2004 Sumatra-Andaman tsunami, for the first time, by considering the elliptical wavefront mimicking the entire fault geometry. Our results show that the magnitude of horizontal velocities of TIDs increase from 3.5% to 65% with respect to the direction of propagation of the tsunami when the actual geometry is considered in place of simple point source assumption. This establishes the significance of considering the actual fault geometry while deriving the TID characteristics. Further, the results of crosswavelet analysis carried out between numerically simulated realistic tsunami wavefront and associated TIDs derived using GPS observations which reveal the dynamic coupling of tsunami and ionosphere are also discussed.

C1.4-0020-18 DEVELOPMENT OF SINGULAR VALUE DECOMPOSITION BASED INDICES FOR REGIONAL MONITORING OF SPACE WEATHER THREATS

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The Sudden and Traveling Ionospheric Disturbances (SID and TID) are the major causes of loss of lock in positioning signals that are widely used in unmanned and/or autonomous vehicles. Such risks have to be detected and tracked regionally in near-real time. Singular Value Decomposition (SVD), which is commonly used in signal processing and data analysis, is applied to Total Electron Content (TEC) maps to detect structural changes in the regional ionosphere. TEC maps that are discretized in space and organized as a vector using lexicographical indexing, are arranged into a matrix format in a sliding time window frame of 15 minutes. When SVD is applied to this matrix of TEC maps, the singular values and corresponding singular vectors representing the energy content of the TEC maps are obtained. The first singular value contains most of the energy present in the TEC maps within 15 min interval, and it provides information about large scale - low frequency (trend-like) variations. The second and third singular values are generally two orders of magnitude smaller compared to the first one, and these singular values represent the secondary spatio-temporal variabilities that are related to the factors other than solar activity such as gravitational, geomagnetic or seismic in nature. In order to utilize the singular values as indicators of ionospheric disturbances and sudden and severe variations in the regional ionosphere, D-index of first singular value and V index of second singular value can be computed and tracked. In this study, singular values of regional TEC maps from Europe are investigated for quiet, positively disturbed and negatively disturbed ionospheric conditions during 2012. It has been observed that the first singular value represent the strong trend structure of ionosphere related directly to the solar activity. The first singular mode is enough to reconstruct the TEC map with an error less than 1%. The second singular value is more related to geomagnetic and seismic disturbances and the values of the lower order modes are related to the intensity of the disturbances in the ionosphere. It has been observed that the track of D-index and V index of singular values in time is very successful in identifying the severity of disturbance as compared to the variability of the ionosphere from three to seven days prior. This study is supported by TUBITAK 115E915 and joint TUBITAK 114E092 and AS CR 14/001.

C1.4-0021-18 A SIMPLE ALGORITHM TO REMOVE ARTEFACTS AND ALIASING FROM THE IONOSPHERIC IRREGULARITIES DETECTED USING GPS

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The Total Electron Content (TEC) measurements using an increasing number of GPS ground stations fill the void of conventional ionospheric TEC measurements in both space and time with an unprecedented detail. GPS-TEC measurements are being increasingly used to map the ionospheric irregularities caused by various factors ranging from Space weather (solar, geomagnetic, etc.) to natural hazards (earthquakes, tsunami, thunderstorms, etc.). Monitoring the ionospheric irregularities is essential to assess its impact on the performance of the GPS system in one hand and on the other hand, it provides a plethora of opportunities to study the corresponding causative phenomena in detail. There are three different methods are being popularly used to estimate the ionospheric irregularities by the ionospheric researchers. 1. Rate of TEC Index (ROTI) derived from Rate of TEC (ROT) which is popularly used to monitor global distribution of ionospheric irregularities in studies related to space weather. 2. Horizontal TEC gradient derived either by numerically differentiating the Line-of-Sight (LOS) TEC between the cadence of observation (dTEC) or 3. Detrended LOS-TEC considering the higher order polynomial fit as a regular characteristic TEC variation are used to detect the Travelling Ionospheric Disturbances (TID) induced by the tsunami, seismic, tropospheric convections, etc. Fixing the order of higher order polynomial is arbitrary in third method and hence the order varies from case to case. However, the ionospheric irregularities derived using all these three methods are contaminated by signal aliasing and artefacts introduced by the non-linear motion of the Ionospheric Pierce Points (IPP) which eventually picks up sharp static spatial variations as signals. This signal aliasing corrupts both frequency and amplitude of the ionospheric irregularities which eventually limits the certainty of irregularities detected using GPS-TEC. In this work, we present a simple algorithm to eliminate the signal aliasing and artefacts introduced by the non-linear motion of the IPP while deriving the ionospheric irregularities from the GPS observations. We also demonstrate that the algorithm not only removes the signal aliasing and artefacts from the ionospheric irregularities but also improves the signal-to-noise ratio >50% by adopting it in three test cases of detecting ionospheric irregularities related to (i) a tsunami; an earthquake; and (iii) a space weather event.

C1.5-0001-18 WHY DO TEMPERATURES INCREASE AT LOW AND MIDDLE LATITUDES DURING GEOMAGNETIC STORMS?

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During geomagnetic storms temperatures in the middle and lower latitudes of the upper thermosphere get much larger (observations suggest that temperature increases can be as much as 600 K at middle latitudes, away from the Joule heating region). Despite the importance of these temperature changes, both scientifically and operationally (e.g., Skylab), we know very little about their global nature and evolution. This is largely the result of very little globalscale data being available about them. In this presentation, we discuss what we know about the global-scale temperature changes, their causes and how they evolve. Particular attention will be paid to the nature of these changes during both Coronal Mass Ejection and Co-rotating Interaction Region events. Finally, we will describe plans to study temperature changes during geomagnetic storms using Global-scale Observations of Limb and Disk data.

C1.5-0002-18 ANTICIPATED OBSERVATION OF GRAVITY WAVES AND TIDES BY THE GOLD MISSION USING A GCM AND GLOW MODEL

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One of the major scientific objectives of the GOLD mission is to address the significance of atmospheric waves and tides propagating from below on the thermospheric temperature structure. The GOLD instrument is an imaging spectrograph that will measure the Earth's emissions from 132 to 162 nm. These measurements will be used to image thermospheric temperature and composition near 160 km on the dayside disk at half-hour time scales. TIE-GCM is used to produce a realistic model atmosphere, where different wave and tidal components can be easily extracted, and GLobal AirglOW (GLOW) model produces the emissions in the spectral bands observed by GOLD. Here we use TIE-GCM as a background atmosphere and impose a gravity wave-like perturbation on the vertical profiles and model how the GOLD instrument will observe the perturbation as changes in the LBH band emission brightnesses.

C1.5-0003-18 GLOBAL-SCALE OBSERVATIONS OF THE LIMB AND DISK (GOLD) MISSION - ULTRAVIOLET IMAGING OF EARTH'S SPACE ENVIRONMENT FROM GEOSTATIONARY ORBIT

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NASA's GOLD Mission of Opportunity successfully launched a far ultraviolet (FUV), imaging spectrograph in on January 25, 2018. The imager is a hosted payload on SES-14, a commercial communications satellite, which is being placed into a geostationary orbit. This orbit allows the imager to stay above one location, over eastern South America at 47.5 degrees west longitude, near the mouth of the Amazon River, when it reaches its planned location. Science operations are expected to begin in October 2018. GOLD is the first NASA science mission to fly as a hosted payload on a commercial, communications satellite. The GOLD imager has two identical channels. Each can independently scan the full disk at a 30-minute cadence, making spectral images of Earth's FUV emission from 132 to 162 nm, as well as observations on the Earth's limb. Data from the GOLD instrument will be used to derive fundamental parameters for the neutral and ionized space environment, including the composition ratio (O/N2) and temperature of the neutral atmosphere on the dayside disk. On the nightside, peak electron densities will be obtained in the low latitude ionosphere. The remote sensing techniques to be used have been proven on previous Low Earth Orbit (LEO) missions, and many of the algorithms developed for the GOLD mission are extensions of ones used on previous Earth and planetary missions, with modifications for observations from geostationary orbit. From geostationary orbit, GOLD's imager can repeatedly observe the same geographic locations over most of the hemisphere at a cadence comparable to that of changes in the thermosphere-ionosphere (T-I) system. The imager's 30-minute cadence and hemispheric coverage will allow the mission to track the changes due to geomagnetic storms, variations in solar extreme ultraviolet radiation, and forcing from the lower atmosphere. In addition to providing a new perspective by being able to repeatedly observe the same hemisphere at a high cadence, GOLD's simultaneous measurements of temperatures as well as composition across the disk will provide a valuable, new parameter for understanding of how the T-I system responds to forcing from both the Sun and the lower atmosphere.

C1.5-0004-18 THERMOSPHERE MASS DENSITY VARIATIONS FROM SOLAR FLARE TO SOLAR CYCLE TIME SCALES

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In this presentation, we will discuss variations in thermosphere mass density include abrupt changes with a time scale of minutes to hours due to solar flare, diurnal variation, solarrotational variation, annual/semiannual variation, and solar-cycle variation, using data and modeling. The neutral density data sets include neutral density observed by the accelerometers onboard the Challenging Mini-satellite Payload (CHAMP) and Gravity Recovery and Climate Experiment (GRACE), neutral density at satellite perigees, and global-mean neutral density derived from thousands of orbiting objects. Modeling results are from the National Center for Atmospheric Research (NCAR) thermosphere-ionosphere-electrodynamics general circulation model (TIE-GCM), and from the NRLMSISE-00 empirical model.

C1.5-0005-18 GLOBAL-SCALE OBSERVATIONS OF THE LIMB AND DISK (GOLD): SCIENCE IMPLEMENTATION

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The Global-scale Observations of the Limb and Disk (GOLD) is a NASA mission of opportunity that will image the Earth's thermosphere and ionosphere from geostationary orbit. GOLD will investigate how the thermosphere-ionosphere (T-I) system responds to geomagnetic storms, solar radiation, and upward propagating tides. The mission is framed by four scientific questions: How do geomagnetic storms alter the temperature and composition structure of the thermosphere? What is the global-scale response of the thermosphere to solar extreme-ultraviolet variability? How significant are the effects of atmospheric waves and tides propagating from below on the thermospheric temperature structure? How does the structure of the equatorial ionosphere influence the formation and evolution of equatorial plasma density irregularities? GOLD will address these questions using data from a pair of identical imaging spectrographs designed to observe emissions from atomic oxygen and molecular nitrogen in the the far-ultraviolet from 132 to 162 nm. During the day, composition and temperature will be determined using molecular nitrogen Lyman-Birge-Hopfield (LBH) band and atomic oxygen 135.6 nm emissions. On the limb, exospheric temperature will be obtained from altitude profiles of LBH emission, and molecular oxygen density will be measured using stellar occultations. Electron density will be derived from 135.6 nm emission at night. This presentation describes the GOLD mission science implementation including the science measurement requirements and the anticipated instrument measurement performance. It also describes the forward modeling approaches used by the GOLD team to validate that the instrument and observing plan will return adequate data to answer the science questions.

C1.5-0006-18 PHYSICAL PROCESSES DRIVING THE THERMOSPHERIC VARIATIONS DURING THE MARCH 2015 ST. PATRICK'S DAY MAJOR GEOMAGNETIC STORM

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The thermosphere changes significantly during geomagnetic storms, when large amount of energy and momentum are deposited from the magnetosphere to the upper atmosphere. The changes in neutral, temperature, winds and composition have significant impacts on the stormtime behavior of the ionosphere through chemical and transport processes. Thus it is of fundamental importance to describe and understand the global temporal and spatial variations of thermospheric winds and composition during geomagnetic storms. In this presentation, we use Thermosphere Ionosphere Electrodynamics General Circulation Model (TIEGCM) to investigate the storm-time changes of thermospheric temperature, winds and composition during the March 2015 St. Patrick's Day major geomagnetic storm. The model results of thermospheric composition (O/N2) will be compared with TIMED/GUVI O/N2 observations to describe the global changes of O/N2 variations over the course of the storm. We also illustrate the association of the O/N2 changes with global wind circulation and neutral temperature changes. Through the diagnostic analysis of the model results, we demonstrate the physical processes that are responsible for the storm-time changes of the neutral temperature, winds and composition. We also determine the recovery time and global patterns of temperature, winds and composition, and the primary physical processes that control the recovery.

C1.5-0007-18 A TOMOGRAPHIC INVESTIGATION OF MID-LATITUDE NIGHTTIME IONOSPHERIC E-F COUPLING

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In this paper, a time dependent computerized ionospheric tomography (CIT) technique (in four dimension, 4-D) is utilized in examining the theoretically proposed E-F coupling during nighttime mid-latitude instabilities. To facilitate CIT, we utilize data from a dense Global Positioning System Earth Observation Network (GEONET) of more than 1000 receivers with average distance between two neighboring points being 25-30 km. Results show an existence of field aligned structures in both E and F regions, with wave fronts aligned NW-SE and propagating southwestward (in the Northern hemisphere). This result is in agreement with theory and simulation studies. Furthermore, in most cases, instabilities were first noticed in the E-region and later in the F-region.

C1.5-0008-18 ASSIMILATIVE ANALYSIS OF LOWAND MID-LATITUDE IONOSPHERIC ELECTRODYNAMICS

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The Earth's lowand mid-latitude ionosphere hosts a number of complex phenomena resulting from the mutually coupled dynamics of thermospheric winds, conductivity, electric fields and currents under the influence of the magnetic field. This region is exposed to constantly varying conditions of both terrestrial weather and space weather, giving rise to large day-to-day variability. In spite of significant progress in the development of the climatological understanding of these phenomena though extensive experimental and modeling studies in recent decades, little progress has been made in terms of explaining their day-to-day variability. The paper presents an attempt to combine a multiple types of electrodynamics and plasma density observations with a first-principles model through a comprehensive data assimilation approach to address causes of the observed day-to-day variability of daytime large scale lowand mid-latitude phenomena, including equatorial plasma drifts, EIA, and EEJ.

C1.5-0009-18 IONOSPHERIC SCIENCE MISSION AND DATA PRODUCT OF FORMOSAT7/COSMIC-2

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For preparation of the space weather mission of the upcoming FORMOSAT-7/COSMIC-2 (F7- C2), we have developed ionospheric observation reanalysis and applications. To capture the day-to-day variability of the ionosphere driven by its interactions with solar outputs, planetary waves, and atmospheric and lunar tides, we develop a global ionosphere specification model using Gauss-Markov Kalman filter with hourly outputs of three-dimensional ionospheric electron density. To advance the ionospheric space weather forecast with advantage of the radio occultation observations, we also develop a physical based forecast model using ensemble Kalman filter. The short range (3-6 hours) forecast is possible at the midand low-latitude regions during magnetic storms. An empirical model of ionospheric scintillation is also constructed for providing global specifications of ionospheric irregularities. The empirical model is expected to be verified by observations of the secondary payloads of F7-C2, namely ion density and velocity measurements and beacon transmitters. The main contribution and advance of F7-C2 will be mapping the hourly global ionosphere specifications in electron density, electric field and irregularities in the midand low-latitude ionosphere.

C1.5-0010-18 WEATHER REVEALED BY COSMIC MISSIONS WITH THE GSI IONOSPHERE DATA ASSIMILATION SYSTEM

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The Formosa Satellite-3/Constellation Observing System for Meteorology, Ionosphere and Climate (FORMOSAT-3/COSMIC) and its follow-on mission, FORMOSAT-7/COSMIC-2, can provide Radio Occultation (RO) slant total electron content (sTEC) with an unprecedented global distribution. Recently, a new ionospheric data assimilation system, the Community Gridpoint Statistical Interpolation (GSI) Ionosphere, is constructed with the NOAA GSI Ensemble Square Root Filter and the Global Ionosphere Plasmasphere and the Thermosphere Ionosphere Electrodynamics General Circulation Model. This paper showcases the ionospheric weather features, such as changes in the equatorial ionization anomaly and its longitudinal variations, unraveled by FORMOSAT-3/COSMIC and FORMOSAT-7/COSMIC-2 missions with the help of the GSI ionosphere. The GSI Ionosphere can provide instantaneous global pictures of the ionosphere variability, and help deepen our understanding of causes of the observed day-to-day variability.

C1.5-0011-18 CHALLENGE IN SPECIFYING AND PREDICTING IONOSPHERE DISTURBANCES

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Physics-based Data Assimilation (DA) has been shown to be a powerful technique for specifying and predicting ionosphere disturbances. However, it is also known that different data assimilation models simulating the same geophysical event can display different ionosphere features even if the same data are assimilated. In this study, we used our Multimodel Ensemble Prediction System (MEPS) of DA models to elucidate the similarities and differences in the individual DA model reconstructions of the mid-low latitude ionosphere when the same data are assimilated. Ensemble model averages were also obtained. For this ensemble modeling study, we selected the quiet/storm period of 16-17 March 2013 (equinox, solar medium). Five data assimilation models and one physics-based model were used to produce an ensemble mean output for TEC, NmF2 and hmF2 for latitudes less than 60 and all longitudes. The data assimilated included GPS TEC and COSMIC occultation data. Both a simple average and a weighted average of the models were used in the ensemble averaging in order to determine if there was an improvement of the ensemble averages over the individual models when compared to independent measurements.

C1.5-0012-18 ESTIMATION OF GLOBAL PLASMA BUBBLE OCCURRENCE USING DATA ASSIMILATION

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In this study we report the improvement in the estimation of global plasma bubble occurrence based on flux tube integrated Rayleigh-Taylor instability (RTI) growth rates calculated using the results of ionosphere data assimilation. Thermosphere ionosphere electrodynamics global circulation model forecast results after assimilating total electron content (TEC) measurements using ground network of global positioning system (GPS) receivers are used in this work. The assimilation of TEC into the model by using the ensemble Kalman filter improved the forecast of eastward pre-reversal enhancement (PRE) electric field. The improved electric field promotes a stronger plasma fountain and deepens the equatorial trough. The adjustment of PRE electric field is enabled through self-consistent thermosphere-ionosphere coupling processes captured in the model. The improved estimate of zonal electric field in the data assimilation forecast essentially leads to the significant improvement in the RTI growth rates. The growth rates calculated during pre-storm and storm conditions in March 2015, reveal good agreement with rate of change of TEC index, as well as ground based all sky airglow observations. The assimilation model is being updated by incorporating FORMOSAT-3/COSMIC measurements, in addition to GPS TEC. With the availability of additional data from various upcoming space missions, a realistic estimate or prediction of plasma bubble occurrence could be feasible by taking advantage of the data assimilation approach adopted in this work.

C1.5-0013-18 SOME INITIAL OBSERVATIONS OF MIDLATITUDE IONOSPHERIC TROUGH VARIATION FROM ADVANCED IONOSPHERIC PROBE ONBOARD FORMOSAT5 SATELLITE

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FORMOSAT-5 satellite was launched into a sun-synchronous orbit at 720 km altitude on 25 August 2017. The onboard scientific payload Advanced Ionospheric Probe (AIP) is capable of measuring the topside ionospheric density, drift velocities, ion composition and temperature with an un-precedent high sampling rate up to 8192 Hz (spatial scale of 7.4 m) in the 2030 LT sector. Here we will present some initial observations of global latitudinal variation of density and ion composition as well as temperature. In particular, we will focus on the equatorward edge of poleward density gradients and ion composition changes in that area. The longitudinal differences in the trough variation relating to the magnetic declination and zonal drift velocities will also be presented.

C1.5-0014-18 THERMOSPHERIC DENSITY ESTIMATION USING SATELLITE LASER RANGING OBSERVATIONS OF LOW EARTH ORBITING SATELLITES

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The thermosphere causes the largest non-gravitational acceleration acting on the Earth orbiting satellites at altitudes up to 500 km. Thermospheric density is a key parameter for precise orbit determination (POD), mission planning, ephemeris computation, and re-entry prediction of these satellites. Since the thermospheric density depends on the level of solar and geomagnetic activity and varies in time and space, a precise determination of this parameter still represents a difficult task. Thermospheric density is provided nowadays by a number of empirical and physical models, and these models provide, unfortunately, rather different thermospheric density values. In this study, we use precise Satellite Laser Ranging (SLR) observations to five spherical satellites to scale the thermospheric density provided by four empirical and one physical model, namely, the Thermosphere Ionosphere Electrodynamics General Circulation Model (TIEGCM). The four empirical models used in this presentation are the COSPAR International Reference Atmosphere model CIRA86, the Naval Research Laboratory Mass Spectrometer Incoherent Scatter Radar Extended (NRLMSISE00), the Jacchia-Bowman 2008 (JB2008) and the Drag Temperature Model 2013 (DTM2013). In our investigation, we use SLR observations of ANDE-RR Active and ANDE-RR Passive satellites launched in 2006 at the initial altitude of about 400 km, ANDE Castor and ANDE Pollux satellites launched in 2009 at the altitude of about 350 km, and SpinSat launched in 2014 at the altitude of about 425 km. From the analysis of SLR observations to these satellites, we estimate 6-12 hour time series of scaling factors of thermospheric density and, thus, the scaled thermospheric density provided by each of five models. The analysis and interpretation of the obtained results will be given in this presentation.

C1.5-0015-18 THE NASA IONOSPHERIC CONNECTION EXPLORER MISSION: GOALS, DESIGN, AND STATUS

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The Ionospheric Connection Explorer is a NASA mission that will make new measurements of the unpredictable space environment near Earth. ICON's new mission design gives it the capability to simultaneously compare forcing of the lower atmosphere to conditions in the ionosphere above. To achieve this, ICON carries a set of visible and ultraviolet imagers and in-situ sensors that make coordinated observations, from the boundary of space up to the peak in ionospheric density. The specific orbit and payload design together provide a continuous set of related observations, with dozens of exact conjunctions between the in-situ and remote observations every day. The opportunities for research and collaboration with the mission science team will be discussed along with mission status, and an update on launch plans for mid-2018. The expected performance of the observatory will also be reported.

C1.5-0016-18 SIMULATING THE IONOSPHERE-THERMOSPHERE SYSTEM WITH THE ICON SAMI3-TIEGCM-AMIE MODEL

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The Ionospheric Connection Explorer (ICON) is designed to study variability of the thermosphere and ionosphere at low latitudes. The ionosphere consists of a weakly ionized plasma embedded in the thermosphere, and is forced by electric field and ion-neutral coupling. The ionosphere-thermosphere (IT) is coupled to the lower atmosphere through upward propagating waves and tides which may induce dynamical and electrodynamical changes influencing the plasma distribution. In addition, the varying magnetosphere-ionosphere coupling and solar radiation add to the variability in the IT system. ICON will measure key IT parameters at low latitudes to describe the coupled IT system (e.g. ion drift, electron density, neutral wind, composition). The mission will be accompanied by numerical modelling to support the data interpretation and to get a comprehensive picture of the IT system response to forcing from the lower atmosphere and from geospace.

In this study we will employ the thermosphere-ionosphere-electrodynamics GCM (TIEGCM) and the Assimilative Modeling of Ionospheric Electrodynamics (AMIE), which will be used during the ICON mission, to simulate geomagnetic quiescent and disturbed periods of 2017. Addtionally, we will present results from the NRL SAMI3 ionosphere/plasmasphere model that will use both TIECGM and AMIE data as inputs. AMIE ingests observed ion drifts and magnetometer data to derived high latitude ion convection and particle precipitation patterns for TIEGCM. The lower atmospheric forcing of TIEGCM will include waves and tides based on TIMEGCM simulations. We will examine the IT response to the September 2017 geomagnetic storm with the ICON TIEGCM/AMIE model and simulate what ICON would have observed as suggested by the model. We will also investigate the ionosphere/plasmasphere response using the ICON SAMI3/TIEGCM/AMIE model. The simulation results will be compared to available ionospheric data, e.g., from COSMIC, ion drift. We will quantify the influence of the temporal variation of the high latitude forcing on the low latitude IT system by conducting numerical experiments to evaluate its sensitivity to the forcing.

C1.5-0017-18 GLOBAL DAND E-REGION ELECTRON DENSITY FROM GPS-RO: A NEW DATASET FOR STUDYING IONOSPHERE-MAGNETOSPHERE-THERMOSPHEREMESOSPHERE COUPLINGS

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A novel retrieval technique is developed for electron density (Ne) in the Dand E-region (80-120 km) using the high-quality 50-Hz GPS radio occultation (GPS-RO) phase measurements [Wu, 2017 in JASTP]. The new algorithm assumes a slow, linear variation in the F-region background when the GPS-RO passes through the Dand E-region, and extracts the Ne profiles at 80-130 km from the phase advance signal caused by Ne. Unlike the conventional Abel function, the new "bottom-up" approach produces sharp Ne weighting functions in the lower ionosphere, allowing the E-region retrieval less affected by the F-region residuals.

The retrieved background Ne profiles are in overall good agreement with the IRI (International Reference Ionosphere) model in terms of monthly morphology (e.g., zonal means and diurnal variations). The monthly Ne maps at high latitudes also reveal clear enhancement from auroral electron precipitation down to the 80-120 km altitudes as well as responses to magnetospheric disturbances (Kp). Strong tidal modulations of the Eand D-region electron density from the lower atmosphere are evident in the GPS-RO observations. The new Ne data allow a joint analysis of the sporadic E (Es) occurrence under different E-region backgrounds and solar activities. While the background E-region Ne is in phase with the solar cycle, the monthly Es amplitudes are out of phase with the 11-year cycle. The GPS-RO E-region electron density measurements provide a new observation source to study energetic electron precipitation (EEP) and its impacts on the upper atmosphere. It can also be used to evaluate influence of atmospheric forcings/processes, such as wave forcing and deep convective lightning, on the lower ionosphere.

The new algorithm for the Dand E-region Ne can be readily applied to other GNSS-RO observations and integrated into ionosphere data assimilation systems. It requires the top of RO tangent height to reach about 120 km, which is NOT implemented by all GNSS-RO operations. To maximize science returns of current and future operational GNSS-RO missions, it is recommended to homogenize the data acquisition from the GNSS-RO instruments such that global 3-hourly space weather monitoring will become feasible for the E-region Ne.

See paper for more details: http://www.sciencedirect.com/science/article/pii/S1364682617301050

C1.5-0018-18 THE SIMULATED PRODUCT OF THE IONOSPHERE CONNECTION EXPLORER (ICON) AND THE UNUNIFORMITY OF OI 630.0 NM NIGHTGLOW

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The NASA Ionosphere Connection Explorer (ICON) mission is scheduled to be launched in 2018. Before the actual ICON measurements are distributed, the NCAR TIEGCM along with the estimated ICON orbit and pointing prediction are used to simulate the ICON dataset. To show the response to the geomagnetic activity, the simulated zonal/meridional wind, neutral temperature and O/N2 product for Memorial Day 2017 storm are compared with the data in solar quiet days. The ununiformity of OI 630.0 nm night glow has been identified such as medium-scale traveling ionospheric disturbances (MSTID) and the midnight brightness wave due to the midnight temperature maximum(MTM). Utilizing the method of constructing the 3 dimensional structure of OI 630.0 nm nightglow from the Imager of Sprite and Upper Atmosphere Lightning(ISUAL) onboard FORMOSAT 2, the red-line brightness measurement from Michelson Interferometer for Global High resolution imaging of the Thermosphere and Ionosphere (MIGHTI) is discussed.

C1.5-0019-18 AN INITIAL ULF WAVE INDEX DERIVED FROM TWO YEARS OF SWARM OBSERVATIONS

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The ongoing Swarm satellite mission provides an opportunity to a better knowledge of the near-Earth electromagnetic environment. Herein, we use a new methodological approach for the detection and classification of ultra low frequency (ULF) wave events observed by Swarm based on an existing time-frequency analysis (TFA) tool and utilising a state-of-the-art high resolution magnetic field model and Swarm Level 2 products (i.e. the Field Aligned Currents

FAC and Ionospheric Bubble Index - IBI). We present maps of the dependence of ULF wave power with magnetic latitude and magnetic local time (MLT) as well as geographic latitude and longitude from the three satellites at their different locations in low-Earth orbit (LEO) for a period spanning two years after constellation's final configuration. We show that the inclusion of the Swarm single-spacecraft FAC product in our analysis eliminates all the wave activity at high altitudes, which is physically unrealistic. Moreover, we derive a Swarm orbitby-orbit Pc3 wave (20-100 mHz) index for the topside ionosphere and compare its values with the corresponding variations of solar wind variables and geomagnetic activity indices. This is the first attempt, in our knowledge, to derive a ULF wave index from LEO satellite data. The technique can be potentially used to define a new Level 2 product from the mission, the Swarm ULF wave index, which would be suitable for space weather applications.

C1.5-0020-18 CHAMP, GRACE, GOCE AND SWARM DENSITY AND WIND CHARACTERIZATION WITH IMPROVED GAS-SURFACE INTERACTIONS MODELLING

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Accelerometers on board of the CHAMP, GRACE, GOCE and Swarm satellites have provided high-resolution thermosphere density data since 2000. This data has improved our knowledge on atmospheric dynamics and coupling processes in the thermosphere-ionosphere region. So far, the differences between different data sets, as well as between data sets and models, have been largely ignored or adjusted using ad hoc scale factors. The origin of these differences arises to a large extent from errors in the aerodynamic modelling of the accelerometer satellites, specifically in the modelling of the satellite outer surface geometry and of the gas-surface interactions (GSI). The first step to remove these differences is to develop and use high fidelity geometry models for the computation of aerodynamic forces. Direct Simulation Monte Carlo (DSMC) computations were used with these geometry models to investigate flow shadowing and complex concave geometries. Now that accurate geometry models of all satellites are available, an improved characterization of the gas-surface interactions can be investigated. The physics of particlesurface collisions is studied with the aim of improving the consistency of thermospheric density and wind products. Diffusive, specular and intermediate reflection modes were investigated. The accelerometer data has been reprocessed using newly estimated GSI parameters, leading to higher fidelity density and wind estimates. The results of the new data sets are intercompared and existing thermosphere density and wind data and models are used to assess increased consistency. The updated products are expected to be useful to the thermosphere-ionosphere science community, for improved validation of and assimilation in atmospheric models, and to further increase the understanding of atmospheric dynamics and long-term change.

C1.5-0021-18 CONTRIBUTION OF THE ESA SWARM MISSION TO THERMOSPHEREIONOSPHERE RESEARCH

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The three-satellite Swarm constellation continuously delivers high-quality data on the thermosphereionosphere region using in-situ measurements of the magnetic field vector, the ionospheric plasma environment and thermosphere neutral density. This presentation will highlight examples of current research utilising Swarm data, and provides an outlook for the future. Following in the footsteps of the CHAMP mission, Swarm extends the available magnetic field, ionosphere and thermosphere data into the next solar cycle, and for the first time provides multi-point measurements of this environment. This enables investigations of the response of the thermosphere to energy inputs and cooling processes over a wide range of external conditions. The high accuracy magnetic and electric field data of the Swarm satellites contribute to improved climatologies of the high-latitude current system and energy exchange. In addition, the high temporal resolution of these measurements enables the investigation of these currents at much smaller scales than has been possible before, uncovering details on the relationship between small and large scale currents. Based on a highly successful nominal mission Swarm has recently received an extension. The satellites are in excellent overall health and carry sufficient propellant for a prolonged on-orbit lifetime. The Swarm team is continuing to invest to improve its data products and science output, bringing together observations on the drivers and response of the thermosphere-ionosphere system, which can feed into improvement of models. In the near future, we can look forward to an excellent synergy with observations of the

thermosphere-ionosphere from NASA's GOLD and ICON missions, promising to bring both a global overview for context of the in-situ measurements, as well as increased detail of the dynamics of the system at midand low latitudes. The Swarm experience should also be of importance for the definition of the next US flagship mission Geospace Dynamics Constellation.

C1.5-0022-18 AN ARTIFICIAL NEURAL NETWORK-BASED IONOSPHERIC MODEL (ANNIM) TO PREDICT NMF2 AND HMF2 USING LONG-TERM DATA SET OF FORMOSAT-3/COSMIC RADIO OCCULTATION OBSERVATIONS: PRELIMINARY RESULTS

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Artificial Neural Networks (ANNs) are known to be capable of solving linear as well as highly nonlinear problems. Using the long-term and high-quality data set of Formosa Satellite3/ Constellation Observing System for Meteorology, Ionosphere, and Climate (FORMOSAT3/COSMIC, in short F3/C) from 2006 to 2015, an ANN-based two-dimensional (2-D) Ionospheric Model (ANNIM) is developed to predict the ionospheric peak parameters, such as NmF2 and hmF2. In this pilot study, the ANNIM results are compared with the original F3/C data, GRACE (Gravity Recovery and Climate Experiment) observations as well as International Reference Ionosphere (IRI)-2016 model to assess the learning efficiency of the neural networks used in the model. The ANNIM could well predict the NmF2 (hmF2) values with RMS errors of 1.87 × 105 el/cm3 (27.9 km) with respect to actual F3/C, and 2.98 × 105 el/cm3 (40.18 km) with respect to independent GRACE data. Further, the ANNIM predictions found to be as good as the IRI-2016 model with a slightly smaller RMS error when compared to independent GRACE data. The ANNIM has successfully reproduced the local time, latitude, longitude, and seasonal variations with errors ranging 15-25% for NmF2 and 10-15% for hmF2 compared to actual F3/C data, except the post-sunset enhancement in hmF2. Further, the ANNIM has also captured the global-scale ionospheric phenomena such as ionospheric annual anomaly, Weddell Sea Anomaly, and the midlatitude summer nighttime anomaly. Compared to IRI-2016 model, the ANNIM is found to have better represented the fine longitudinal structures and the midlatitude summer nighttime enhancements in both the hemispheres.

C1.5-0023-18 THERMOSPHERIC DENSITY VARIATIONS FROM ANALYSIS OF GRACE ACCELEROMETER DATA

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The pair of the GRACE (Gravity Recovery And Climate Experiment) satellites has been orbited in a near circular and polar orbit during the 15.5-year mission that began from March 17, 2002. The GRACE-Follow-On mission, with a scheduled launch in April 2018, will use the same orbit configuration to continue monitoring the mass redistributions of the Earth and variations the upper thermosphere. The high-accuracy accelerometer (ACC) data carried by the GRACE satellites is used to measure the effects of the non-gravitational forces acting on the spacecraft, including atmospheric drag, solar and earth radiation pressure and translational accelerations associated with attitude control and orbit maintenance maneuvers. Past results have demonstrated that the GRACE accelerometer data are particularly well suited for measuring the atmospheric neutral density and its variations in response to changes in the solar and geomagnetic activity and the altitude, which occurred during the GRACE Mission lifetime. Neutral density measurements are obtained at altitudes between the initial launch at 495 km and the end of mission at 300 km. This presentation describes the solar and magnetic activity in solar cycle 23 and 24 induced atmospheric neutral variations along with the altitude dependent effects that were observed during the 15.5-year GRACE Mission. The neutral density measurements are compared with model-based predictions from the suite of current neutral density models, including the NRLMSIS-00 and the JB2008 models.

C1.5-0024-18 ESA FIELD ALIGNED CURRENTS - METHODOLOGY INTER-COMPARISON EXERCISE

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Currently, ESA provides two different estimates of the Field Aligned Currents (FACs) from Swarm magnetic field data, based on single or dual-spacecraft approach: - single spacecraft FAC products, based on 1 Hz magnetic field data, which provide three individual products for each of the three satellites - dual spacecraft FAC product, based on 1 Hz magnetic field data collected by the lower pair (Swarm A and Swarm C), low pass filtered at 20 seconds time scale in order to meet the time stationarity assumption. Various ESA projects are developing new methods to compute the FACs and the ionospheric currents from Swarm data. Also several proposals in response to the first ESA Swarm Call for Ideas for new data products and services (May 2016) focussed on FACs, suggesting possible new approaches to estimate FAC densities and quality indicators. In order to identify a possible evolution of the present FAC products, and / or potential new FAC products and FAC quality indicators, ESA organized a FAC Methodology Inter-comparison Exercise (FAC-MICE), which consisted in a comparison of the different FAC methods, based on a test dataset of 28 Swarm auroral crossings. This comparison allowed to highlight the strengths of the various approaches, suggesting that several FAC products are useful, but for different purposes. In order to implement these new FAC approaches, in addition to the current Swarm L2 FAC products whose production will continue unchanged, we are implementing an open source platform for user definable FAC calculation. This presentation illustrates the main findings of FAC-MICE comparison, and the main features of the ESA open source platform for FAC calculation.

C1.5-0025-18 LATITUDINAL PROFILE OF THE FIELD ALIGNED CURRENT (FAC) ESTIMATED FROM SWARM CONSTELLATION.

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We make use of the estimated the Field Aligned Currents (FAC) data provided by SwarmA/B/C constellation, to study the characteristics of the FAC in the northern geographic hemisphere. using 679 days of good FAC data provided by SwarmA/C. We got a profile of the FAC intensity at low and whole northern latitudes[15°,50°] at different Magnetic Local Time (MLT), seasons and latitudes. A statistical analysis of two months for each solstice in southern and northern showed that summer southern hemispheric FAC intensity is always larger than winter FAC intensity while northern summer and winter FAC are comparable. The mean FAC value each 5° latitude in the northern geographic hemisphere 15°-50° showed that; the night side FAC intensity FAC is always larger than the dayside FAC. Close to the equator the FAC is slightly larger than the low and mid latitude FAC regions until 40° latitudes, then it begins to increase slightly again with latitudes >40°. The latitudinal profile of the FAC intensity at different seasons showed that winter FAC is smaller than summer FAC within latitudinal region [15°- 50°], while summer FAC becomes larger than winter FAC within latitudinal region [50°- 65°].

The dawn time and day time FAC always have the same sign in summer and winter, while the nightside summer and winter have the reverse direction. The low latitudinal FAC always has positive value regardless the local time or the season. At low latitudes the FAC has no geomagnetic activity dependence except within dawn time region, while with increasing the latitude >45°, above this latitude the dusk-side FAC dramatically increases with increasing the magnetic activity.

C1.5-0026-18 HIGH LATITUDE INPUTS TO THE IONOSPHERE-THERMOSPHERE SYSTEM WITH THE ICON TIEGCM-AMIE MODEL

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The Ionospheric Connection Explorer (ICON) is designed to study variability of the thermosphere and ionosphere at low latitudes. The ionosphere consists of a weakly ionized plasma embedded in the thermosphere, and is forced by electric field and ion-neutral coupling. The ionosphere-thermosphere (IT) is coupled to the lower atmosphere through upward propagating waves and tides which may induce dynamical and electrodynamical changes influencing the plasma distribution. In addition, high latitude magnetosphere-ionosphere coupling adds to the variability in the IT system. ICON will measure key IT parameters at low latitudes to describe the coupled IT system, e.g., ion drift, electron density, neutral wind, composition. The mission will be accompanied by numerical modelling to support the data interpretation and to obtain a comprehensive picture of the IT system response to forcing from the lower atmosphere and from geospace.

In this study we will employ two models which will be used for the ICON mission, the thermosphere-ionosphere-electrodynamics GCM (TIEGCM) and the Assimilative Modeling of Ionospheric Electrodynamics (AMIE) to simulate geomagnetic quiescent and disturbed periods during 2017. For the baseline ICON mission, AMIE ingests observed ion drifts and magnetometer data to derived high latitude ion convection and particle precipitation patterns for TIEGCM. Given the ion convection and auroral particle precipitation the TIEGCM calculates the ionospheric conductivities and solves globally for the electric potential considering the prescribed high latitude AMIE ion convection and the middle and low latitude wind dynamo. The high-latitude field-aligned current in the TIEGCM is mainly defined by the AMIE patterns however it also depends on the TIEGCM conductivities and, in regions equatorward of the ion convection reversal boundary there are important contributions from the wind dynamo. To evaluate the TIEGCM/AMIE simulations, the simulated high latitude field-aligned current will be compared to the AMPERE-derived field-aligned current.

C1.5-0027-18 IDENTIFYING INTERVALS OF PC1 WAVE ACTIVITY IN THE TOPSIDE IONOSPHERE BASED ON SWARM OBSERVATIONS

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The recent magnetic field mission of Swarm has enabled us to study in situ the occurrence of ultra low frequency (ULF) waves in the topside ionosphere with great detail. In this study, we identify ULF wave events in the Pc1 frequency range (0.2-5 Hz) observed, for the first time, by the Swarm satellites. Additionally, we derive maps of the dependence of Pc1 wave power on magnetic latitude and magnetic local time (MLT) as well as geographic latitude and longitude from the three satellites at their different locations in the topside ionosphere for a period spanning two years after the constellation's final configuration. The observed wave events are disturbances in the Pc1 band in the Swarm frame - which could be Pc1 proper at low L-shell value but likely are related to magnetosphere-ionosphere coupling at higher latitudes. Our initial results emphasize the fact that the Pc1 power distribution at low-Earth orbit (LEO) as provided by the Swarm spacecraft is better organized in geographic than geomagnetic coordinates. We discuss some possible implications of this geographic ordering of the LEO disturbances in terms of the impact of dipole tilt on these signatures, and a possible relationship to magnetosphere-ionosphere coupling.

C1.5-0028-18 IONOSPHERIC RESPONSES TO THE 21 AUGUST 2017 SOLAR ECLIPSE BY USING DATA ASSIMILATION APPROACH

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Using the physical based thermosphere-ionosphere model with ensemble Kalman filter, this study reports the first data assimilation results of the ionosphere responses to the solar eclipse on 21 August 2017. The system with 2-minute assimilation cycle of ground-based GNSS observations show the dynamic variations of the equatorial ionization anomaly (EIA) due to modifications of the electrodynamics by the solar eclipse. Two major ionosphere responses are captured. First, there was an early appearance of EIA at the westward boundary of moon shadow, followed by the feature of the enhanced EIA at lower latitudes and the suppressed EIA at the higher latitudes. These eclipse-induced conjugate EIA variations are produced by the eastward electric field perturbation around magnetic equator and the westward electric field perturbation at the higher latitudes.

C1.5-0029-18 COMPARISON OF IONOSPHERIC VERTICAL TOTAL ELECTRON CONTENT DURING HIGH SOLAR ACTIVE YEAR AND LOW SOLAR ACTIVE YEAR FOR INDIAN REGION BASED ON IGS STATION GPS OBSERVABLES

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The Total Electron Content (TEC) is the ionospheric parameter that has the main effect on radio wave propagation. The dispersive nature of the ionosphere makes it possible to measure its TEC. Thus Global Positioning System (GPS), which uses dual-frequency radio signals is an ideal system to measure TEC. The International GNSS Service (IGS) has been continuously contributing to reliable IGS combined vertical total electron content (VTEC) maps in both rapid and final schedules. We figure out the percentage change of TEC during low and high solar activity over Indian landmass. The Total Electron Content (TEC) is computed from GPS from Bangalore (13.02°N, 77.57°E) and Hyderabad (17.417°N, 78.551°E) IGS stations for the low solar active year 2009 and the high solar active year for the period of 2014-2016. We compute both the slant TEC and vertical TEC for these two stations and compute the percentage change in TEC variation. We also compare our findings with existing IRI models.

SPACE STUDIES OF THE UPPER ATMOSPHERES OF THE EARTH AND PLANETS INCLUDING REFERENCE ATMOSPHERES (C)

PHYSICS, DYNAMICS AND CHEMISTRY OF THE MESOSPHERE AND LOWER THERMOSPHERE (MLT) REGION (C2.1)

C2.1-0001-18 INVESTIGATING GRAVITY WAVE DYNAMICS AND MESOSPHERIC TEMPERATURE VARIABILITY USING AN ADVANCED MESOSPHERIC TEMPERATURE MAPPER (AMTM)

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The Advanced Mesospheric Temperature Mapper (AMTM) is a wide-field (120°) high-performance digital imaging system developed at Utah State University. The AMTM is capable of precision measurements of the OH(3,1) band intensity and rotational temperature (2K in < 30 sec) important for quantifying the effects of a broad-spectrum of gravity waves at the 87 km level, with periods ranging from several minutes to many hours. The nocturnal OH temperature data are also of high value for planetary wave (PW) and seasonal studies. Four AMTM's have been developed: two are currently operational at high latitudes, in Antarctica (McMurdo and South Pole), one in the Arctic (ALOMAR, Norway / Poker Flat, Alaska), and one recently sited in South America at Rio Grande, Argentina. This presentation highlights observations and results from several campaigns and illustrate the variety of the data often obtained in coordination with lidar and radar measurements. Selected studies include (a) gravity wave propagation and fluxes and PW temperature signatures at polar latitudes, (b) mountain wave breaking events at meospause heights, (c) opportune daytime observations of OH airglow structure during the 2017 Solar Eclipse, and (d) new coordinated AMTM and lidar observations under the largest gravity wave "hot spot" on Earth!

C2.1-0002-18 LIDAR OBSERVATIONS OF DOWNWARD PROPAGATING GRAVITY WAVES

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Experimental and modeling efforts show that small-scale gravity waves (GW) essentially affect large-scale circulations, thermal states, and dynamics from the surface to the middle atmosphere. In climate modeling and weather-forecasting applications the gravity-wave drag and its interaction with large-scale dynamics are referred to as sub-gridscale, i.e. unresolved processes and are the most uncertain aspect of these models. Another remaining uncertainties come from secondary gravity-waves. Such waves are generated in situ, propagate in different directions and transport energy. The lack of our knowledge about secondary GWs is because observation of such waves is challenging. One possibility to quantify secondary waves is observation of downward propagating gravity-waves.

Advances in lidar measurement techniques allow for experimental studies of GWs at very small spatial and temporal scales, which are not accessible by other means. The state of the art Doppler Rayleigh/Mie/Raman lidar at the ALOMAR research station located in Northern Norway (69N, 16E) provides an observational database of GWs at the edge of the polar vortex connected to global dynamics of the Earth atmosphere.

The Doppler Rayleigh Iodine System (DoRIS) provides horizontal wind measurements in addition to temperature observation. This gives us a unique possibility to obtain wave propagation direction, intrinsic frequency, and horizontal wavelength from the single station. Making use of the advantage of this system, we derive wave parameters precisely. In this paper we will demonstrate different methods for resolving downward propagating gravity waves. One method is based on 2D-FFT analysis and allows for general description of wave parameters. Another method is based on the hodograph technique and delivers detailed description of selected waves.

C2.1-0003-18 THE ROLE OF INERTIAL INSTABILITY AND THE QUASI 2-DAY WAVE IN COUPLING WINTERTIME PLANETARY WAVES WITH THE POLAR SUMMER MESOPAUSE

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Recent work has documented the link between planetary waves in the winter stratosphere and the occurrence of polar mesospheric clouds (PMCs) through interhemispheric coupling. Breaking planetary waves in the winter hemisphere lead to warming in the low-latitude mesosphere and cooling in the stratosphere. These temperature anomalies lead to a weakening of the summer easterlies in the upper mesosphere and a strengthening of the summer easterlies in the stratosphere. These wind shifts can influence the occurrence of PMCs through a modification of gravity wave forcing in the upper mesosphere and subsequent weakening of the upper branch of the residual circulation. There is also a resulting enhancement to the wind shear near the equatorward flank of the summer jet, leading to enhanced baroclinic instability, and resulting growth of the 2-day wave. The 2-day wave can lead to a decline in PMCs by weakening the residual circulation, and forcing meridional advection and warming of the PMC region. The 2-day wave can also grow as a result of low-latitude inertial instability (negative EPV); inertial instability is associated with strong curvature of the mid-latitude summer easterlies, producing baroclinic and barotropic instability. This work considers inertial instability as a possible link between wintertime planetary waves and the growth of the summertime 2-day wave. Data from the Navy Global Environment Model (NAVGEM) and the Sounding of the Atmosphere Using Broadband Emission Radiometry (SABER) instrument are used to diagnose regions of inertial instability, identified as vertically stacked or "pancake" structures in temperature that occur in regions of anomalous EPV. Results suggest that low-latitude inertial instability may have contributed to the growth of the 2-day wave in 2014 which was responsible for the anomalous decline in PMCs in early August.

C2.1-0004-18 THE MOMENTUM BUDGET IN THE MIDDLE ATMOSPHERE BASED ON A WHOLE ATMOSPHERE MODEL SIMULATION OVER 11 YEARS

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A momentum budget is examined in the middle atmosphere using simulation data covering a period of 11 years from a whole atmosphere model in terms of the respective contributions of gravity waves (GWs), Rossby waves (RWs) and tides. The GW forcing is dominant in the MLT region, as indicated in previous studies. However, RWs also cause strong westward forcing, described by Eliassen-Palm flux divergence (EPFD), in all seasons in the MLT region as well as in the winter stratosphere. In addition, despite the relatively coarse model resolution, resolved GWs with large amplitudes appear in the MLT region. The EPFD due to the resolved GWs is eastward (westward) in the summer (winter) hemisphere, similar to the parameterized GW forcing. These RWs and resolved GWs are likely generated in situ in the MLT region.

Previous studies suggested that a possible mechanism of in situ RW generation in the MLT region is the barotropic/baroclinic instability. This study revisits this possibility and examines causes of the instability from a potential vorticity (PV) viewpoint. The instability condition is characterized as the maximum of PV magnitude at middle latitudes on an isentropic surface. Positive EPFD for RWs is distributed slightly poleward of the PV maximum. This feature indicates that the RW radiation acts to reduce the PV maximum. The PV maximum is climatologically maintained by the parameterized GW forcing in both the winter and summer mesospheres.

A likely mechanism of the resolved gravity waves in the MLT region is shear instability. In the summer MLT region, the mean zonal winds have a strong vertical shear formed by parameterized gravity wave forcing. In addition, shear instability occurs in the low (middle) latitudes of the summer (winter) MLT region and is associated with diurnal (semi-diurnal) migrating tides.

These results strongly suggest that the forcing by gravity waves originating from the lower atmosphere causes the barotropic/baroclinic and shear instabilities in the mesosphere that, respectively, generate Rossby and gravity waves and indicate that the in situ generation and dissipation of these waves play important roles in the momentum budget of the MLT region.

C2.1-0005-18 FIRST SIMULTANEOUS NA DOPPLER AND FE BOLTZMANN LIDAR OBSERVATIONS OF THE UPPER ATMOSPHERE-SPACE AT ARRIVAL HEIGHTS NEAR MCMURDO, ANTARCTICA

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After full seven years of observations with an Fe Boltzmann lidar in Antarctica, a new Na

Doppler lidar, named STAR (Student Training and Atmospheric Research), was successfully installed into the same lab as the Fe lidar at Arrival Heights Lidar Observatory (77.84°S, 166.67°E)

by the University of Colorado Boulder lidar group in the 8th season (2017-2018). Simultaneous Na Doppler and Fe Boltzmann lidar observations started in January 2018 and will continue through the Antarctic summer and winter. These two sophisticated resonance-fluorescence lidars provide unique opportunities to study the complex physical, chemical, neutral dynamical and electrodynamics processes in the Earth's atmosphere and space environment. In particular, we will explore the recently discovered thermosphere Fe and Na layers to the E-F region, explore the neutral temperature and vertical winds in the mesosphere and thermosphere, investigate high-frequency waves in addition to the persistent gravity waves, and measure the wave-induced heat, Na and Fe fluxes in the mesopause region.

Initial 48-hour continuous observations with the Na and Fe lidars in February 2018 have revealed interesting phenomena in the Fe and Na layers as well as polar mesospheric clouds, which deserve further studies. Nearly 8000 hours of Fe lidar data have been collected in the last seven years covering all 12 months of a year. Many new science discoveries have been resulted from the data. In this paper we will report the first simultaneous Na and Fe lidar observations in the Antarctic season 2018 and also highlight several discoveries emerged from the first seven years of Fe lidar campaign.

C2.1-0006-18 UNUSUAL CHANGES IN THE MESOSPHERIC DYNAMICS DURING 2017 MINOR SSW OVER THE TROPICAL REGION

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The observations from advanced meteor radar located at Tirupathi (13.63oN, 79.4oE), a tropical station India, has been used to investigate the 2017 minor Sudden Stratospheric Warming (SSW) effects on the tropical mesosphere and lower thermosphere (MLT) region. Two minor warmings were noticed on 1 and 26 February 2017 with the enhancement of 35 K in the polar stratospheric temperature followed by a weakening of eastward wind of 25 m/s. The observations show the large zonal wind shear at 75-80 km during SSW. The 14-16 day waves in the MLT zonal wind during the SSW, and the secondary waves (2-9 day) in the meridional wind after the SSW are noticed. Large enhancement (30 m/s) in the semi-diurnal tidal amplitude and reduction in diurnal tidal amplitude is observed during the SSW, and the possible reasons are discussed. The present results reveal entirely different features than that reported earlier and are in a similar manner to that observed during the major SSW.

C2.1-0007-18 HOW DO SSW SIGNATURES PROPAGATE OVER THE LATITUDES IN THE MLT REGION?

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The changes in the thermal and dynamical structure of the polar middle atmosphere brought about by sudden stratospheric warmings are found to significantly affect the mesosphere lower thermosphere region over high, middle as well as low latitudes. The signatures of SSW events over these regions have been examined individually in numerous studies. But, how these signatures propagate over the latitudes have not been explored in detail. Thus the high latitudelow latitude coupling associated with SSW events has to be addressed to gain deeper insights into the dynamics of the middle atmosphere. Using a network of meteor wind radars located from polar regions to low latitudes, the latitudinal propagation of changes in the MLT region in association with SSW events are examined in this study. The response of mean winds, diurnal and semidiurnal oscillations, quasi 2-day waves and quasi 16-day waves are investigated in detail. As a first step, climatologies of mean winds, tidal oscillations and planetary waves over each of the observational sites were constructed. Each individual SSW event was then studied with multi station observations to delineate the respective changes in the MLT region. The analysis clearly shows that the response of mean winds is most prominent in the high latitude MLT region in contrast to the low latitude counterparts. On the other hand, quasi 2-day waves over lower latitudes showed amplified responses compared to those over higher latitudes. Further, the temporal evolution of the different changes observed is also examined in detail. An attempt is also made to bring out the longitudinal asymmetry of the observed signatures, especially in the polar regions, with respect to the location of the polar vortex. The significance of the present study lies in investigating the changes of SSW signatures in the MLT region over the latitudes, right from polar to equatorial regions, using ground based observations.

C2.1-0008-18 ON HOW THE DYNAMICS COUNTERACTS THE DIRECT HEATING FROM THE SUN IN THE SUMMER MESOPAUSE DURING SOLAR MAXIMA.

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The coldest place in the earth-atmosphere system is as good as constantly sunlit. Even during solar maxima, when the upper parts of the atmosphere are significantly warmer due to intensified physical and chemical processes, the summer high latitude mesopause temperature appears to be relatively unaffected by direct diabatic heating, particularly in the northern hemispheric summer. We show, using the nudged and extended version of the Canadian Middle Atmosphere Model (CMAM30), that the increased diabatic heating during the more active phase of the sun is counteracted by a strengthening of the meridional residual circulation, which cools the summer polar mesosphere adiabatically.

C2.1-0009-18 SUPER SOAKER: A SOUNDING ROCKET EXPERIMENT TO CREATE AND STUDY POLAR MESOSPHERIC CLOUDS

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Water deposition in the Mesosphere and Lower Thermosphere (MLT) from space traffic can lead to significant variations in the energetics, composition and dynamics of the region. A variety of satellite and ground-based observations show that the fast global-scale plume transport from NASA's Space Shuttle launches can lead to the formation of Polar Mesospheric Clouds (PMCs), which typically appear in the summer near 85 km altitude. This is an important finding because PMCs have been implicated as possible indicators of long-term climate change. There has been a great deal of focus on the fate of concentrated water plumes in the MLT region, which is ordinarily extremely dry. The water plume phenomenon raises a number of important questions about lower thermospheric and mesospheric processes, ranging from dynamics and chemistry to PMC formation and climatology. The Super Soaker sounding rocket mission, funded by the NASA Heliophysics Technology and Instrument Development for Science (HTIDes) program, seeks to investigate the impact of a locally concentrated plume of water vapor on temperature and ice cloud formation as well as the resultant impact on water transport in the MLT. The mission explores this impact at high northern latitudes in the wintertime, when ambient conditions are unfavorable for PMC formation. Super Soaker successfully launched on January 26, 2016 from the Poker Flat Rocket Range (65 N) in Alaska and the mission included three sounding rockets; the first two carrying trimethyl aluminum tracers and the third rocket carrying 220 kg of liquid water. The experiment was designed to explosively distribute the water at 85 km from a rocket and observe the response of the atmosphere using a suite of ground-based instruments that included Rayleigh, sodium, and iron lidars, an Advanced Mesospheric Temperature Mapper, and the Poker Flat Incoherent Scatter Radar. In this paper we review the Super Soaker

souding rocket mission and describe initial numerical modeling results to provide a semi-quantitative view of the response of chemistry and energetics to the water plume deposition in the lower thermosphere.

C2.1-0010-18 NEW RESULTS FROM THE AIM AND SBUV SATELLITE MISSIONS: SOLAR FORCING OF POLAR MESOSPHERIC CLOUDS (PMC)

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The NASA satellite mission Aeronomy of Ice in the Mesosphere (AIM) has been in orbit for over ten years, and has produced a bonanza of scientific accomplishments which have greatly advanced our understanding of this upper atmospheric phenomenon. The series of NASA Solar Backscatter Ultraviolet (SBUV) satellite measurements, designed to measure middle atmospheric ozone has measured, as a by-product, a longer time series of PMC properties since 1979. Ozone satellite measurements with newer instrumentation are now in orbit, and will continue for the indefinite future. PMC are water-ice clouds occurring at the 'edge of space' during summer at high latitude, and serve as a tracer of atmospheric dynamics and chem- istry in this historically inaccessible region. This presentation will highlight some of the AIM achievements, and focus on recent results for long-term solar effects on PMC as measured by the SBUV experiments. This study illustrates the importance of PMC for the understanding of decadal changes in the entire mesosphere, and not just in the region of PMC occurrence in the cold summertime polar region.

C2.1-0011-18 SMALL SCALE ATMOSPHERIC DYNAMICS REVEALED BY NOCTILUCENT CLOUDS

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Noctilucent clouds (NLC) at the edge of space (about 83 km) consist of tiny water ice particles of a few tens of nanometers in diameter. These clouds were first observed in 1885 and have been the only source of information from the upper atmosphere for a long time. NLC occur from high to mid-latitudes in summer, are linked to processes in the lower atmosphere and are affected from above through solar cycle effects and due to thermal tides. Long-term changes of the clouds are impacted by changes of water vapor, methane, and ozone in layers below the clouds. In the altitude range of ice particle existence small-scale dynamics is ubiquitous and plays a major role even for the thermal and dynamical structure on hemispheric scales. To understand the development of NLC, these small-scale processes are currently parameterized in models. In observations small-scale processes lead, for example, to the variance of particle sizes in a given atmospheric volume as seem by lidar. When looking at the clouds by naked eye or camera small scale structures are evident as wavy patterns. NLC exist in an altitude range where the multi-scale interaction of waves, e.g. tides, inertia gravity waves and small-scale gravity waves, is of importance for the global circulation. With new high resolution observations it has become evident that NLC are useful targets for studying multi-scale wave interactions and the transition to turbulence. We will present observations of the horizontal structure in NLC from observations by camera in combination with lidar and meteor radar measurements. Using this combination, partly with a time resolution of seconds, we quantify the vertical and horizontal structure of clouds and the underlying atmospheric dynamics.

C2.1-0012-18 NLC AND MSE AT A MIDLATITUDE SITE: ADVECTION VS. LOCAL PRODUCTION OF ICE PARTICLES

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Ice particles in the summer mesopause region can be observed either optically as Noctilucent Clouds (NLC) or by radar as (Polar) Mesosphere Summer Echoes ((P)MSE). These phenomena are directly related to atmospheric properties like temperatures, humidity and winds. Studying ice layers provides additional insight into an atmospheric region, where long-term visual observations of NLC exist, but records of other parameters are sparse. For the interpretation of the ice observations it is important to know whether the midlatitude clouds are formed locally during unusually low temperatures or whether they are advected from polar latitudes. Simultaneous observations of small (freshly formed) and large ice particles require the combination of radar and daylight-capable lidar techniques. This combination is quite rare, especially at midlatitudes. Since 2010 we operate a daylight capable Rayleigh-Mie-Raman lidar at our site at Kühlungsborn/Germany (54°N, 12°E) for optical observations of NLC independent from solar elevation. In combination with the co-located OSWIN VHF radar we are for the first time able to compare the occurrence and altitude structure of NLC and MSE at midlatitudes. The lower edges of simultaneously observed NLC and MSE typically agree, as expected from observations at polar latitudes. The top edge of MSE is on average nearly 500 m above the NLC edge, indicating the presence of ice particles being too small to be observed by lidar. Surprisingly, the height difference is much smaller than observed at polar latitudes. This hints at a lower abundance of small ice particles in the upper part of the ice layer, hence different growing conditions compared to high-latitude clouds. The data suggest that advection from polar latitudes plays a more prominent role for ice cloud occurrence at our site, compared to local formation. This is supported by, e.g., wind measurements showing a higher probability for ice occurrence during equatorward winds. Therefore, our findings indicate that midlatitude NLC do not only depict local mesospheric conditions, but also upstream (high-latitude) conditions. These results should be considered for, e.g., the evaluation of NLC in climate research.

C2.1-0013-18 UNDERSTANDING THE EFFECTS OF POLAR MESOSPHERIC CLOUDS ON THE ENVIRONMENT OF THE UPPER MESOSPHERE AND LOWER THERMOSPHERE

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We use a version of the NCAR Whole Atmosphere Community Climate Model (WACCM) that includes a parameterization for polar mesospheric cloud (PMC) formation to consider the effects of PMC formation on the environment of the upper mesosphere and lower thermosphere. The formation of PMCs sequesters a significant fraction of the ambient water vapor causing a noticeable dehydration in the upper mesosphere above the cloud layer. This dehydration reduces the source of atomic hydrogen and thus the H abundance as measured by the Sounding of the Atmosphere by Broadband Emission Radiometry (SABER) instrument reveals a local minimum in H at mid-high latitudes each summer. In addition, as a result of the anticorrelation between HOx and Ox, this seasonal depletion in atomic hydrogen causes a localized maximum in ozone which has heretofore not been discussed. WACCM/PMC simulations as compared with Aeronomy of Ice in the Mesosphere (AIM) ice water content, SABER H and O3 agree well. There is a tendency to overestimate the dehydration compared with Solar Occultation for Ice Experiment (SOFIE) data, a problem which has been seen with other models as well. Finally, we consider how these seasonal variations in atomic H might propagate up into the thermosphere and be indicators of coupling between the stratosphere and the thermosphere.

C2.1-0014-18 THE SOLAR CYCLE RESPONSE OF THE POLAR MESOSPHERE, A LONG TERM PERSPECTIVE FROM MULTIPLE DATA SETS

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It has long been considered that the 11-year solar cycle will impact the upper atmosphere by altering photochemistry, heating, and the circulation. Solar maximum should be characterized by higher temperatures and lower water vapor in the mesosphere, which in turn will reduce the amount of ice in polar mesospheric clouds (PMC). While the expected response is evident in PMCs during the 1980's and 90's, it appears to be absent from 2000 to present. The response of the polar upper mesosphere to the 11-year solar cycle is investigated using various observations during 1979 - 2017. Satellite observations from SBUV, HALOE, SABER, CIPS, and SOFIE are used to characterize PMCs, temperature, and water vapor. Apparent changes in the response to solar forcing are explored, with consideration of the potential roles of other mechanisms.

C2.1-0015-18 PROBABILITY DENSITY DISTRIBUTIONS OF NLC/PMC

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In this paper we present a new description about statistical probability density distributions (pdfs) of Polar Mesopheric Clouds (PMC) and noctilucent clouds (NLC) occurrence frequencies. The analysis bases on observations of maximum backscatter ratios measured by the ALOMAR RMR-lidar for all NLC seasons from 1997 to 2013. From these lidar data record we estimate an additional observational quantity of ice water density. For these two data sets we derive new classes of pdfs that describe the statistics of PMC/NLC events dierent from previously statistical methods using the approach of an exponential distribution commonly named g-distribution. The new theory is very successful in describing the probability statistic of ALOMAR lidar data. It turns out that the former g-function statistic is embedded in our new theory as a special case. In general the new theory allows to derive basic parameters of climatological ice particle distributions, namely mean ice radii and variances, and, secondly, the theory can be generally applied to many kinds of dierent observational data sets, e.g. measurements of albedo, ice water content, and ice water densities by satellite instruments, or backscatter signals by lidars, respectively.

C2.1-0016-18 SOLAR 27-DAY SIGNATURES IN STANDARD PHASE HEIGHT MEASUREMENTS ABOVE CENTRAL EUROPE

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We report on the effects of solar variability at the 27-day and the 11-year time scale on standard phase height measurements carried out in central Europe. Using the superposed epoch analysis (SEA) method, we extract statistically highly significant solar 27-day signatures in standard phase heights. The 27-day signatures are anti-correlated to solar proxies. The sensitivity of standard phase height change to solar forcing at the 27-day time scale is found to be in good agreement with the sensitivity for the 11-year solar cycle, suggesting similar underlying mechanisms. Several findings are, however, unexpected. The amplitude of the 27-day signature in standard phase height is larger during solar minimum than during solar maximum, indicating that the signature is not only driven by photolysis of NO.

C2.1-0017-18 LONG-TERM OBSERVATIONS OF MESOSPHERE LOWER THERMOSPHERE DYNAMICS OVER THE LOW AND EQUATORIAL LATITUDES

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The dynamics of the mesosphere and lower thermosphere region of the Earth's atmosphere is dominated by the myriad atmospheric waves of various spatial and temporal scales propagating from the lower atmosphere. In general, these waves are identified as gravity waves, tides and planetary waves. Most of the planetary waves observed in the earth's atmosphere correspond to normal-mode solutions for oscillations in an isothermal atmosphere. Apart from these waves, over low and equatorial latitudes, equatorial waves play a major role in shaping the structure and dynamics of MLT region. In the present study, long-term observations of MLT region over low and equatorial latitude are reported using meteor radar observations over Thumba (8.50 N, 770 E) and Kototabang (0.20S, 100.30E). Observations from TIMED/SABER and TIDI are also used to substantiate the radar observations as well as investigating the spatial variabilities. Apart from long-term changes in the mean winds and tides, climatology of planetary waves and gravity waves are constructed using meteor radar observations over the study regions. The gravity waves are quantified in terms of momentum flux and drag, whereas planetary waves are quantified in terms of amplitude and phases. The planetary waves with periods quasi 2-, 5- and 16-day are investigated and their contributions to observed variances in the background winds are quantified. A detailed discussion on the long term variability of these waves and their impact on the background MLT dynamics are presented. Significance of the present study lies in bringing out a comprehensive perspective of MLT dynamics over low and equatorial latitudes, which is envisaged to be helpful in evaluating the middle atmospheric models simulations.

C2.1-0018-18 VERTICAL VELOCITY IN THE HIGH-LATITUDE UPPER MESOSPHERE: ENERGETICS AND DYNAMICS

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More than 12 years of near continuous measurement of meteor radar data from two nearby station Andenes (16°E, 69°N) and Tromso (19°E, 70°N) were combined to derive horizontal winds and gradients in them. The gradient products, which were derived using a new concept called MMARIA (Multistatic Multifrequency Agile Radar for Investigations of the Atmosphere), were used to derive the horizontal divergence and vertical vorticity in horizontal winds. For the current investigation we derive the vertical velocity from the horizontal divergence measurements for all the years. Interestingly, we have found that the vertical velocity during summer is mostly positive (varies from 2 to 15 cms−1) and maximized near the mesopause suggesting upwelling and resulting adiabatic cooling. We found a positive relationship between our horizontal wind divergence and mesopause level temperature measured using the Earth Observing System (EOS) Microwave Limb Sounder (MLS) satellite data. We explain this relationship based on the mesospheric cooling due to upwelling and dynamics. The role of gravity waves will be discussed in the context of long term changes, and summer winter differences.

C2.1-0019-18 CHARACTERISTICS OF THE WIND AND AIRGLOW VARIABILITY IN THE POLAR MESOPAUSE REGION

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Observations of the wind and airglow above Eureka Nunavut (80 N, 85 W) have been taken during polar winter over the past 9 years at the Polar Environment Atmospheric Research Laboratory (PEARL) using the PEARL All Sky Imager (PASI, airglow images)) and the ERegion Wind Interferometer II (ERWIN2, wind, airglow irradiance and temperature). These instruments view the wind and airglow irradiance of hydroxyl (both) O2 (ERWIN2), sodium (PASI), and oxygen green line (both) in the meospause region. In this paper, the variability is characterized in terms of frequency and spatial scale where appropriate. It is found that much of the variability occurs in the range of 7 to 14 hours in the winds. The variability in the airglow is more difficult to characterize because of twilight effects but appears to peak at higher frequencies. Some of this variability can be attributed to wave effects. In this paper the nature of these variabilities are described and correlations between observations with the various emissions presented and interpreted.

C2.1-0020-18 THE POSSIBLE LINK BETWEEN THE NEUTRAL CONSTITUENTS IN THE MESOPAUSE REGION AND THE LOWER ATMOSPHERIC/SOLAR ACTIVITIES

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The mesopause and lower thermosphere region is a transition region from the neutral atmosphere to the space plasma, which can be affected by the upward propagating waves from the lower atmosphere OR be coupled with the ionosphere under the modulation of the solar activities. The deposition of the meteors into the Earth’s atmosphere, on one hand forms the permanent metal layers in the mesopause region through the photo-chemical reactions, on the other hand generates trails of plasma which can be used as an indication of the neutral atmospheric dynamics. The ground-based remote-sensing techniques can obtain the information of the atmospheric paramters in the mesopause region through the measurements of the metal layers or the plasma in the meteor trails. Based on the ground-based optical and radio observations, we will report the possible link between the neutral constituents in the mesopause region and the lower atmospheric/solar activities. (1) The lidar observational results on a statistical basis showed evidence that thunderstorm activities can affect the metal layer, by identifying a statistically significant enhancement of the neutral metal Na layer above thunderstorms at Haikou, China (20.0N, 110.3E). The thunderstorm-generated gravity waves, and electric field effects could be the mechanisms responsible for the lightning-associated enhancement of Na layer.

The estimated atmospheric density in the mesopause region from a meteor radar chain from the North Pole to South Pole indicated a strong negative correlation with the geomagnetic kp index and suggested possible modulation from solar wind and solar stroms.

C2.1-0021-18 ROLE OF DYNAMICS AND CHEMISTRY FOR THE OCCURRENCE OF TROPICAL (10°N-15°N) MESOSPHERIC INVERSION LAYERS

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ABSTRACT

The inversion of temperature gradient from negative to positive superimposed upon the characteristically decreasing mesospheric thermal structure is known as Mesospheric Inversion Layer (MIL). Although MILs have been known for decades through all sorts of available techniques, their study is still of significant relevance for understanding of the energy and momentum budget of mesosphere and lower thermosphere (MLT) region. The suggested dominant causative mechanisms for the occurrence of MILs are: gravity wave (GW) breaking, planetary wave (PW) critical level interaction, GW-tidal interaction and chemical heating. In the present study, all these principal causative mechanisms have been addressed through a few case studies from Rayleigh lidar and TIMED-SABER (Thermosphere Ionosphere Mesosphere Energetics and Dynamics - Sounding of Atmosphere by Broadband Emission Radiometry) observations over Gadanki (13.5°N, 79.2°E) region. A large MIL has been observed at 79-84 km (ΔT 50

K and Δz 4.5 km) on the night of 24 January 2007 over Gadanki and it is attributed to large eddy diffusion by small scale (T 33 min, Λz 6.4 km) GW breaking. Further it is found that the chemical heating due to the exothermic reactions among H, O, O3, OH, HO2 played dominant role over dynamics for the occurrence of a few large MILs at 80-85 km during January-February 2011. In another special case study, a triple layered MIL event with three inversion layers at 70 km (11 K), 80 km (44 K), 90 km (109 K) has been observed in September 2011. The three inversion layers are found to be due to PW breaking, GW-tidal interaction and large chemical heating by the reaction, O+O+M→O2+M respectively.

C2.1-0022-18 ON THE ORIGIN OF VARYING NON-LTE CONTRIBUTIONS TO OH ROTATIONAL TEMPERATURES

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The departure of OH rotational level populations from the local thermodynamic equilibrium (LTE) can be an issue for the interpretation of the amount and variations of OH rotational temperatures Trot, which are an important diagnostic tool for the Earth's mesopause region. In order to improve our understanding of the impact and origin of such varying non-LTE effects, we performed a combined study which involved OH population and Trot measurements related to spectra of the high-resolution UVES spectrograph at the Very Large Telescope in Chile, OH emission layer and mesopause chemical composition data from the SABER radiometer on the TIMED satellite and the NRLMSISE-00 model, and a kinetic model of the relevant chemical reactions, collisional processes, and radiative transitions. We focussed our analysis on the vibrational level v = 9, which is the highest v that can be populated by the OH-producing reaction of hydrogen and ozone. We found significant non-LTE contributions to Trot in the observed and modelled data. The climatology of the variations of these effects appears to be mainly caused by their steep increase with altitude, the OH-specific weighting of the different altitudes depending on the emission rate, and the variability of the effective OH emission altitude. Moreover, our study resulted in rate coefficients for the rotational relaxation process by thermal collisions. In our presentation, we will also discuss the impact of these results for the non-LTE contributions to Trot of lower v, which are more frequently used for the analysis of temperature variations in the mesopause region.

C2.1-0023-18 NEW NON-LTE MODEL OF THE IR EMISSIONS OF HYDROXYL, OZONE AND CARBON DIOXIDE IN THE NIGHTTIME MLT

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We present a new non-LTE model which couples IR emissions of OH, O3 and CO2 bands in the nighttime MLT. The model treats a large number of vibrational levels and ro-vibrational bands of these three optically active molecules as well of N2(v) and O2(v), which all are coupled by a variety of interand intra-molecular collisionally induced exchanges of vibrational energy. We compare model calculations of limb emissions in the 1.6 and 2.0 μm OH Meinel bands, 9.6 μm O3 band and 4.3 μm CO2 band with nighttime limb radiances measured by SABER/TIMED. Particular attention is given to the effect of the recently discovered mechanism of OH(v) quenching by collisions with O(3P), subsequently producing O(1D), which further transfers its energy to the N2, CO2 and O3 vibrations, and therefore influencing OH, O3, and CO2 emissions. We also present a novel retrieval algorithm and show the application of the new model/algorithm to retrieving O(3P) and OH densities in MLT from the OH 1.6 and 2.0 μm Meinel band emissions measured by SABER. We compare retrieved densities with observations of other airglow emissions (WINDII, OSIRIS, SCIAMACHY), as well as model results of WACCM. Implications for the aeronomy and energy budget of the MLT are discussed.

C2.1-0024-18 A NEW LOOK AT THE TERTIARY OZONE MAXIMUM IN THE POLAR WINTER MESOSPHERE

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Observations from satellites and a ground-based station are combined to construct a global dataset for investigating the tertiary ozone maximum in the winter mesosphere for the period August 2004-June 2017. These give a comprehensive picture of this ozone maximum in latitude, pressure, and time. The location of the tertiary ozone maximum shifts in latitude and pressure with the evolving season; the ozone peak occurs at lower latitude and higher pressure around the winter solstice. Highest average nighttime ozone concentrations and greatest degree of interannual variability are seen in late winter in the Northern Hemisphere. The hemispheric differences and interannual variability in nighttime ozone are related to variations of temperature, H2O and OH associated with dynamical activity. Elevated stratopause events in the Northern Hemisphere winter are associated with transport of air that is depleted in H2O and high in OH; photochemistry then leads to downward displacement of the altitude of maximum ozone and enhancement in the ozone amount. Transport by planetary waves in the NH extends the region of high ozone further from the pole and leads to longitudinal variations. The analysis shows that, while the tertiary ozone maximum responds to a particular radiative situation as shown in previous studies, it also is the result of very dry air and high OH found in the winter polar mesosphere.

C2.1-0025-18 TEMPORAL VARIABILITY OF ATOMIC HYDROGEN FROM THE MESOPAUSE TO THE UPPER THERMOSPHERE

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We investigate atomic hydrogen (H) variability from the mesopause to the upper thermosphere, on time scales of solar cycle, seasonal, and diurnal, using measurements made by the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument on the Thermosphere Ionosphere Mesosphere Energetics Dynamics (TIMED) satellite, and simulations by the National Center for Atmospheric Research Whole Atmosphere Community Climate Model eXtended (WACCM-X). In the mesopause region (85 to 95 km), the seasonal and solar cycle variations of H simulated by WACCM-X are consistent with those from SABER observations: H density is higher in summer than in winter, and slightly higher at solar minimum than at solar maximum. However, mesopause region H density from the Mass-SpectrometerIncoherent-Scatter (NRLMSISE-00) empirical model has reversed seasonal variation compared to WACCMX and SABER. From the mesopause to the upper thermosphere, H density simulated by WACCM-X switches its solar cycle variation twice, and seasonal dependence once, and these changes of solar cycle and seasonal variability occur in the lower thermosphere (95 to 130 km); whereas H from NRLMSISE-00 does not change solar cycle and seasonal dependence from the mesopause through the thermosphere. In the upper thermosphere (above 150 km), H density simulated by WACCM-X is higher at solar minimum than at solar maximum, higher in winter than in summer, and also higher during nighttime than daytime. The amplitudes of these variations are on the order of factors of 10, 2, and 2, respectively. This is consistent with NRLMSISE-00.

C2.1-0026-18 THE RESULTS OF THE DETERMINISTIC-PROBABILISTIC MODELING OF THE D-REGION OF THE IONOSPHERE

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It has finally become clear that ionosphere influences propagation of almost all wavelength ranges being used in radio systems. Therefore, creating ionosphere models of various complexity levels is a very topical problem. Probabilistic-statistical modeling is the best way to describe such irregular environment as ionosphere, because output model's parameters are not the median values, but probability density functions, which provide us more complete and detailed information of ionospheric components behavior. The deterministic-probabilistic model is based on the five-component system of the ionization-recombination cycle of the D-region of the ionosphere. The modeling consists of experimental database processing of the input system's parameters and finding their probability density functions in various heliogeophysical conditions. Further, parameters' profiles are generated according to the obtained distributions and used to solve the system of differential equations to find electron density. The number of values is determined by the convergence of the solution. The resulting average values of the electron concentration demonstrate good agreement with the experimental database. So, obtained probability density functions of electron concentration can be used for radio wave propagation problems in considered conditions.

C2.1-0027-18 MODELING OF SIMULTANEOUS MULTIPLE PATH VLF OBSERVATION OF SOLAR FLARE USING ZENITH ANGLE PROFILE AND LWPC

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Excess solar X-ray radiation during solar flares causes an enhancement of ionization in the ionospheric D-region and hence affects sub-ionospherically propagating Very Low Frequency (VLF) signal. It causes VLF signal amplitude perturbation (ΔA), phase perturbation (ΔP), amplitude time delay (Δt) and other associated characteristics. The nature of solar flare associated VLF perturbation events are strongly dependent on the characteristics of the signal propagation path, i.e. a given solar flare generally causes completely or partially different types of perturbative effects on VLF signals observed simultaneously across different propagation paths at different parts of the globe having different geophysical conditions. To study this phenomenon, we observe a C-class flare on 20th January 2016 simultaneously from a number of such paths, namely, VTX-Bharati, VTX-IERC, NWC-Bharati, NWC-Dunedin and NWC-Maitri. During these observations, the signal-to-noise ratio was significantly low at those observation stations. The amount of observed VLF amplitude perturbations at different paths are notably different. The diurnal solar flux profiles over the paths having different ground conductivity profiles are mainly responsible for it and so we model the zenith angle profile over the path. We have used the Long Wave Propagation Capability (LWPC) code to model the D-region including the zenith angle effects. The simulated VLF signals resemble with its observational counterpart. Finally, we performed a correlation analysis for a quantitative comparison.

C2.1-0028-18 PMWE-1 SOUNDING ROCKET CAMPAIGN

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Polar Mesosphere Winter Echoes (PMWE) are relatively strong coherent radar returns from 55-85 km altitudes, which primarily occur in the winter season at high latitudes. PMWE are also observed at mid-latitudes, although very much more rarely. Because of their extremely low occurrence rate, they are still poorly investigated. Consequently, the origin of these echoes is still under debate. Currently the most accepted explanation of PMWE formation mechanism suggests that the neutral air turbulence plays the key role. However, there are some features, which need additional players to explain this phenomenon. The most important among them is the background electron density, which is needed to make PMWE detectable for the radars. This explains why PMWE more often occur during daytime when the solar radiation ionizes the Earth's atmosphere. Another suggested important player in the formation of PMWE are the dust particles or the so-called Meteor Smoke Particles (MSP). Their importance was suggested by interpretation of the PMWE observations with the European Incoherent Scatter radar (EISCAT). The PMWE sounding rocket mission aims at in situ measuring the key parameters that may explain the formation mechanism of the winter radar echoes. The Middle atmosphere ALOMAR Radar System (MAARSY) is capable of measuring the echoes along the rocket's flight path and is used to define launch criteria. Two instrumented sounding rockets will be launched from the Andøya Space Center (ASC) in northern Norway during the first PMWE campaign scheduled for beginning of April 2018. In this paper we will present the first results of the PMWE-1 sounding rocket campaign.

C2.1-0029-18 AIRGLOW MONITORING AND THE PROJECT OF METEOR MAP FOR APPLIED RESEARCH

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Investigation of solar-terrestrial relations was a priority for the main geophysical projects of a global scale, starting from the 1957 International Geophysical Year, when the first artificial Earth's satellite was launched. When studying the influence of the Sun on the ionosphere, other factors of influence were taken into account, such as a meteoroid which enters Earth's atmosphere from outer space. During meteoroid passage, the atoms and molecules of the atmosphere become excited, therefore ionization processes occur. The meteoroid entry is accompanied by some other effects, which are the result of the interaction of a rapidly moving meteoroid and the Earth's atmosphere. An ionization trail appears behind the moving meteoroid. There is a special term "the meteor zone of the atmosphere" for the layers of the atmosphere on altitudes about 70-120 km, where meteors are mostly observed by astronomers. The chemical composition of the meteoroid affects the color of the meteor that are investigated by astronomers. Meteoroid passages can make their special contribution to the glow of the sky, as explained by atmospheric chemistry. The airglow (also called nightglow) is light emission from the Earth's upper atmosphere. This is studied by geophysicists. The airglow is observed in the altitude region between 80 and 110 km of the Earth's atmosphere. To see it needs long dark adaptation. Unlike the aurora, the airglow is visible all over the globe. Explanation of the origin of the glow is in debate. This can arise due to the interaction of the Sun and cosmic rays with the Earth's atmosphere. Meteoroid passages can play a role as well. Here the meteor map project for applied research is proposed. Such a map would be of particular interest to airglow researchers. The map will be filled with up-to-date information about meteor showers, indicating their activity and parameters of the possible composition of each shower (if the composition data are available). This will provide additional information to the researcher who assesses the effects of the Sun and cosmic radiation on processes that take place in the Earth's atmosphere.

C2.1-0030-18 QBO EFFECT ON THE MIGRATING DIURNAL TIDE IN THE MLT REGION

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The stratospheric quasi-biennial oscillation (QBO) effect on the migrating diurnal tide (DW1) is investigated using the extended Canadian Middle Atmosphere Model (eCMAM) 31.5-yr run (1979-2010). Composite analyses are conducted to identify the DW1 zonal wind response under the westerly QBO (WQBO) and easterly QBO (EQBO). The DW1 amplitude is found to be stronger in WQBO than EQBO and the difference exhibits a semi-annual variation (bigger difference during the equinoxes than the solstices). We then investigate in detail the physical causes for 1) the tidal difference during the two phases of QBO and 2) its seasonal variation through momentum budget analysis. Different terms in the momentum budget are compared and the most important terms are identified. We then dissect the terms further to examine the latitudinal and vertical wind shears under the two phases and the resulting difference in the tide - mean flow interaction and consequently the tidal amplitude.

C2.1-0031-18 CHARACTERISTICS OF SHORT-TERM TIDAL VARIABILITY OF DW1 FROM DAILY TO SOLAR CYCLE TIME SCALES IN ECMAM30 AND SABER

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Wavelet analysis on DW1 (the migrating diurnal tide) using data from the extended Canadian Middle Atmospheric Model (eCMAM30) run (1979-2010) and the sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument on NASA's TIMED (Thermosphere Ionosphere Mesosphere Energetics Dynamics) satellite revealed strong short term tidal variability on time scales from few days to 1 month apart from the inter-annual, seasonal and intra-seasonal variabilities. Atmospheric tides have been observed to fluctuate on short-term time scales at the periods of planetary waves (few days to 30 days). In this research we investigate the tidal variability of DW1 as a function of the inter-annual variations such as solar flux, QBO, and ENSO, and seasonal harmonics (12, 6, 4 and 3 months) based on the regression model. We then further investigate the statistical properties (covariance, autocorrelation and time dependent probability density functions) of the short-term tidal variability with periods less than 30 days. The relative contributions from the quasi 23-day, quasi 16-day, and quasi 10-day waves to these statistical properties are noted.

C2.1-0032-18 STATISTICAL MODELING OF TIDAL WEATHER IN THE MLT REGION

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We attempt to build a vector autoregression (VAR) model and an empirical statistical model to simulate day-to-day variability of the atmospheric tides. We will present some of the statistical properties of the day-to-day variability of the tides, and the process to build the models, what we can learn about the physical processes governing the variability from the models, and exam their predictability, pro and cons. This is a quite new approach to try to understand and simulate the complex tidal variability from a statistical point of view.

C2.1-0033-18 A MODEL STUDY OF THE DRIVERS OF PMC CHANGES USING A WHOLE ATMOSPHERE MODEL WITH PARAMETERIZED PMCS

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Polar mesospheric clouds (PMC) are excellent monitors of mesospheric conditions due to their extreme sensitivity to temperature and water vapor. Both ground-based and satellite instruments have suggested changes in PMC abundance and brightness over the past several decades; however, the relative importance of the potential forcing terms is controversial. Possible sources of PMC change include changes in middle atmospheric structure due to anthropogenic CO2 and CH4, long-term change in global-scale dynamics, as well as solar irradiance changes. There is also the suggestion that PMCs respond to changes in ozone depleting substances such as chlorofluorocarbons (CFC). Temperature in the stratosphere responds to changes in stratospheric ozone, where decreasing O3 induces stratospheric cooling. Coupling of the stratosphere and mesosphere occurs through hydrostatic contraction, where a cooler stratosphere results in cooling near the mesopause, which in turn might enhance PMC formation. It is reported that cooling trends in the stratosphere became leveled off after 1995. This pause in cooling has been associated with slowly decreasing stratospheric concentrations of ozone-depleting substances. To study the influence of CFCs, we performed controlled numerical experiments with a version of the NCAR's Whole Atmosphere Community Climate Model (WACCM) that includes a parameterization for PMC formation. Rather than an overall trend analysis, where it may be difficult to disentangle the impacts of different forcing factors, we have more simply changed each term in isolation. For example, we will compare two runs, one with a background level of CFC abundance appropriate for earlier in the 20th century, to a run with present day values. Our results will enable subsequent trend analyses to more readily sort out the many possible causes of multi-decadal PMC variability. Acknowledgements: This work was funded by the NASA Heliophysics Supporting Research Program

C2.2-0001-18 FULL-WAVE MODELING STUDIES OF ATMOSPHERIC GRAVITY WAVES IN THE ATMOSPHERE

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Atmospheric gravity waves are a ubiquitous phenomenon in the terrestrial atmosphere and also in other planetary atmospheres. The importance of these waves to the terrestrial upper atmosphere is now reasonably well understood, based on a combination of observations and modeling over the last few decades. One type of model is the full-wave model. Here I will discuss this model and its variants, which have been used over the last two decades to simulation the propagation and dissipation of gravity waves in the atmosphere. This steady-state, single-gas Eulerian model solves the linearized Navier-Stokes equations subject to boundary conditions in a non-isothermal atmosphere, including height-dependent mean winds, viscosity, thermal conductivity, Coriolis force and ion drag. The model has been used to simulate gravity waves ducted in the terrestrial mesosphere and lower thermosphere, freely propagating gravity waves that dissipate in the terrestrial thermosphere, and gravity wave propagation and dissipation in planetary atmospheres (e.g., Jupiter, Mars) in order to examine wave influences on the mean state. A spectral version of the model, in which a few thousand individual monochromatic waves are simulated and then summed in a Fourier sense, has been used to simulate the response to a tsunami-like disturbance at the lower boundary. In spite of the fact that vertical advection of an air parcel should lead to fluctuations of gas properties such as molecular weight and specific heat, historically single gas steady-state models have never accounted for such effects in the thermosphere. Therefore, a second variant of the full-wave model was developed that treats the atmosphere as a single gas with a height-dependent mean molecular weight and also admits fluctuations of molecular weight and specific heat due to the effects of vertical advection. This increases by two the number of equations solved in the model. Earlier research suggests that this is an improvement over the standard single gas approach used in steady-state dynamical models. A third variant of the full-wave model treats the thermosphere as a binary gas. This model includes all the physical processes of the original full-wave model and also includes the effects of binary collisions in the momentum and energy equations, and mutual diffusion. Comparisons between simulations using this model with the second variant of the model, described above, suggest that including fluctuations of molecular weight and specific heat is the best approach for single gas steady-state models. Here, I will discuss the basic fullwave model and its variants, and present a number of model simulations that demonstrate the model's usefulness in improving our understanding of the effects of various physical processes on gravity wave propagation and dissipation. Vertical wavelengths and wave fluxes and their dependence on various physical processes will be discussed.

C2.2-0002-18 ATMOSPHERE-IONOSPHERE COUPLING DUE TO PLANETARY WAVES AND TIDES

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Over the past decade, first-principles whole-atmosphere models have revealed a lot about how planetary waves (PW) and tides determine the mean state and day-to-day variability of the quiet-time ionosphere. Some key elements of the atmosphere-ionosphere (A-I) coupling process include the dynamo generation of electric fields, wave-wave interactions, wave-mean flow interactions, and wave-induced composition changes. All of these produce different types of spatial and temporal variability, some over different time scales than others. An overview of these mechanisms is presented, with concrete examples for a few. Finally, open questions and remaining challenges regarding wave coupling in the A-I system are identified.

C2.2-0003-18 THE ATMOSPHERIC WAVES EXPERIMENT (AWE) ON THE INTERNATIONAL SPACE STATION

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The Atmospheric Waves Experiment (AWE) plans to deploy a high-resolution infrared imager (based on the successful Utah State University Advanced Mesospheric Temperature Mapper) on the International Space Station (ISS) to gain a transformative set of gravity wave (GW)

-resolving temperature measurements using the OH nightglow emission (altitude 87 km). The ISS provides an ideal combination of altitude, geographic and local time coverage to accomplish our proposed science objectives, which seeks not only near-global measurements of GW characteristics in the mesopause region, but

also quantification of GW momentum and energy fluxes driving the Ionosphere-Thermosphere (IT) from below. Combined with state-of-the-art high-resolution models, the AWE mission will also assess the relative importance of sources versus propagation conditions in explaining the observed spatial and temporal variability of the GWs.

The AWE mission is currently in a "Phase A" study as part of the NASA 2016 Heliophysics Explorers Mission of Opportunity (MO) Program. In this presentation, we describe the primary goals of this program and introduce our proposed research methods using proven IR instrument technology. AWE's exceptional capabilities are illustrated with recent discoveries in observing GWs from the ground and from aircraft during the NSF DEEPWAVE campaign, promising a major step forward in understanding how troposphere weather translates to space weather.

C2.2-0005-18 ATMOSPHERE-IONOSPHERE COUPLING AND EQUATORIAL SPREAD-F

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This paper discusses about the influence of Stratospheric Sudden Warming (SSW) events in modulating the occurrence time of the Equatorial Spread-F (ESF) through enhanced Planetary Wave (PW) activity during the winter months. The analysis based on the data from a Digital Ionosonde and Proton Precession Magnetometer over Trivandrum (8.5o N, 77o E, 0.5o N dip lat.), revealed that the PWs of quasi-16 day periodicity influence the start time of the ESF to a significant extent during the SSW years. On the other hand, during a normal year such effect is not very evidently present. It has been observed that the quasi-16 day wave propagate to ionospheric dynamo region from the atmosphere below and modify the electrodynamical processes like the Equatorial Electrojet and Pre-Reversal Enhancement, which is more pronounced during both the SSW periods. Such a modification in the electrodynamics can modulate the equatorial plasma fountain and influence the F-region neutral dynamics, which in turn can affect the occurrence of ESF by modifying the seeding conditions.

C2.2-0006-18 ATMOSPHERIC WAVE OBSERVATIONS AND PREDICTIONS FOR THE NASA IONOSPHERIC CONNECTION EXPLORER

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Earth's ionosphere varies from one day to the next in ways that cannot be predicted. The Ionospheric Connection Explorer (ICON) is set to launch in the Summer of 2018 with a mission to discover the causes of this variability. Since the decision by NASA in 2013 to develop the mission, there have been a number of research results that predict the presence of a number of science targets that are now better-defined. These include a remarkable variety of atmospheric waves and products of wave-wave interactions that may may be expected and identifiable in the ICON data products, including wind and temperature profiles in the lower E-region (90-140 km altitude). Here we will describe those potentially important drivers of ionospheric variability and how they may appear in the ICON data products. We use a TIEGCM model analysis of the ionosphere where large spatial and temporal scale waves are introduced along with atmospheric tides to elucidate these potential effects.

C2.2-0008-18 MODELING AND OBSERVATIONS OF LITHOSPHERE-ATMOSPHERE-IONOSPHERE COUPLING DRIVEN BY EARTHQUAKE SURFACE WAVES

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It is known that earthquakes generate acoustic and gravity waves that drive ionospheric perturbations [Shuanggen et al., ESR, 2015; Komjathy et al., Radio Sci., 2016]. Rayleigh waves travel along the surface (3-5 km/s) of the Earth from epicenter creating vertical displacements. These displacements are a source of upward-propagating acoustic waves, with amplitudes growing exponentially with altitude due to the conservation of energy. Plasma density fluctuations with periods of 5mHz were observed and reported after several severe earthquakes using GNSS Total Electron Content (TEC) measurements [e.g. Ducic et al., GRL, 2003; Galvan et al., JGR, 2011; Tulasi Ram et al., JGR, 2017]. Observed fluctuations and their velocities are consistent with time of propagation of the acoustic wave signal to the ionospheric F2 layer (10 min), carrying the "imprint" of Rayleigh waves phase speeds. Rolland et al. [JGR, 2011] performed modeling of TEC perturbations driven by Rayleigh waves based on lithosphere-atmosphere coupling of normal modes [Lognonne et al., GJI, 1998; Artru et al., GJI, 2004], demonstrating this mechanism. In this work, we investigate the propagation of acoustic waves in atmosphere and ionosphere induced by Rayleigh waves after severe earthquakes. Case studies for Sichuan 7.9 Mw 2008, Tohoku-Oki 9.1 Mw 2011 and Nepal 7.8 Mw 2015 earthquakes are examined. We use the normal mode summation technique implemented in the 1D PREM Earth model [Dziewonski et al., PEPI, 1981] to simulate the propagation of Rayleigh waves from the earthquake's epicenter based on centroid moment tensor information about seismic source. Surface perturbations are then impose as a lower boundary condition for nonlinear 2D simulations using the Model for Acoustic-Gravity wave Interactions and Coupling (MAGIC) and the Geospace Environment Model for Ion-Neutral Interactions (GEMINI) [Zettergren and Snively, JGR, 2015] to study the propagation of acoustic waves to ionospheric altitudes. Modeling captures the primary features of lithosphere-atmosphere-ionosphere coupling, and reveals the spatial and temporal evolutions of acoustic waves in the atmosphere driven by fast surface waves, providing new insight into their generation and propagation. We also assess their detectability in data relative to other wave processes occurring above the epicenter.

C2.2-0009-18 SATELLITE OBSERVATIONS OF GRAVITY WAVES

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Vertical coupling by atmospheric gravity waves (GWs) from the lower atmosphere plays an important role in the energy and momentum balance of the thermosphere/ionosphere (T/I). However, the penetration of GWs into the T/I system is not fully understood in modeling as well as in observations. For a better understanding of this vertical coupling, satellite observations of GWs at different altitude levels can be utilized as a guidance. We here analyze observations of GWs at different layers of the atmosphere. In the middle atmosphere (30-90 km) GW momentum fluxes are extracted from temperature measurements of the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) satellite instrument. In the T/I, at altitudes of 220 km and 400 km, respectively, GW induced fluctuations are derived using mass density from the Gravity field and Ocean Circulation Explorer (GOCE) and CHAllenging Minisatellite Payload (CHAMP) satellites. We found similar features in GW horizontal distributions at the different altitude levels considered. Further, spatial correlations between these horizontal distributions are generally positive. These findings demonstrate the importance of the vertical coupling by GWs between lower atmosphere and T/I. Two coupling mechanisms may contribute: (1) fast GWs generated in the troposphere and lower stratosphere propagate directly to the T/I and (2) primary GWs having their origins in the lower atmosphere dissipate while propagating upwards and generate secondary GWs, which then penetrate up to the T/I and maintain the spatial patterns of GW distributions in the lower atmosphere. In addition to the mountain-wave related hot spot over the Andes and Antartic Peninsula, we found latitude-longitude variations in the summer midlatitudes in observations of all instruments. This, together with positive correlations in the summer midlatitudes, suggest the propagation of GWs with convective origins into the T/I. In addition, we estimate for the first time GW momentum fluxes using observations of GOCE and CHAMP. Limitations of the observations and of our research approach are discussed.

C2.2-0010-18 GRAVITY WAVE COUPLING FROM THE TROPOSPHERE TO THE MESOPAUSE REGION INVESTIGATED WITH GROUND BASED AND AIR BORNE OBSERVATIONS

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Between 2013 and 2016 the DLR-Institute of Atmospheric Physics has conducted a series of three coordinated ground based and air borne field campaigns to study the life cycle of gravity waves from their excitation in the troposphere to their dissipation in the mesopause region. Two of these field campaigns were carried out in in Northern Scandinavia (Northern hemisphere winter 2013/14 and 2015/16) and we also participated in the NSF-led DEEPWAVE mission in New Zealand in Austral winter 2014. Ground based observations comprised Rayleigh lidar temperature measurements between 20 - 90 km as well as OH airglow measurements. Airborne in-situ observations of momentum and energy fluxes were used to characterize the propagation characteristics of the waves across the tropopause, a topic which was further investigated using airborne wind lidar measurements. In this paper we present the major results of these campaigns focusing on 1) the role of the tropopause in determining the fraction of tropospheric waves that reach the middle atmosphere, 2) the refraction and horizontal propagation of waves by the background wind, and 3) the dissipation and wave mean flow interaction in the mesopause

region. Finally, we will also briefly introduce our plans for a combined ground based and airborne field campaign focusing on the Southern hemisphere gravity wave hotspot in the Southern Andes that is currently planned for September - December 2019.

C2.2-0011-18 GRAVITY WAVE DISSIPATION IN THE UPPER ATMOSPHERE

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A question of fundamental importance is the altitudes to which gravity waves originating in the lower atmosphere can propagate. It is well known that high frequency quasi-monochromatic waves that are initially small amplitude may propagate to great heights before they dissipate, while slower stronger waves are damped at lower altitudes. Less well known are effects on wave packet attenuation related to their spectral nature, specifically dispersion and scale-dependent dissipation. Dispersive wave packets launched in the lower atmosphere may suffer strong attenuation by dispersion alone before they propagate great distances from their sources. Dispersion combined with dissipation has a strong effect on the spectra of wave packets and this affects their propagation and dissipation. For highly dispersed wave packets, the component of the packets with long vertical wavelengths (the component with rapid vertical propagation) reaches the dissipative regions of the thermosphere first. This depletes the fast waves first and causes a shift in the central wavenumber toward shorter slower waves and causes wave packets to slow down. On the other hand, if minimal dispersion occurs before wave packets reach strongly dissipative regions, scale-dependent dissipation depletes the shorter slower waves and the opposite effects are seen. The effects of dispersion are greatest for broadband disturbances. The spectral nature of wave packets has significant implications for wave packet trajectories, amplitudes and wave drag (including drag parameterizations). The theory and modeling of wave packet propagation subject to dispersion and viscous dissipation will be reviewed.

C2.2-0012-18 OBSERVATION OF ATMOSPHERIC COUPLING AND INTERNAL WAVES BY AIRGLOW IMAGERS

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We will review our recent progress on the observation of atmospheric coupling processes through gravity waves using multi-point all-sky airglow imagers of Optical Mesosphere Thermosphere Imagers (OMTIs). Three-dimensional Fourier analysis of airglow images makes it possible to analyze long-term airglow imaging data to see the short-period gravity wave activities. Using this method, Takeo et al. (JGR, 2017) studied 16-year variation of horizontal phase velocity and propagation direction of mesospheric and thermospheric waves in airglow images observed by an airglow imager at Shigaraki (34.8N), Japan. We also extend this 16-year analysis to another station at Rikubetsu (43.5N), Japan to investigate latitudinal difference/similarity of the gravity wave characteristics. We show yearly, seasonal, and local time variation of gravity wave propagation characteristics as well as their relation to the stratospheric sudden warming. We also show gravity wave characteristics in the thermosphere based on statistical study of medium-scale traveling ionospheric disturbances (MSTIDs) in the 630-nm airglow images and through simultaneous observations of the MSTIDs by an airglow imager and the CHAMP satellite over Indonesia at a latitude of 0.2S. We observed thermospheric neutral density variations by the CHAMP satellite associated with the southward-propagating MSTIDs in the 630-nm airglow images over Indonesia, indicating that these MSTIDs are caused by gravity waves penetrating into the thermosphere. We also show geomagnetic conjugacy and non-conjugacy of ionospheric and thermospheric variations accompanied by a midnight brightness wave at low latitudes reported by Fukushima et al. (EPS, 2017) using airglow imagers, ionosondes and an Fabry-Perot interferometer at Thailand and Indonesia.

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C2.2-0013-18 INTERACTIONS OF SMALL AND MEDIUM-SCALE GRAVITY WAVES IN THE MESOSPHERE AND LOWER THERMOSPHERE.

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Gravity Waves play an important role in transporting energy and momentum from the lower to upper atmosphere. However, their propagation, evolution, and momentum deposition depend highly upon the prevailing atmospheric conditions (Fritts and Alexander., Geophys. Rev., 41, 103, 2003). High-frequency, small scale waves in particular are suggested to carry large momentum flux into the Mesosphere and Lower Thermosphere (MLT) region (Fritts et al., JGR, 119, 2014). However, temporal variances in atmospheric winds and temperatures caused by other, longer period waves can significantly influence their progress into the dissipative region. Currently, wave dynamics at these scales are often parameterized using linear, steadystate approximations in General Circulation Models (GCMs).

In this study, numerical simulations are used to explore linear and nonlinear interactions between small (10s km, sub hour periods) and medium-scale (100km, hour periods) gravity waves in order to understand and characterize the dominant dynamical effects at these scales. Doing so will be important for the next generation of high-resolution GCMs, which will partially resolve and partially parameterize the gravity wave spectrum (e.g. Liu et al., GRL, 41, 2014). It is found that small-scale wave breaking can occur along preferential phases of the medium scale wave. This breaking can induce a mean flow and shear which in turn influences the medium-scale wave. At finite amplitudes, both the medium-scale and small-scale waves are nonlinearly and time-dependently depositing energy into the mean flow causing self, and 'mutual accelerations' between the two waves (when the time dependent acceleration of the mean flow by one wave also acts to accelerate the other wave). Results suggest that time-dependent dynamics are required in order to properly describe these nonlinear wave-wave interactions. Next-generation GCMs will require parameterization schemes that can account for these effects between resolved (medium scale) and unresolved (small scale) gravity waves of relatively fast group and phase velocities.

C2.2-0014-18 IMPLEMENTATION OF A GRAVITY WAVE PARAMETERIZATION INTO A WHOLE ATMOSPHERE GCM AND SIMULATION OF THERMOSPHERIC GRAVITY WAVE EFFECTS

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Using a general circulation model (GCM), the effects of gravity wave (GW) drag on the general circulation in the thermosphere is examined. A whole atmosphere GCM developed by Miyoshi and Fujiwara (2003) is used in this study. A GW parameterization specifically designed for thermospheric heights developed by Yigit et al (2009) is implemented in the GCM. The horizontal resolution of the GCM is 2.8 degrees longitudes by 2.8 degrees latitudes. Therefore, the GW drag in the model is mainly estimated by the GW parameterization. Comparing the results obtained by the GCM with and without the GW parameterization, we first examine the effects of the GW drag on the zonal mean zonal wind and meridional circulation in the thermosphere. Next, the impacts of the GW drag on the upward propagating tides from below. In particular, the interaction between the GW drag and the migrating diurnal and semidiurnal tides is investigated in detail. Our results indicate that the GW drag modulates the vertical and latitudinal structure of the migrating tidal amplitude in the thermosphere.

C2.2-0015-18 MODELING THE QUANTIFIABLE SIGNATURES AND EFFECTS OF GRAVITY WAVES IN THE MESOSPHERE AND LOWER THERMOSPHERE: NONLINEAR EVOLUTIONS AND HYDROXYL AIRGLOW LAYER RESPONSES

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Imaging of the hydroxyl (OH) airglow layer provides one of the most promising capabilities to assess gravity wave propagation and processes in the mesosphere and lower thermosphere (MLT). Filtered imaging techniques to derive OH rotational temperature can enable measurements of gravity wave perturbations, for quantification of their energy and momentum fluxes and subsequent effects [e.g., Fritts et al., JGR, 119(24), 2014; Pautet et al., App. Opt., 53(26), 2014]. In this talk, we provide additional modeling basis for the quantitative interpretation of gravity waves in the MLT region. The 3D Model for Acoustic-Gravity wave Interactions and Coupling (MAGIC) [e.g., Snively and Pasko, JGR, 113(A6), 2008; Zettergren and Snively, JGR, 120, 2015, and references therein] is applied to investigate the evolutions of short-period, small-scale gravity wave packets as they impact the MLT at large amplitude under varied ambient conditions. The comprehensive nonlinear evolutions of the gravity waves are simulated from ground to thermosphere, while also capturing their perturbations to major (N2, O2, O) and minor (e.g., H, O3, OH(v)) species and resulting signatures in OH(3,1) emission rate, integrated intensity, and brightness-weighted temperature [e.g., Snively et al., JGR 115(A11), 2010, and references therein]. We assess the quantitative estimation of fluxes and effects from these synthetic data, in comparison with the underlying physical quantities, and find promising agreement using present techniques especially when the ambient atmospheric state can be characterized. We also consider the effects of the simulated gravity waves above the MLT in the thermosphere, with implications for the overlying ionosphere (IT). Results demonstrate new opportunities towards the interpretation of MLT and IT observations using comprehensive numerical simulations.

C2.2-0016-18 TIDES, PLANETARY WAVES, AND ATMOSPHERIC COUPLING

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A growing number of studies report linkages between disparate stratospheric and upper atmospheric phenomena. For example, stratospheric warmings correlate with ionospheric perturbations, and with reductions in polar mesospheric cloud occurrence. Understanding these so-called teleconnections is important for ionospheric prediction, and interpreting global change proxies. This presentation will focus on the roles of tides and planetary waves in transmitting tropospheric and stratospheric variability into the thermosphere and ionosphere. I will review several key studies demonstrating strategies that will inform NASA's upcoming ICON and GOLD missions.

C2.2-0017-18 COUPLING BETWEEN TIDAL AND PLANETARY WAVE MODES IN THE MLT-I SYSTEM

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Individual spatial modes from tidal and planetary waves are known to structure the ionosphere. However, wind observations from a single station, even those that image over scales much smaller than these waves, produce a time-series from which only the net period and phase of the total superposed spatial wavenumber components can be derived. Thus, neither the amplitudes of the individual wave modes nor the interactions between them can be observed. While satellite data can give both temporal and spatial components, the time and spatial information is generally not separable without assuming stationarity. Here, hourly mean meteor wind data from a longitudinal chain of 8 high-latitude northern hemisphere SuperDARN radars have been combined in order to provide the spatial tidal and planetary wave components as a function of time. This has been used to extract the migrating and non-migrating components of the semidiurnal tide, as well as the S1 and S2 planetary wave components in the lower thermosphere meridional wind between 1995 and 2016. We find that the semidiurnal tide is dominated by the migrating (W2) component, though substantial W1 and W3 contributions to the semidiurnal tide occur, especially around the equinoxes. Similarly, the S1 planetary wave amplitudes in the northern hemisphere are generally largest, but there are periods where the S2 mode becomes dominant. Due to their large amplitudes in the northern hemisphere, these planetary wave modes can couple into individual tidal components and may enhance their presence in the ionosphere. Data analysis and validation will be presented, together with initial results on the inter-annual variability of the tidal and planetary wave components and their possible coupling to the ionosphere.

C2.2-0018-18 INTERACTION BETWEEN SMALL-SCALE GRAVITY WAVES AND MIGRATING DIURNAL TIDE IN EARTH'S MIDDLE AND UPPER ATMOSPHERE

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Gravity (buoyancy) waves (GWs) and solar tides of lower atmospheric origin are important for the energy and momentum budget of the middle and upper atmosphere [Yiğit and Medvedev, 2015]. Here, the effects of subgrid-scale GWs on the diurnal migrating tides are investigated from the mesosphere to the upper thermosphere during equinox, using a general circulation model coupled with the whole atmosphere nonlinear GW parameterization of Yiğit et al. [2008]. Systematical simulations show that GWs appreciably impact the mean circulation and cool the thermosphere by up to 18%. GWs significantly affect the winds modulated by the diurnal migrating tide, in particular, in the low-latitude mesosphere and lower thermosphere and in the high-latitude thermosphere. These effects depend on the mutual correlation of the diurnal phases of the GW forcing and tides: GWs can either enhance or reduce the tidal amplitude. In the low-latitude MLT, the correlation between the direction of the deposited GW momentum and the tidal phase is positive due to propagation of a broad spectrum of GW harmonics through the alternating winds. In the Northern Hemisphere high-latitude thermosphere, GWs act against the tide due to an anticorrelation of tidal wind and GW momentum, while in the Southern high-latitudes they weakly enhance the tidal amplitude via a combination of a partial correlation of phases and GW-induced changes of the circulation. The variable nature of GW effects on the thermal tide can be captured in GCMs provided that a GW parameterization scheme (1) considers a broad spectrum of wave harmonics, (2) properly describes their propagation, and (3) correctly accounts for the physics of wave breaking/saturation [Yiğit and Medvedev, 2017].

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C2.2-0019-18 SHORT-TERM VARIABILITY OF GRAVITY WAVES AND TIDES DURING A RECORD LONG 10-DAY CONTINUOUS LIDAR SOUNDING AT MIDLATITUDES

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Gravity waves (GWs) play a crucial role for the understanding of the circulation in the Earth's atmosphere. The propagation of these waves is strongly affected by the slowly varying background wind, which is modulated by tidal and planetary waves. These large scale waves are also influenced by GWs. Such wave-wave interactions are rarely observed and they are also not adequately implemented in many circulation models. Exceptional weather conditions in May 2016 allowed for an unprecedented 10-day continuous sounding with the daylight-capable Rayleigh-Mie-Raman (RMR) lidar at the midlatitude station Kühlungsborn (54° N, 12° E). The lidar operates independently from daylight conditions and typically provides temperature profiles in an altitude range between 30 and 75km with a temporal resolution of 2h or relative density profiles with 10min resolution. The data set shows a large variability of GWs and tides on time scales of days. GWs and tides are separated using a 1-dimensional spectral filtering technique, and their temporal evolution is studied. During the measurement period a strong 24h-wave is detected mainly between 40 and 60km and vanishes after a few days. The disappearance is related to an enhancement of GWs with periods of 4-8h. Short periodic GWs with periods of a several minutes to 4h are extracted by using the high resolution lidar raw data instead of temperature data. These waves show a similar enhancement during the last days. Wind data provided by ECMWF are used to analyze the meteorological situation above the station. The local wind structure changes during the observation period, which leads to a strong GW activity in the last days of the measurement. The analysis indicates a further change in wave-wave interaction resulting in a minimum of the 24h tide. The observed variability of tides and GWs on timescales of a few days clearly demonstrates the importance of continuous measurements with high temporal and spatial resolution to resolve this short-term variability.

C2.2-0020-18 ATMOSPHERIC GRAVITY WAVE PROPAGATION ACROSS THE STRATOSPHERE, MESOSPHERE, AND THERMOSPHERE OVER ALASKA, AND THE ROLE OF THERMAL GRADIENTS IN THE POLAR REGIONS ON VERTICAL GRAVITY WAVE PROPAGATION

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A broad spectrum of atmospheric waves is responsible for transporting energy across atmospheric layers from the troposphere and deep into thermosphere. Recent developments in general atmospheric circulation modeling are allowing for analysis of coupling mechanisms between these atmospheric layers in terms of wave activity. One of the difficulties are implementing the role of small-scale gravity waves with wavelengths less than 100 km and periods in the orders of minutes. These short-period gravity waves are known to be a major contributor to transporting momentum fluxed across atmospheric regions. As these waves propagate vertically through the atmosphere, they are subject to dispersion and dissipation due to varying winds and temperature, as well as eddy diffusion in upper atmosphere and lower thermosphere. A collaborative project between Utah Valley University, University of Alaska, Fairbanks, and Utah State University involved gravity wave measurements in the stratosphere, mesosphere, and thermosphere during the 2011-2014 period. In this presentation, we highlight new results of this study and discuss impacts of mesospheric thermal gradients as observed by SABER on the wave propagation and coupling between atmospheric layers in the Polar regions.

C2.2-0021-18 GRAVITY WAVES GENERATED IN THE IONOSPHERE DURING 21 AUGUST 2017 TOTAL SOLAR ECLIPSE AS SEEN THROUGH GPS-TEC OBSERVATIONS

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The present work investigates ionospheric effects of the 21 August 2017 total solar eclipse, particularly targeting eclipse-generated gravity waves in the ionosphere. Ionospheric total electron content (TEC) derived from Global Positioning System (GPS) data obtained from a number of stations located both along and across the path of eclipse totality has been utilized for this purpose. Distinct gravity wave-like signatures with wave periods around 20-90 min (with dominant peak at 25-30 min wave period) have been observed at all locations both in the path of totality and away from it. The observed gravity waves are more intense at locations closer to the path of totality, and the wave amplitudes decrease gradually with increasing distance from the path of totality. Our result highlights the manifestation of eclipse-generated waves in the variability of the terrestrial ionosphere.

C2.2-0022-18 ON SOME EFFECTS OF UPPER ATMOSPHERE COOLING OVER GWS PROPAGATION

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The study of cooling and trends in general in the upper atmosphere has gained interest since the early 1990's as a consequence of the great concern about the global warming observed in the troposphere. Since then it has become a significant topic in global change investigations. Some research works link these trends to the increase in greenhouse gases concentration, and others to natural causes. Based on many observational and model results a global pattern of trend emerged with the dominant driver of upper atmosphere trends being the increasing concentration of greenhouse gases. At these heights, a cooling effect is expected, and also observed, together with a decrease in neutral concentration. The propagation of gravity waves (GWs) in the thermosphere depends strongly on neutral temperature and total mass density, so changes should also be expected in GW propagation and dispersion characteristics. In order to analyze these changes, a GW ray tracing method, which take into account kinematic viscosity and thermal diffusivity was applied. NRLMSISE-00 and HWM14 models were used to assess the parameters needed for the ray tracing code. As result of decreasing the temperature and neutral density background values, the heights reached by the GWs are lower, as expected from theoretical analysis. Although the assessed variations are small, upper atmosphere cooling effect over GWs behavior are a challenging and topical scientific issue worth of deep study and comprehension which can become more noticeable in the future if the increase in greenhouse gases continues.

C2.2-0023-18 MODELING IONOSPHERIC TEC AND MAGNETIC FIELD SIGNATURES OF LARGE-AMPLITUDE ACOUSTIC AND GRAVITY WAVES GENERATED BY NATURAL HAZARD EVENTS

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Ocean and solid earth responses during earthquakes are a significant source of large amplitude acoustic and gravity waves (AGWs) that perturb the overlying ionosphere-thermosphere (IT) system. IT disturbances are routinely detected following large earthquakes (M > 7.0) via GPS total electron content (TEC) observations, which often show acoustic wave (3-4 min periods) and gravity wave (8-15 min) signatures with amplitudes of 0.05-4 TECU. In cases of very large earthquakes (M > 8.0), persistent acoustic waves are estimated to have 100- 300 m/s compressional velocities in the conducting ionospheric E and F-regions and should generate detectable dynamo currents and magnetic field signatures. Indeed, some recent reports (e.g. Hao et al, 2013, JGR, 118, 6) show evidence for magnetic fluctuations, which appear to be related to AGWs, following recent large earthquakes. Physical processes, including both ionospheric and oceanic dynamos, responsible for generating the magnetic field perturbations are not yet well-understood to the point that we can characterize their dominant physical source mechanisms nor their detailed spatial and temporal structure. TEC responses, while betterunderstood, still cannot be modeled and predicted to the extent necessary to interpret their natural hazard AGW sources.

This work investigates spaceand time-dependent behavior of both TEC and magnetic fluctuations following recent large earthquakes, with the aim to improve physical understanding of these perturbations via detailed, high-resolution, twoand three-dimensional modeling case studies with coupled neutral atmospheric and ionospheric models, MAGIC (Model for AcousticGravity wave Interactions and Coupling) and GEMINI (Geospace Environment Model for Ion Neutral Interactions) as described by Zettergren and Snively (2015, JGR, 120, 9). We focus on the recent 2011 Tohoku-Oki earthquake, which has a well-characterized ocean surface response (e.g. Mikumo et al, 2013,

JGR, 118) and published examples of magnetic field perturbations, and also perform modeling for recent large Chilean earthquakes in 2010 and 2015. AGW sources for MAGIC-GEMINI are chosen, for each event, based on available information from ocean buoy, seismometer data, and TEC data. Simulations reveal the 3D structure of plasma density and currents, and TEC latitude and longitude structure, and provide fundamental insight into the degree to which the ionosphere contributes to magnetic perturbations following natural hazards. Comparisons of simulation results against available TEC and magnetic field data from these events provide evidence supporting the processes identified in these spatially-resolved simulations.

C2.2-0024-18 MIDDLE ATMOSPHERE EFFECTS OF LOCALIZED GRAVITY WAVE FORCING (MATELO) - NEW SIMULATIONS AND RESULTS

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New experiments and results of sensitivity simulations performed with a mechanistic circulation model are presented. The study is focused on possible effects of a localized gravity wave (GW) breaking region on the large-scale circulation and transport and, more generally, a possible influence of the spatial distribution of gravity wave activity on middle atmospheric dynamics. The analysis was originally inspired by Sacha et al. (2015) describing a localized area of enhanced gravity wave activity and breaking in the lower stratosphere of the east Asian-northwestern Pacific region.

The results indicate the important role of the spatial distribution of GW activity for the polar vortex stability, formation of planetary waves, and for the strength and structure of the zonalmean residual circulation. Furthermore, the zonally asymmetric forcing plays an important role in the longitudinal variability of the circulation in general and Brewer-Dobson circulation in particular. The first results were described by Sacha et al. (2016). Here we present results of new experiments that were focused on the impact of various spatio-temporal characteristics of the localized GW activity, and potential coupling with tropospheric climate oscillations like ENSO and NAO.

C2.2-0025-18 A MODELING STUDY OF NON-MIGRATING TIDAL EFFECTS ON IONOSPHERIC STRUCTURE DURING BOREAL WINTER

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Non-migrating tides of lower atmospheric origin have a dramatic impact on the large-scale longitudinal structure of the low latitude ionosphere. For example, wave-3 and wave-4 features associated with DE2, DE3, DW4, among others, are typically observed in the equatorial ionization anomaly (EIA). Day-to-day ionospheric structure is continually changing due to the varying amplitudes of the non-migrating tides. Studies with coupled atmosphere-ionosphere models have been able to capture such day-to-day variability. Recently, we have used SAMI3 coupled with the Specified Dynamics Whole Atmosphere Community Climate Model, extended version (SD-WACCM-X) to show that the model captures much of the observed day-to-day variability in the ionosphere. We also found that non-migrating tides are modulated during a stratospheric warming period in January 2010. In this study, we extend our modeling studies to simulate three boreal winter seasons (January - February 2010, 2013 and 2016). We characterize non-migrating tidal variability that impacts the ionospheric structure. Specifically, we address whether or not the non-migrating tidal variations we identified in January 2010 are unique to the stratospheric warming event, or simply characteristic of the season. The Navy atmospheric analysis from the High-Altitude Navy Global Environmental Model (HA-NAVGEM) is used to constrain the meteorology of the numerical simulations up to 90 km.

C2.2-0026-18 GLOBAL DISTRIBUTION OF MEDIUM SCALE TRAVELING IONOSPHERIC DISTURBANCES SEEN BY SWARM AND CHAMP SATELLITES

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This study investigates the activity of medium-scale traveling ionospheric disturbances (MSTIDs) on a global basis by analyzing the measurements of the electron density and magnetic fields by Swarm and CHAMP satellites. The combination of the CHAMP (2001-2008) and Swarm (2014-2017) observations provides us an opportunity to identify the variation of the MSTID activity during a solar cycle. Because the irregularities produced by MSTIDs are not distinguishable from the irregularities produced by plasma bubbles (equatorial region) and by particle precipitation or horizontal plasma convection (high latitudes), our investigation focuses on the MSTID distribution in middle latitudes. Several studies derived the MSTID distribution from satellite observations, but notable discrepancies exist among the results derived using different parameters. Our study determines the appropriate parameters for the detection of MSTIDs from satellite observations by comparing with ground-based observations. We report the variation of the MSTID activity with local time, season, latitude, magnetic activity, and solar cycle and use this knowledge for the identification of the onset condition of MSTIDs.

C2.2-0027-18 WAVE DYNAMICS OF THE WHOLE ATMOSPHERE MODELS: TIDAL VARIABILITY AND ITS EFFECTS IN THE ITM

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The paper presents comparative analysis of tidal variability, as simulated by two whole atmosphere models, WAM and WACCM-X, constrained by the meteorological analyses of NASA/GMAO in the troposphere and stratosphere. Both models with the meteorology of the lower atmosphere reproduce the main features of the day-to-day, annual and year-to-year variability of diurnal and semidiurnal tides, as deduced from the multi-year (2009-present) space-borne observations and middle atmosphere data assimilation case studies. As observed and simulated by models, the March-April semiannual maxima of the 24-hr tidal amplitudes and their strong quasi-biennial modulations can represent a good illustration for strong wave coupling and interactions of tidal and gravity waves with prevailing flow in the equatorial middle atmosphere. Sensitivity of the mean flows and tides simulated by WAM and WACCM-X to the model gravity wave physics will be highlighted. The influence of the mid-winter Arctic sudden stratospheric warming dynamics on the global tidal structures and the low-latitude anomalies of electrodynamics and plasma transport will be discussed and compared with the data.

C2.2-0029-18 QUASI-6 DAY PLANETARY WAVES AND UPPER ATMOSPHERIC EFFECTS

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The ionosphere is under the influence of various forcing mechanisms and its electrodynamic state varies significantly from day to day. This ionospheric variability results not only from solar radiation and magnetospheric forcing, but also from atmospheric waves that propagate to the ionosphere from the lower layers of the atmosphere. Previous studies mainly focused on the role of atmospheric tides, which have large amplitudes (several 10 m/s) in the dynamo region of the ionosphere (90-150 km). At dynamo region heights, tidal winds serve as a source of ionospheric variability, as they drive electric fields and currents. Similar ionospheric effects may be expected from planetary waves, Kelvin waves, and gravity waves, which can also partly penetrate into the dynamo region. In this light, we examine the variation of the equatorial electrojet derived from the magnetic field measurements by the Swarm and CHAMP satellites. The equatorial electrojet is a relatively strong zonal ionospheric current flowing along the magnetic equator at approximately 110 km. Case studies are presented, in which the equatorial electrojet intensity at a fixed longitude shows an oscillatory variation with a period of approximately six days. We discuss the possible contribution of the quasi-6 day planetary wave.

C2.2-0030-18 HORIZONTAL WIND'S FACTOR IN FORMATION OF SPORADIC E UNDER INFLUENCE OF ATMOSPHERIC WAVES

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An importance of meridional and zonal background wind for formation the sporadic E under the influence of atmospheric gravity waves (AGWs) and shear excited vortical type perturbations (shear waves) are considered. It is shown, that the mid-latitude northward horizontal wind influences downward motion of the long-lived heavy metallic ions (e.g., Fe+) and can cause their density increase at lower thermospheric heights, where their vertical diffusive displacement is comparatively smaller. In the similar way, the combined action of ions collision with zonal neutral wind particles and Lorentz Forcing also influence on the ions vertical drift, which can provide an additional convergence or divergence of their density at mid-latitude and equatorial regions as well. The values of northward wind velocity providing the ions vertical convergence into a horizontal layer and the location of region of additional convergence under influence of zonal wind are estimated. It is shown that AGWs along with horizontal homogeneous/inhomogeneous wind can cause additional convergence of ions and formation multilayered sporadic E. The numerical results describing formation sporadic E under an influence of horizontal wind and its multilayered structure caused by the declined propagation AGWs and shear waves are demonstrated. Acknowledgement: This study is supported by Georgian Shota Rustaveli National Science Foundation Grant no. FR17-357.

C2.2-0031-18 INVESTIGATION ON 15-DAYS OSCILLATIONS IN THE EQUATORIAL SPREADF

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An intensive study on the start time of equatorial plasma bubble, observed by an all sky imager deployed at São João do Cariri (7.4°S, 36.5°W), and equatorial spread-F, observed by a coherent back scatter deployed at São Luís (2.5°S, 44.2°W) was conducted from 2001 to 2009. Oscillation of 14.5 days was clearly observed in three month (September 2003, October 2005 and January 2008) in the airglow images with amplitudes of 45-60 min. Furthermore, using the data from the radar range time integration (RTI) maps, several events were observed with dominant period of 14.5 days in September 2001, November 2002, January-February 2003, October-December 2005 and November 2008. In such case, the amplitudes of the oscillations were from 3 min up to 60 min. This oscillation could be related to the semidiurnal lunar tide, which appear as an important contributor to the time of occurrence of equatorial spread-F.

C2.2-0032-18 COMPARISON OF ATMOSPHERIC FIELDS IN THE TROPICAL UPPER STRATOSPHERE AND LOWER MESOSPHERE BETWEEN MULTIPLE REANALYSIS DATA

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Several kinds of meteorological reanalysis data have been used for climate and atmospheric science studies. Their accuracy and reality depend on the forecast model and data assimilation method used therein, but they have never been quantitatively evaluated. In order to overcome this problem, the SPARC Reanalysis Intercomparison Project (S-RIP), which is a coordinated activity to compare all reanalysis data sets, was established in 2012. In this presentation, we will introduce an S-RIP activity on the evaluation of atmospheric fields in the tropical upper stratosphere and lower mesosphere.

C2.2-0033-18 SIMULATING MSTIDS GENERATED FROM TROPOSPHERIC WEATHER

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It is well known that gravity waves generated from deep convection and jet instabilities can propagate into the ionosphere and generate structures such as Medium Scale Traveling Ionospheric Disturbance. (MSTIDs). In this study, a high resolution, first-principles ionosphere model, SAMI3/ESF is driven by new specifications of the neutral atmosphere that include forcing from below to quantify the effect of the wave perturbations on the ionosphere. Gravity waves predicted by an extended altitude version of the Navy's mesoscale numerical weather prediction system, COAMPS (Coupled Ocean-Atmosphere Mesoscale Prediction System) are propagated to ionospheric altitudes using gravity-wave ray models. The perturbed thermospheric gravity wave fields are used to examine the effects of the neutral density, temperature and wind gradients on the ionosphere.

C2.2-0034-18 RECENT RESULTS ON THE WAVE CHARACTERISTICS IN THE LOW-LATITUDE UPPER ATMOSPHERIC REGION OBTAINED BY OPTICAL AND RADIO TECHNIQUES

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The importance of neutral wave dynamics in the upper atmosphere is well-known. Recent results of optical emission measurements obtained over large spatial extents (latitudes/ longitudes) and multiple wavelengths yielded information on different aspects of horizontal and vertical coupling in the low-latitude upper atmospheric regions. Some of the results include deriving the first three dimensional wave characteristics in the daytime, obtaining their propagation characteristics during geomagnetic quiet and disturbed conditions, and their dependence on the equatorial driving sources. These results were obtained through measurements of oxygen dayglow emissions at 557.7, 630.0, and 777.4 nm that originate from around 130, 230, and 300 km, respectively. These measurements were enabled by a high spectral resolution imaging spectrograph operating from a low-latitude location, Hyderabad (Geographic: 17.50 N, 78.50 E; Geomagnetic: 8.60 N, 151.80 E), in India. This spectrograph enables information on these three daytime airglow emission intensities simultaneously over a large FOV. New insights on the coupling aspects in the equatorialand low-latitude regions obtained from these investigations will be presented. While such measurements of neutral wave characteristics are conventionally obtained using optical airglow emissions in both the day and nighttime, as the thermospheric waves affect the ionospheric species as well, in this paper we will also describe the use of a radio technique that provides information on the thermospheric wave behaviour. This technique is used to derive neutral wave characteristics in the ionosphere-thermosphere region.

C2.2-0035-18 ESTIMATION OF THE QBO FORCING OF EQUATORIAL WAVES USING THE TIMED/SABER DATASET

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The Equatorial quasi-biennial oscillation (QBO) is driven by the wave-drag of the equatorial waves. In this work, the temperature data collected by the SABER/TIMED mission in 2002- 2016 are used to investigate the equatorial waves activities. The Fast Fourier Synoptic Mapping (FFSM) method is applied to delineate planetary wave components with the zonal wavenumber spanning over -6 to +6, hereby, positive (negative) wavenumber is assigned to westward (eastward) propagating waves. The vertical shear of zonal wind is derived by using the rawinsonde data at Singapore. Results show that in height range 70-10 hPa, Kelvin waves of wavenumber 1 to 3 are prominent. At 50 hPa level, wave 1 component exhibits amplitude spectral peak at three kinds of period, 8, 11 and 20 day. Meanwhile, shifting to shorter period is seen in amplitude spectra as wave number increases,for example, the 20-day period spectrum is attenuated substantially for wave 2 and wave 3 components. Although with small amplitude, mixed Rossby-gravity waves of wavenumber 4 and 5 with shorter periods of 4-7 days are discernable. Zonal forcing of the Kelvin waves attains maxima along with the downward propagation of the maximum positive shear zone (corresponding to that the Westerlies are above the Easterlies), the magnitude is 0.1 m/s/ day. Contrast to the Kelvin waves, the mixed R-G wave activity is substantially weak.

C2.2-0036-18 A RECORD BREAKING DURATION OF THE EASTWARD PHASE OF THE STRATOSPHERIC QBO AT 20 HPA: SOME NEW INSIGHTS INTO THE RECENT QBO DISRUPTION

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The equatorial stratospheric interannual variability is dominated by the presence of the Quasi Biennial Oscillation (QBO), which is a spectacular long-period oscillation with the alternating eastward and westward winds every year in the 20-40 km height domain. The period of the QBO varies between 22-36 months with mean period of 28 months. In the present communication, a recorded breaking duration (23 months) of the eastward phase of the QBO at 20 hPa is reported and details of the tropical wave activity during the recent anomalous QBO (2015/2016) are discussed. The Modern-Era Retrospective analysis for Research and Applications-Version 2 (MERRA-2) reanalysis dataset has been used for the present study along with radiosonde observations over Singapore (1.350 N, 103.810 E). A detailed analysis of day-to-day variability of zonal winds revealed that the deceleration of eastward winds at 40 hPa started in the month of November, 2015. The zonal wind perturbations have revealed the presence of eastward propagating waves with 10-12 day time period during JulyAugust 2015 and a long period westward propagating oscillation with 30-40 day time period and zonal wave number 1 from November, 2015 onwards. These results are confirmed using two-dimensional Fourier analysis, which also revealed the presence of westward propagating 10-15 day waves. The time evolution of 30-40 day oscillation provided a clue on the sustainable forcing observed during the QBO disruption event. A combination of the mid-latitude Rossby waves and the 30-40 day oscillations seems to be most probable mechanism for observed disruption of the QBO. However, the uniqueness of this combination and the interaction between the 30-40 day oscillations and midlatitude Rossby waves over the tropics are yet to be investigated. The significance of the present study lies in reporting the record breaking duration of the eastward phase of the QBO at 20 hPa and providing new insights in to the recent QBO disruption.

C2.2-0037-18 POSSIBLE "TROPICAL CYCLONES -IONOSPHERE" COUPLING MECHANISMS

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The objective of this topic is to put new facts into understanding of the coupling processes in the atmosphere-ionosphere system during the tropical cyclone (TC) action. Advanced international investigations of the correlation between tropical cyclones (TCs) and the ionosphere are connected with extreme difficulties of proving the action of possible mechanisms of TC (greatest troposphere hazard) effect on the ionosphere. There are two of the possible "TC-Ionosphere" coupling mechanisms - the Gravity Waves and the electric. GWs generated at tropospheric altitudes propagate to the F-region. Middle atmospheric dynamics, and particularly atmospheric waves, play a leading role in determining the variability of the atmosphere-ionosphere system. GWs generated from storms break near 100 km and produce secondary waves that continue to propagate upward GWs modulate the E-region plasma producing polarization fields that map to F-region altitudes. Strong convection cells produce a wide spectrum of GWs. GWs increase in amplitude within creasing altitude and may become unstable. Only waves propagating at the certain angles and with the correct amplitude can reach thermospheric altitudes. Once in the thermosphere, only those waves oriented to the magnetic field in a particular manner may produce ionospheric disturbances (dr.Rebecca Bishop, PSL/SSAL, 30 March 2012). An effect of external electric currents on the global atmosphere-ionosphere electric circuit may be one of possible mechanisms of interaction between atmospheric and ionospheric components. External currents with a horizontal scale of about one hundred of kms may be related to the vertical large - scale convection of the cloudy atmosphere in the zone of a TC and to the charge separation in this region. The electric field disturbance arises due to perturbation in the atmosphere - ionosphere electric circuit generated by the upward transport of charged water drops and aerosols in TC convection zone (Sorokin et al, 2005). In this paper authors analyze the ionospheric data from South hemisphere during TC action for the last century years.

Sorokin, V., Isaev, N., Yaschenko, A., Chmyrev, V., Hayakawa, M., 2005. Strong DC electric field formation in the low latitude ionosphere over typhoons. J. Atmos. Sol. Terr. Phy. 67 (14), 1269 - 1279.

C2.2-0038-18 EXCITATION OF ZONAL FLOW AND MAGNETIC FIELD BY FINITE-AMPLITUDE COUPLED ELECTROMAGNETIC PLANETARY WAVES IN THE E IONOSPHERIC REGION

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The excitation of zonal flow and magnetic field by finite-amplitude coupled electromagnetic (EM) planetary waves in the Earth's E ionospheric region is reviewed. Coupling of diverse EM low-frequency electromagnetic modes under the typical conditions of ionospheric E layer is revealed. Propagation of different coupled internal-gravity-Alfvén (CIGA), coupled RossbyKhantadze (CRK) and coupled Rossby-Alfvén-Khantadze (CRAK) waves is shown and studied. Appropriate nonlinear equations describing the interaction of such waves with sheared zonal flow is derived. The instability of short wavelength turbulence of such coupled waves with respect to the excitation of low-frequency and large-scale perturbation of the sheared zonal flow and sheared magnetic field is inferred. This nonlinear instability's mechanism is caused by the parametric excitation of triple finite-amplitude coupled waves leading to the inverse energy cascade towards the longer wavelength. The possibility of the intense mean magnetic field's generation is shown. The obtained growth rates are discussed for each considered coupled waves.

C2.2-0039-18 IONOSPHERIC F2 REGION VARIABILITY ASSOCIATED WITH SUDDEN STRATOSPHERIC WARMINGS

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The ionospheric F2 region response to sudden stratospheric warming (SSW) has been extensively analyzed for the major event of year 2009, apart from a few reports on other major and minor events. Morphology of ionospheric response during SSW can be better comprehended by analyzing such warming events under varying solar, geomagnetic, and meteorological conditions. In view of this, we investigate the features of F2 region variability following the SSW events of 2010, 2011, 2012, 2013, 2014, 2015, and 2016, using ionosonde data from the Asian region covering a broad latitudinal range from 26.6°N to 45.1°N. We find perceptible ionospheric variations in electron densities during these warming events which is accompanied by a large variation of 117% within enhancements, as compared to a meagre variation of 11% within depressions, during these events. Further, the maximum and minimum variations in F2 layer critical frequency are observed during each SSW period when analyzed for six months. The influence of quasi-stationary 16-day planetary waves is seen during these SSW events. It is also found that a recently proposed parameter, "SSW integrated strength" by Vieira et al. (2017), to characterize SSW event with respect to ionosphere, does not fit well for these seven SSW events at these latitudes and longitudes.

C2.2-0040-18 GLOBAL IONOSPHERIC RESPONSE TO SUDDEN STRATOSPHERIC WARMING EVENTS

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Recent studies have shown variations in the low latitude ionosphere that are linked to Sudden Stratospheric Warming (SSW) events. Although previous studies have provided important information on the ionospheric response to SSW events, they have been fairly localized. Therefore, broader observational capabilities and data are required that can unambiguously reveal the instantaneous global response of the ionosphere to SSW events. In this paper, we present results from the Ionospheric Data Assimilation Four-Dimensional (IDA4D) algorithm to describe a global view of the ionospheric variability during the Northern Hemisphere SSW events in 2009, 2010, and 2013. We will present the dynamical response of the ionosphere to SSWs and the global structure of lunar semi-diurnal tides in the ionosphere during these events. We will show the ability of the data assimilation technique to successfully delineate a time-dependent structure of the lunar semidiurnal tide in the ionosphere during SSW events. These results enable us to identify the evolution, on a global scale, of the enhanced lunar semi-diurnal tides during SSWs.

C2.2-0041-18 PLANETARY WAVE-GRAVITY WAVE INTERACTIONS DURING MESOSPHERE TEMPERATURE INVERSION EVENTS OVER TROPICS (10°N-15°N)

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ABSTRACT

The nightly temperatures from Rayleigh lidar and TIMED-SABER (Thermosphere Ionosphere Mesosphere Energetics and Dynamics - Sounding of Atmosphere by Broadband Emission Radiometry) observations show a few large mesospheric inversion layer (MIL) events at 75-85

km during 20-26 January 2007 over a tropical region, Gadanki (13.5°N, 79.2°E). The MIL

amplitudes in SABER temperature averaged for 10°N-15°N and 70°E-90°E show a clear 2 day modulation during 20-26 January 2007. The two dimensional spectrum of SABER temperatures confirms the dominant presence of 2-day planetary wave (PW) with zonal wave numbers, k=2, 3 at inversion height. It is evident from the wavelet spectrum of SABER temperatures that the 2-day wave propagates with increasing amplitudes and dissipated in the MIL region above 80 km. Further the FFT spectrum of lidar temperatures show the gravity wave (GW) activity with periods 18 min, 38 min, 38 min, and vertical wavelengths 6.4 km, 4.0 km, 6.4 km respectively on 20, 22, and 24 January 2007. The eddy diffusion due to the GW breaking could cause the MILs between 75 km and 85 km. Further eddy momentum flux of 2-day PWs and drag forces of GWs are calcualted using medium frequency radar winds over (8.7°N,77.8°E). It is inferred that the MILs are caused mainly due to gravity wave breaking and the inversion amplitudes got modulated by the background 2-day PW. Further the eddy diffusion associated with the gravity wave force drag caused the suppression of 2-day planetary wave in the inversion region.

C2.2-0042-18 SOLAR AND LUNAR TIDAL VARIABILITIES IN GPS-TEC AND GEOMAGNETIC FIELD VARIATIONS: SEASONAL AS WELL AS DURING THE SUDDEN STRATOSPHERIC WARMING OF 2010

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The Global Positioning System (GPS) deduced total electron content (TEC) data at 15°N (geomagnetic), which is the northern crest region of equatorial ionization anomaly, are used to study solar and lunar tidal variabilities during the years 2008 and 2009 and also during the 2009-2010 winter, when a major sudden stratospheric warming (SSW) event has occurred. The diurnal and semidiurnal tidal amplitudes show semiannual variation with maximum amplitudes during February-March and September-November, whereas terdiurnal tide is larger during April-September. They show significant longitudinal variability with larger (smaller) amplitudes over 250°E-150°E (200°E-250°E). Lunar semidiurnal tidal amplitudes show sporadic enhancements during northern winter months and negligible amplitudes during northern summer months. They also show notable longitudinal variabilities. The solar migrating tides DW1 and SW2 show semiannual variation with larger amplitudes during spring equinox months, whereas TW3 maximizes during northern summer. DW2 shows larger amplitudes during summer months. During the SSW, except TW3, the migrating tides DW1 and SW2 show considerable enhancements. Among solar nonmigrating tides, SW1, TW2, and DS0 show larger enhancements. Solar tides in TEC and equatorial electrojet strength over Tirunelveli vary with the time scale of 60 days during October 2009-March 2010 similar to ozone mass mixing ratio at 10 hPa, and this confirms the vital role of ozone in tidal variabilities in ionospheric parameters. Lunar tidal amplitudes in changes in horizontal component of geomagnetic field (H) are larger over Tirunelveli, a station near dip equator. Solar semidiurnal tides in H have larger amplitudes than lunar tides over polar stations, Mawson and Godhavn.

C2.2-0043-18 NEAR-INFRARED CAMERA OBSERVATIONS OF MESOSPHERIC GRAVITY WAVES IN PATAGONIA

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Airglow imaging has been widely used for the detection of gravity wave in the upper atmosphere since the 1990s owing to the development of highly sensitive charge-coupled device detectors. This imaging technique is useful for investigating the two-dimensional horizontal characteristics of small-scale (horizontal wavelength less than 100 km) gravity wave motions in the mesosphere and lower thermosphere (MLT). Gravity waves are known to contribute greatly to MLT dynamics through their dissipation, which is accompanied by the momentum transfer into the MLT mean flow.

The ANtarctic Gravity Wave Instrument Network (ANGIWN) project has started in 2011 to understand gravity waves over the Antarctic and the effects on general circulation. It is known that the southern Andes is a hot spot of gravity waves and would also contribute significantly to the dynamics in the upper atmosphere in the southern hemisphere. We installed an all-sky airglow camera in November 2017 at Rio Gallegos station (51.6S, 69.3W), Patagonia, Argentina, as an extension the ANGWIN network. The Patagonia camera has an InGaAs array sensor, which is sensitive to the near-infrared (900-1700 nm), and can image OH Meinel band airglow (height: 85 km) without interference filter, obtaining an OH airglow image every 5 s with an exposure time of 2 s. The system is similar to the imagers of ANGWIN network at Davis,

McMurdo, Halley, Syowa and the south-pole. We expect that the airglow imaging at this site would contribute to reveal the characteristic of gravity waves generated around the hot spot at Andes and Antarctic Peninsula.

In this presentation, we will share details of the airglow imaging observation in Patagonia and some initial results.

C2.2-0044-18 EFFECTS OF HORIZONTAL WIND STRUCTURE ON THE GRAVITY WAVE ENERGY IN THE UPPER STRATOSPHERE OVER SYOWA, THE ANTARCTIC

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Gravity waves (GWs) transport their momentum and energy from the lower atmosphere to the upper atmosphere and drive the general circulation, which significantly changes the temperature in the middle atmosphere [Fritts and Alexander, 2003]. To understand this role quantitatively will improve the modern general circulation models. GW activities and its seasonal variations have been studied at various places all over the world. Nowadays, some studies have shown global maps of the typical activities from satellite observations. However, what causes a shorter temporal and local variations of the activities are poorly understood, especially above the upper stratosphere.

To understand this cause, we estimated the potential energy of GW (Ep) over Syowa Station (69°S, 40°E) from a Rayleigh/Raman (RR) lidar observation between 2011 and 2015. We found a clear enhancement of the Ep during 8th-21st August 2014. The Ep values in this period were about two and five times as large as the winter mean in the other years at 50 and 60 km, while the ones between 20 and 40 km were as small as the winter mean. One of possibility is that some source would exist around 45 km, but there seemed no specific source within the Modern-Era Retrospective analysis for Research and Applications (MERRA) [Rienecker et al., 2011]. The second one is that the GWs would converge from the lower atmosphere at various latitudes due to the meridional gradient of the westerly wind [Dunkerton, 1984]. The polar night jet around

40°E during the enhancement period slanted to 70°S from 50°S and the gradient was larger. In such condition, the GWs with west-ward wavenumber can converge to Syowa. We estimated paths of GWs in order to examine whether the GWs could converge to Syowa. The estimation shows that the large-scale GWs could converge to 50-55 km altitudes over Syowa in that period. We conclude that the

enhancement could be caused by the convergence of the GWs. In this presentation, we will show the potential energy, the wind field and the paths of the GWs during the enhancement period, and highlight an importance of the wave's horizontal propagation.

C2.2-0045-18 TSUNAMI IONOSPHERIC COUPLING: THEORY, MODELLING AND INVERSIONS

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Ionospheric seismology, which was at most seen as an exotic way to record doubtful signals in the early 2000 has gain maturity, especially after the worldwide observations made during the Tohoku 2011 earthquake and tsunami. These ionospheric signals have been detected by a variety of technics: GPS, Doppler sounders, Over-the-horizon radars and airglow camera from either ground instruments or spaceborne instruments. In many cases, these observations systems are by nature dual, offering both scientific and security/defense applications. We compare and illustrate the different observation techniques available today, with a focus on ground, air-based and space-based GPS measurement and airglow and illustrate the later with data recorded during the Tohoku 2011

and Haida Gwai earthquake and tsunamis. We then discuss the physics enabling the conversion of seismic waves into electron perturbation (for GPS data) and light emission (for airglow). This allow us to model these signals and to discuss the sensitivity of the coupling between seismic or tsunami waves and acoustic or gravity waves to the atmosphere structure, the subsurface and crust structure, the ocean thickness and local time, ionospheric state and magnetic latitude. We then show that these signals can already be inverted and used to predict with very high accuracy the amplitudes of tsunami at the sea level and a characterization of the seismic source of large earthquake, enabling important perspective for the future improvement of the global and regional tsunami warning systems.

C2.2-0046-18 IONOSPHERIC TILT MEASUREMENTS AS A PROXY OF TID CLIMATOLOGY AND CHARACTERISTICS

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Ionospheric vertical incidence sounders are capable of measuring ionospheric "tilts", which are a measure of horizontal gradients in the ionosphere. Digisondes routinely make skymap measurements, which represent a set of angles of arrival for each reflection point of the ionosphere, from which tilts are derived by computing a representative "mean" point of reflection of HF waves. We illustrate the reliability of the digisonde tilt measurements by comparing the expected angles of arrival (AoA) measurements calculated using simple "mirror model" as well as 3D raytracing to the real AoA measurements on a corresponding HF link. The accuracy of the AoA prediction and sources of errors are discussed. Digisonde at Ebro Observatory in Spain routinely measures ionospheric plasma drift and tilts. Analysis of the tilt measurements made in 2012-2015 is presented. Spectral analysis with Lom-Scargle method is used to identify the presence and exact periods of the wavelike disturbances that we associate with the Travelling Ionospheric Disturbances (TIDs). The tilts are represented in terms of North-South and East-West components with the biases and daily trends removed. Using several years of observations a climatological distribution of the TIDs is established. Most of the TIDs occurrence is determined by the solar terminator passage and the most frequently observed periods are from 30 min to 1.5 hour. These characteristics are typical for middle-scale TIDS (MSTIDS). Summertime appears to have the most frequent occurrence of the disturbances in the tilts. Variations in tilt intensity appear to moderately increase with the increase in solar activity and geomagnetic disturbances. Direction of propagation is also analyzed and compared to the neutral wind direction calculated with the TIEGCM model. There is a noticeable correlation between the two, although the agreement is not perfect. This is also an indication that most of the observed TIDs originate in the troposphere. We also present a comparison of the ionosonde tilts and those derived from the GNSS TEC measurements and discuss under what conditions the latter ones are reliable.

C2.2-0047-18 DIFFERENT PROPAGATION CHARACTERISTICS OF MESOSPHERIC GRAVITY WAVES OVER SYOWA AND DAVIS, THE ANTARCTIC, USING OH AIRGLOW IMAGERS AND MF RADARS

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Gravity waves transport momentum and energy from the lower atmosphere to the upper atmosphere, and drive the general circulation, which significantly changes the temperature in the middle atmosphere [Fritts and Alexander, 2003]. Understanding this role quantitatively will improve the modern general circulation models.

The polar night jet is known to contain regions of high gravity wave (GW) activity. However, their source, propagation and intermittency are only poorly understood because of a lack of observations. To understand their source and propagation, our group has observed the gravity waves over Syowa (69°S, 40°E) using some instruments (e.g., lidar, OH imager and MF radar). We also compared the gravity waves over Syowa and Davis (69°S, 79°E), at which terrain and meteorological conditions are similar, to investigate their horizontal variation over the east Antarctic. We found, from the lidar temperature observations, that the vertical profile of gravity wave potential energy is similar between Syowa and Davis, except for a clear enhancement around 30-40 km over Davis [Kogure et al., 2017]. Horizontal propagation characteristics are more clearly observed by airglow imaging measurements of 90 km altitude. The comparison of four imagers' results between April-May 2013 have indicated that the major propagation directions were westward at three station (Syowa, McMurdo, Halley), but at Davis GWs seems to propagate all the directions, which is totaly different from the other three. [Matsuda et al., 2017]. It seems like the GWs over Davis did not experience the same wind filtering in the middle atmosphere.

The goal of this study is to compare the gravity waves over Syowa and Davis in many different ways and with more observational data. In this presentation, we will show the ground-based horizontal phase speed spectrum over the two stations derived from OH imagers in more detail. We analyzed the OH airglow imager data obtained for eight months (from March to October in 2016) over the two stations with M-transform [Matsuda et al., 2014]. We analyzed the data without clouds and aurora contaminations continuously for at least one hour. The numbers of nights with such data sets are 40 at Syowa and 55 at Davis. The seasonal variations of the nightly mean variance were very similar with winter maximum, but the variance over Syowa was significantly larger than that over Davis in September. The reason for a larger variance over Syowa in September was the existence of southward propagating gravity waves with the phase speed of 10 - 80 m/s. In 2016, clear sky and aurora free data were available at both station on ten nights. Comparison of phase velocity spectra obtained on the same night showed similarity on only one night out of ten. On five nights, the spectra were quite different. On the other four nights, the spectral peaks with slow westward phase velocity (> 50 m/s) were commonly observed but additional spectral peaks were found over Davis and not over Syowa. We calculated transmission diagram, which indicates the GW phase speeds for which a GW would encounter turning and critical level [Tomikawa, 2015], and we found that the diagrams over both stations were similar. These results suggest that the difference was not caused by wind filtering or reflection. We will show these spectra and transmission diagrams, and discuss what causes the different spectra. We will, moreover, present paths of gravity waves and discuss where the gravity waves were generated.

C2.2-0048-18 SIMULATION RESULTS AND PERFORMANCE ANALYSIS OF PHASE VELOCITY SPECTRAL ANALYSIS SOFTWARE (M-TRANSFORM) FOR AIRGLOW IMAGING DATA

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Airglow imagers have been deployed in various locations to study the atmospheric gravity waves (AGWs) in the last few decades, which provide a huge amount of data. This groundbased imaging observation has been proven to be very effective to study energy and propagation characteristics of AGWs. However, the lack of sophisticated analysis methods prevented quantitative studies using huge data that have been collected over such long period of observation. Matsuda et al. [2014] developed a new phase velocity spectrum analysis method based on 3D FFT algorithm (M-transform) to address this issue. This algorithm can efficiently deal with extensive amounts of imaging data without bias and treat dynamical/physical effect of AGWs by precisely reflecting amplitude, area and lifetime of each AGW event. Based on Matsuda et al. [2014] method, we have developed a simple and user-friendly function to be used in IDL. The input of this program is a three dimensional array of a time series of 2-D image array where the wave parameters (e.g. horizontal wavelength (h), wave period (), phase speed (c), image resolution in space (dx, dy) and time (dt)) can be customized by the user in one-line command to execute the program. Various simulations by using artificial wave images as test data have been done in order to exhibit the new program's performance and the characteristics/interpretation of the spectral analysis. The simulation was done by using test data with different time resolution (dt=1 min, 3 min, 5 min and 7 min), image size (256x256, 512x512), duration (30 min, 60 min, 90 min, 120 min) and by changing the horizontal wavelength and wave periods with a fixed phase speed (40 m/s). In addition, by using observational data from Syowa station we conducted an investigation how waves with different horizontal wavelengths behave independently. We divided the horizontal wavelength into three categories: 5< h <20 km, 20< h <100 km and 5< h <100 km. We found that propagation direction for small scale, close to ripple scales (5< h <20 km), showed omni-directional feature, as previously suggested by Nakamura et al. [1999]. Beside the detail discussion on the simulation results and performance test, this presentation also aims to guide how to use the program within a practical computation time.

C2.2-0049-18 THE LUNAR TIDES IN THE IONOSPHERE OVER BRAZIL

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The atmospheric lunar tide is excited by gravitational action in the lower atmosphere and by the movement of the oceans and Earth's surface. Due to the fact that the source of the lunar tide does not change, the determination of this oscillation in the ionosphere is an excellent tool for understanding the coupling mechanism between the neutral and ionized atmospheres. The lunar tide has been studied in the mesosphere-thermosphere-ionosphere in different longitudinal sectors and using different observational techniques and simulations. However, there are some aspects of lunar tide that still need explanation, for example, the temporal variability of this oscillation. So, in this work, the diurnal and semidiurnal lunar tides are investigated in the ionosphere using ionosonde data over Brazil. The ionosonde measurements were collected at Cachoeira Paulista (22.7° S; 45.0° W) and São Luis (2.6° S; 44° W) from 2001 to 2009 with a temporal resolution of 15 minutes. Using these data, it was possible to extract the characteristics of the lunar tide. Salient features of this oscillation are presented and discussed in this work. For instance, the semidiurnal lunar tide is dominant comparing to the diurnal tide and had amplitude of 0.6 MHz in foF2 and 7 km in hmF2.

C2.2-0050-18 LIGHTNING INDUCED IRREGULARITIES IN THE LOWER IONOSPHERE, MEASURED BY GLOBAL NAVIGATION SATELLITE SYSTEM

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Atmosphere is divided into two layers with respect to electrical charge of the medium; namely Troposphere from above the Earth surface up to approximately 60 km altitude and Ionosphere from 60 to 1000 km and higher altitudes. There are some interactions between these two layers, which are referred to as Troposphere/ Ionosphere coupling. Lightning is an electrical discharge that occurs within Troposphere and can cause upward propagation of electric field into lower Ionosphere (60-100 km altitude) and makes some variations in electron density, Total Electron Content (TEC) and conductivity of such medium. These variations in the Ionosphere parameters affect propagating of radio signals travelling through this medium. Thus, it is important to investigate the influence of lightning on the Ionosphere parameters e.g. Vertical Total Electron Content (VTEC). In this paper, we have investigated the VTEC variations in lower Ionosphere due to lightning activity during a geomagnetic quiet day (with geomagnetic activity index of day Ap<4). To achieve this purpose, we used data from the Worldwide Lightning Location Network (WWLLN) data for detecting time and location of the lightning events and also we used the Global Navigation Satellite Systems (GNSS) data for VTEC calculations. After calculating the VTEC values in both lightning and non-lightning days we compared them to obtain the lightning effects on VTEC.

C2.2-0051-18 CHANGING SPATIAL STRUCTURE OF THE BREWER-DOBSON CIRCULATION IN CCMI SIMULATIONS - COMPETING ROLE OF WAVE DRIVING

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The mean age of stratospheric air (AoA) is a useful transport diagnostic and one of the best tools for accessing the Brewer-Dobson circulation (BDC) change. Analyzing AoA output from CCMI REFC2 model simulations we found a remarkable agreement among majority of models in projecting the largest mean age-of-air (AoA) negative trends and changes in localized regions in the extratropical LS on both hemispheres (approximately between 200000 and 250000gpm and 20°- 40°N and 20°- 40°S). The occurrence of those regions are a direct function of the climatological AoA distribution, upward shifting trend of the circulation and of widening of the AoA izolines due to a negative trend in aging by mixing. The negative trend in aging by mixing is primarily caused by the speeding up of the residual circulation in the shallow BDC branch, which is connected with an interplay (not only compensation) between spatial structures and magnitudes of gravity and resolved wave drag leading to strengthening trend of the total drag.

C2.2-0052-18 CHARACTERIZING GRAVITY WAVES OVER ANTARCTICA USING BALLOON BORNE RADIOSONDE OBSERVATIONS DURING INDIAN SCIENTIFIC EXPEDITIONS

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Gravity waves play a momentous role in shaping the observed thermal and dynamical structure of the middle atmosphere. Over polar regions, they have myriad effects such as controlling the general circulation of the middle atmosphere, affecting the formation of polar stratospheric clouds, thereby controlling the chemistry of the stratosphere and so on. Atmospheric general circulation models employ parameterizations to represent gravity waves. The Antarctic stratosphere is consistently found to have a cold bias in model representations for which improper parameterization of gravity wave drag is considered to be the reason. Thus more realistic observations of gravity waves are required in order to provide physical constraints for these models. In this regard, a study was conducted to characterize gravity waves in the Antarctic lower stratosphere using balloon borne radiosonde observations. Balloon soundings were carried out in campaign mode from the Indian research base at Antarctica, Bharati (69S, 76E) during the austral summers of 2014-15, 2015-16 and 2016-17. Gravity wave potential energy, being a proxy for wave activity, was estimated from the vertical profiles of temperature. The average potential energy densities in the lower stratosphere were found to be less than 1 J/kg. There were small but significant variabilities in the potential energy densities between the three austral summers. The wavelet based approach was employed to extract individual gravity wave packets from the vertical profiles of horizontal winds. The extracted packets were subjected to Stokes Parameter analysis to infer propagation characteristics. Further, to extend the analysis to larger spatial and temporal scales, an attempt is made to validate the MERRA-2 Reanalysis datasets using the available observations. It was seen that the broad features are captured well by the MERRA-2 datasets. The momentum flux values obtained from radiosonde as well as MERRA-2 datasets are compared. The significance of the present study lies in extracting

the gravity wave parameters by employing wavelet analysis and utilizing MERRA reanalysis datasets for the study of gravity waves over the Antarctic.

C2.2-0053-18 RELATIONSHIPS BETWEEN THE CHARACTERISTICS OF THE HAYASHI WAVES IN THE NORTHERN STRATOSPHERE WITH CLIMATE VARIABILITY INDICES IN WINTER

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By using the winter (from November to March) ERA-Interim reanalysis geopotential data in the troposphere and stratosphere (up to the 1 hPa isobaric level) for 1979-2016, an analysis of the Hayashi spectra for wave disturbances with zonal wave numbers 1 k 10 and with periods from 2 to 156 days is performed. In this, contributions of the eastward traveling (E), westward traveling (W), and stationary (S) waves are estimated. We found statistically significant positive correlations of the W-waves energy EW and, to a smaller extent, of the S-waves energy ES in the upper stratosphere with the index of sudden stratospheric warmings (SSWs). The latter index was defined in our previous papers and based on the number of SSWs of different types (with specific weight factors for each SSW type) during given winter. In turn, the E-waves energy EE is negatively correlated with thus defined SSW index. We also found the strong positive correlation waves energy EW and ES with the conventional indices of the North Atlantic and the Arctic Oscillations in the mid-latitudinal troposphere and stratosphere. E-wave energy is also positively correlated with those indices, but only in the troposphere and in the lower stratosphere. In the tropical and subtropical troposphere as well as in the subtropical lower stratosphere E-waves energy is correlated with the indices of the Southern Oscillation and El Nino/La Nina-related sea surface variability (EE increases during El Nino events and decreases during La Nina ones). The spatial domain of the strongest correlation co-locates with the region of the tropopause break. This suggests a possibility of the E-waves-related mechanism of the El Nino-Southern Oscillation influence on the troposphere-stratosphere exchange. In turn, Wand S-waves and negatively correlated with the El Nino/La Nina-related sea surface variability indices in the troposphere and lower stratosphere of the mid-latitudes as well as in the tropical upper troposphere.

C2.2-0054-18 WAVE ACTIVITIES AND TURBULENCE INFLUENCING STRATOSPHERE TROPOSPHERE EXCHANGE (STE) OF OZONE OVER COSTA RICA DURING 2016

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High vertical resolution radiosondes and ozonesondes are launched every week from stations in Southern Hemisphere ADitional OZonesondes (SHADOZ) network. We have analyzed the data of winds, temperature, ozone mixing ratio and relative humidity of a tropical station Costa Rica (10° N, 83.4° W) for the year 2016 to study transport of ozone between stratosphere and troposphere (STE/TSE). Five STE and three TSE events could be identified in the data. The intrusion are normally shallow with a maximum of 5.7 DU in the month of August. Transport of ozone is observed to occur mostly during May to August when convection prevails in the region. Spectral analyses and correlation results confirm the gravity wave and Inertia/Rossby gravity wave activities to be responsible for the transport. Exchange of ozone between stratosphere and troposphere is found to be associated with Kelvin wave near the tropopause and Madden-Julian oscillation in the troposphere. Eddy diffusivity computed by using simultaneous radiosonde measurements display high values of turbulence, particularly, below the tropopause, where laminar structures are mostly observed. Wind shear is also high in the region. We conclude that a combination of wind shear, wave activity and local turbulence is responsible in the transport of minor constituents between troposphere and stratosphere.

C2.2-0055-18 EXPLORING LIMITS OF THE DOWNWARD CONTROL PRINCIPLE

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The Downward Control Principle (DC) in the form that was formulated in Haynes et al. (1991) is one of the most popular concepts in current research of wave-induced forces impacts on the global-scale circulations, namely on the stratospheric Brewer-Dobson circulation (gyroscopic pumping). It is also often used for separating relative roles of the resolved and gravity waves driving. However, this principle relies on zonally symmetric basic states and forces and it has been argued even in the original paper that the longitude-dependent force would set-up a secondary Rossby wave - a situation that has been confirmed by numerical simulations described in Sacha et al. (2016). Thus, by definition the principle should not be used for gravity wave driving, which is inherently zonally asymmetric.

In this study we use circulation model sensitivity simulations with different distributions of wave forcings to quantify the deviations from DC as measured by a difference in the net upward mass flux across 70 hPa computed directly from the stream function and using the DC. We artificially add wave drag perturbations and modify their longitudinal distribution between the simulations, while always adding the same net zonal mean force, which is added also symmetrically for a reference. We also investigate the validity of the DC in terms of addition of the same value of zonally symmetric force but at different altitudes above the turnaround latitude position at 70 hPa (following angular momentum curves) so that the DC integral remains the same, but the induced acceleration differs significantly according to the altitude of the perturbation. To conform the DC concept we analyze steady state results only.

C2.2-0056-18 SIGNATURE OF A SECONDARY WAVE IN THE BRAZILIAN EQUATORIAL IONOSPHERE

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In the past decade, understanding of the day-to-day variability of the ionosphere induced by waves propagating from bellow has considerably been advanced. More recently, several studies have pointed out that the secondary waves arising from the nonlinear interaction between tides and planetary waves could significantly impact the ionosphere. From the meteor radar wind at Cariri (7.4°S, 36.5°W) and ionossonde measurements at Fortaleza (3.9°S, 38.4°W) we investigated the presence and effects of secondary waves in the Brazilian equatorial MLT and ionosphere. We found an evidence of the nonlinear interaction between an ultra-fast Kelvin wave and the diurnal tide in the MLT wind. We identified a 1.3-day secondary wave arising from this interaction and found it to propagate upward with a relatively long vertical wavelength (44 km), which may allow it to penetrate into the ionosphere. From the ionossonde measurements at Fortaleza we found indications of the modulation of the F-layer height by the 1.3-day secondary wave. In this paper, we will present and discuss details of this study.

C2.2-0057-18 ANGWIN: INTERNATIONAL GROUND-BASED OBSERVATION NETWORK FOR THE STUDY OF GRAVITY WAVES IN THE POLAR REGION

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Atmospheric gravity waves play an important role in transporting energy and momentum between atmospheric spheres and drive circulations that affect key processes such as formation of the ozone hole and the cold summer polar mesosphere. One of the reasons that still avoid the full understanding and description of gravity waves is the lack comprehensive observations over the Antarctic region. The ANtarctic Gravity Wave Instrument Network (ANGWIN) is a highly successful grassroots programme that was started in 2011. It seeks to use a network of observations to measure gravity waves continent wide and through all levels of the atmosphere, in order to fully understand their impact and constrain modelling work. Although ANGWIN initially focused on the Antarctic, the group is now aiming to develop collaborations in both polar regions.

Current member countries of ANGWIN are Australia, Brazil, Japan, South Korea, the United Kingdom and the United States of America. The objective of ANGWIN network include; Qualify the longitudinal variations in gravity waves and determine causes; Characterize wave propagation and influence; Relate observed gravity waves to sources throughout the atmosphere; Study interactions of gravity waves with planetary scale waves; Compare polar wave observations to model parameterizations; Determine the effects of gravity waves on polar stratospheric cloud formation.

The ANGWIN network, its objectives and some recent results will be presented in the poster.

C2.2-0058-18 OBSERVATIONS OF ANTARCTIC MESOSPHERE AND LOWER THERMOSPHERE WITH A NEW FREQUENCY-TUNABLE RESONANCE SCATTERING LIDAR AT SYOWA STATION (69S)

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The National Institute of Polar Research (NIPR) is leading a prioritized project of the Antarctic research observations. One of sub-project is entitled the whole atmosphere system revealed by precise profiling over the Antarctic. Profiling dynamical parameters such as temperature and wind, as well as minor constituents is the key component of observations in this project, together with a long term observations using existent various instruments at Syowa, Antarctica (69S). As a part of the sub-project, a new resonance scattering lidar system with frequency-tunable alexandrite laser was developed. The lidar has a capability to observe temperature profiles and variations of minor constituents such as Fe, K, Ca+, and aurorally excited N2+. The lidar system was installed at Syowa Station by the 58th Japan Antarctic Research Expedition (JARE 58) and successfully received the first light from K layer in March 2017. From July to October in 2017, the MLT temperature profiles were derived from K or Fe resonance scatter signals. Also we challenged to receive some resonance scatter signals from Ca+ and N2+. This presentation will report preliminary results of the lidar observations at Syowa.

C2.2-0059-18 OBSERVATIONS OF SUPERDARN GLOBAL TIDES IN THE MLT AND THEIR RESPONSE TO SUDDEN STRATOSPHERIC WARMING EVENTS

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Meteor wind data derived from a longitudinal chain of eight SuperDARN radars are used to determine the mean response of the migrating semidiurnal tide to the chemical and dynamical changes driven by sudden stratospheric warmings (SSWs). The radars span a limited range of latitudes around 60 degrees N and are located over nearly 180 degrees of longitude allowing the different zonal wavenumbers of the tide in the mesosphere and lower thermosphere to be distinguished. The migrating tide is extracted from the non-migrating components observed in the meridional wind, and climatologies of the different components are presented. The composite response of the amplitude of the components of the tide over 13 SSWs are presented and the drivers of the variability are discussed with the aid of corresponding WACCM-SD simulations.

C2.2-0060-18 STATISTICAL ANALYSIS OF 16-YEAR PHASE VELOCITY DISTRIBUTION OF MESOSPHERIC AND IONOSPHERIC WAVES IN AIRGLOW IMAGES: COMPARISON OF RIKUBETSU AND SHIGARAKI, JAPAN AND ATHABASCA, CANADA

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We study atmospheric gravity waves (AGWs) in the mesopause region and medium-scale traveling ionospheric disturbances (MSTIDs) in the thermosphere from 1999 to 2014, by applying a three-dimensional spectral analysis technique to airglow images at wavelengths of 557.7 nm (emission altitudes: 90-100 km) and 630.0-nm (200-300 km) obtained at Rikubetsu (43.5N, 143.8E) and Shigaraki (34.8N, 136.1E), Japan. Such a long-term multipoint analysis of AGWs and MSTIDs using airglow images has not been reported previously. The propagation direction of mesospheric AGWs seen in 557.7-nm airglow images is northeastward in summer and southwestward in winter at both stations, probably due to wind filtering of these waves by the mesospheric jet. In winter, the propagation direction of AGWs shifted from southwestward to northwestward as time progresses from evening to morning at both stations, which can also be explained by the wind filtering effect. The propagation direction of AGWs changed from southwestward to northeastward at Rikubetsu on the day of the zonal wind reversal at 60N at 10 hPa by the stratospheric sudden warming (SSW), while such a SSW-associated change was not identified at Shigaraki, indicating that the effect of SSW wind reversal reached only to the Rikubetsu latitudes. For MSTIDs, the major propagation

direction is southwestward with a minor northeastward peak in all seasons at both stations. A negative correlation is found between yearly variation of power spectral density and solar F10.7 flux. This negative correlation can be explained by considering the linear growth rate of the Perkins instability. We have also applied this 3D FFT spectral analysis technique to the 557.7 nm and 630.0 nm airglow images obtained from 2005 to 2017 at Athabasca, Canada (54.7N, 246.7E before 25 September, 2012 and 54.6N, 246.3E after 27 September, 2012). We discuss similarities and differences of the propagation characteristics of AGWs and MSTIDs over Japan and Canada.

C2.2-0061-18 VARIABILITIES OF LOW-LATITUDE MIGRATING AND NONMIGRATING TIDES IN GPS-TEC AND TIMED-SABER TEMPERATURE DURING THE SUDDEN STRATOSPHERIC WARMING EVENT OF 2013

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The Global Positioning System deduced total electron content (TEC) data at 15°N (geomagnetic), which is the crest region of equatorial ionization anomaly, are used to study tidal variabilities during the 2013 sudden stratospheric warming (SSW) event. The results from space-time spectral analysis reveal that the amplitudes of migrating diurnal (DW1) and semidiurnal (SW2) tides are larger than those of nonmigrating tides. After the SSW onset, the amplitudes of DW1, SW2, SW1, and DS0 increase. Moreover, they show 16 day variations similar to the periodicity of the high-latitude stratospheric planetary wave (PW), suggesting that the nonmigrating tides (SW1 and DS0) are possibly generated due to nonlinear interaction of migrating tides with PW. Similar spectral analysis on temperature at 10°N obtained from the Sounding of Atmosphere by Broadband Emission Radiometry (SABER) shows that the SW2 enhances at stratospheric heights and the SW2 is more dominant at 80-90 km, but its amplitude decreases around 100 km. The amplitudes of nonmigrating tides become comparable to those of SW2 around 100 km, and their contribution becomes increasingly important at higher heights. This suggests that the nonlinear interaction between migrating tides and PW occurs at low-latitude upper mesospheric heights, as SW2 exhibits 16 day periodicity in SABER temperature at 100 km as observed in TEC. Besides, it is observed that the eastward propagating tides are less dominant than westward propagating tides in both TEC and SABER temperatures.

SPACE STUDIES OF THE UPPER ATMOSPHERES OF THE EARTH AND PLANETS INCLUDING REFERENCE ATMOSPHERES (C)

ADVANCES IN EXTERNAL FORCING STUDIES FOR THE MIDDLE ATMOSPHERE AND LOWER IONOSPHERE (C2.3)

C2.3-0001-18 CONTRIBUTION OF ENERGETIC PARTICLE PRECIPITATION TO ANTARCTIC OZONE VARIABILITY

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In polar regions, the natural variability of the upper stratospheric and mesospheric ozone is expected to be affected by energetic particle precipitation (EPP). Indeed, EPP boosts the concentration of odd nitrogen (NOx) and odd hydrogen (HOx) species which efficiently destroy ozone. Since ozone change has the potential to further influence atmospheric dynamics and regional climate, the evaluation of the EPP impact on long time scales is a critical issue. Nevertheless, the assessment is complicated by constraints in satellite observations and by the other drivers of ozone variability. This talk deals with the ozone response to EPP by analyzing satellite observations from Solar Backscatter Ultraviolet Radiometer and Microwave Limb Sounder. We focus on the Antarctic region where the reduced inter-annual variability of the vortex dynamics, compared with the Arctic, makes easier to distinguish EPP effects. Overall, during the austral winter we found an average EPP-induced ozone depletion larger than 10 % in both mesosphere and upper stratosphere, the latter caused by an indirect impact of EPP-NOx produced at upper altitudes. Such changes are coherent with forcings from different EPP populations and are coupled with enhancements in HOx and HNO3. This confirms the necessity of taking the EPP forcing into account in climate models as recently recommended for the ongoing Coupled Model Intercomparison Project Phase 6 (CMIP6).

C2.3-0002-18 IMPACT OF MEDIUM-ENERGY ELECTRON PRECIPITATION ON POLAR OZONE OVER DECADAL TIME SCALES

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One of the key challenges in polar middle atmosphere research is to quantify the total forcing by energetic particle precipitation (EPP) and assess the related response over solar cycle time scales. This is especially true for electrons having energies between about 30 keV and 1 MeV, so-called medium-energy electrons (MEE), because there has been a persistent lack of adequate description of MEE ionization in chemistry-climate simulations. The most recent solar forcing recommendation for the Coupled Model Intercomparison Project (CMIP) includes EPP for the first time, with MEE represented as daily zonal mean using a proxy model driven by the geomagnetic Ap index. Here we use the Whole Atmosphere Community Climate Model (WACCM) and include EPP forcing by solar proton events, auroral electron precipitation, and MEE precipitation. We contrast our results from an ensemble of simulations (147 years in total) with those from the fifth phase of CMIP in order to show the importance of the recommended MEE forcing to the middle atmospheric ozone, odd hydrogen, and odd nitrogen over decadal time scales. In addition, over shorter time periods, we demonstrate the importance of detailed lower ionospheric chemistry as represented in the WACCM-D variant as well as the importance of considering the MEE dependence on magnetic local time. We further discuss how these, if included, might affect our results and conclusions from the 147-year simulation.

C2.3-0003-18 EMPIRICAL MODEL OF NITRIC OXIDE IN THE MESOSPHERE FROM SCIAMACHY/ ENVISAT SATELLITE OBSERVATIONS

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Solar, auroral, and radiation belt electrons as well as soft solar X-rays produce nitric oxide (NO) in the mesosphere and lower thermosphere (MLT, 50–150 km). NO downward transport, in particular during polar winters, influences the lower atmosphere by, for example, catalytically reducing ozone. These changes in the NO and ozone chemistry also change the dynamics of the mesosphere and can impact the stratosphere.

We present ten years of daily global NO number density measurements obtained by the satellite instrument SCIAMACHY on board Envisat. The densities are derived from UV limb scans of the mesosphere for altitudes from 60 km to 90 km. From this data set, from 08/2002 to 04/2012, we construct an empirical model of NO in the mesosphere. In particular, we link NO production and its lifetime to geomagnetic disturbances (given by the AE index) and to the solar UV radiation (using the Lyman-α index).

The derived parameters constrain how solar and geomagnetic activity influence the NO content in the mesosphere. Our model will help to fill gaps in measurements and to validate and improve chemistry climate models; it complements similar work done using AIM/SOFIE data (90–140 km) and Odin/SMR data (85–115 km). In the longer term, including additional dynamical effects in the model would help to distinguish between direct production and transport processes.

C2.3-0004-18 A MODEL PROVIDING LONG-TERM DATASETS OF ENERGETIC ELECTRON PRECIPITATION INCLUDING ZONAL DEPENDENCE

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In this study 30–1000 keV energetic electron precipitation (EEP) data from low Earth orbiting POES satellites were processed in two improved ways, compared to previous studies. Firstly, all noise-affected data were more carefully removed, in order to provide more realistic representations of low fluxes during geomagnetically quiet times. Secondly, the data were analyzed dependent on magnetic local time (MLT), which is an important factor affecting precipitation flux characteristics. We developed a zonally averaged EEP model, and a new model dependent on MLT, which both provide better modeling of low fluxes during quiet times. The models provide the spectrum of EEP assuming a power-law gradient. Using the geomagnetic index Ap with a time resolution of 1 day, the spectral parameters are provided as functions of the L-shell value relative to the plasmapause. Results from the models compare well with EEP observations over the period of 1998–2012. Analysis of the MLT-dependent data finds that during magnetically quiet times, any significant fluxes are only observed around local midnight. As disturbance levels increase, the flux increases at all MLT. During disturbed times, the flux is strongest in the dawn sector, and weakest in the late afternoon sector. The MLT-dependent model emulates this behaviour. The results of the models can be used to produce ionization rate datasets over any period of time for which the geomagnetic Ap index is available (recorded or predicted). This ionization rate dataset will enable simulations of EEP impacts on the atmosphere and climate with realistic EEP variability.

C2.3-0005-18 SOFIE OBSERVATIONS AND MODELLING OF NITRIC OXIDE IN THE POLAR MESOSPHERE AND LOWER THERMOSPHERE

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A reservoir of Nitric Oxide (NO) in the lower thermosphere efficiently cools the atmosphere after periods of enhanced geomagnetic activity. Transport from this reservoir to the stratosphere within the winter polar vortex allows NO to deplete ozone levels and thereby affect the middle atmospheric heat budget. As more climate models resolve the mesosphere and lower thermosphere (MLT) region, the need for an improved representation of NO related processes increases.

We use NO observations made by the Solar Occultation for Ice Experiment (SOFIE) instrument onboard the Aeronomy of Ice in the Mesosphere (AIM) satellite in the Antarctic MLT region and compare them to simulations performed by the Whole Atmosphere Community Climate Model with Specified Dynamics (SD-WACCM). The morphology of the simulated NO is in agreement with observations though the long term mean is too high and the short term variability is too low. The NO production and transport processes are investigated using multiple linear regressions and superposed epoch analyses in the SOFIE observations. A similar approach on SD-WACCM data allows us to determine how well these processes are represented in the model and identify possible improvements.

C2.3-0006-18 CHEMICAL IMPACTS OF ENERGETIC PARTICLE PRECIPITATION IN THE POLAR MESOSPHERE-LOWER THERMOSPHERE

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Energetic particle precipitation generates perturbations in the abundance of various neutral and ionic species in the mesosphere-lower thermosphere, partly through a complex ion cluster chemistry. In particular, mesospheric polar nitric acid enhancements have been attributed to energetic electron precipitation (EEP), but this phenomenon is not reproduced in current wholeatmosphere chemistry-climate models. We investigate such nitric acid enhancements following a series of EEP events during April and May 2010 with WACCM-D, a recently developed variant of the Whole Atmosphere Community Climate Model (WACCM) that includes a sophisticated ion chemistry tailored for the D-layer of the ionosphere (50-90 km). Whereas the standard WACCM includes only 5 positive ions, WACCM-D comprises 21 negative ions and 20 positive ions. Using the specified-dynamics mode, i.e. nudging dynamics in the troposphere and stratosphere, we perform a one-year long simulation (July 2009-July 2010) and contrast WACCM-D with the standard WACCM. Both WACCM and WACCM-D simulations are performed with and without a parametrization of the medium-to-high energy electron precipitation, allowing a better representation of the energetic electrons penetrating in the mesosphere. We demonstrate the effects of the EEP events on nitric acid and on key ion cluster species, as well as other key species of the nitrogen family. The one-year long simulation allows placing the event-related changes on key neutral and ionic species in the context of their annual cycle. We especially highlight the important role played by medium-to-high energy electrons in triggering ion cluster chemistry in the mesosphere and lower thermosphere.

C2.3-0007-18 RELATIVISTIC ELECTRON MICROBURST EVENTS: FROM OCCURRENCE TO ATMOSPHERIC IMPACT

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Relativistic electron microbursts are short-duration (< 1 second), high-energy (>1 MeV) precipitation events that are thought to be an important loss mechanism for radiation belt particles. Previous work by Turunen et al. (2009, JASTP) to estimate their atmospheric impacts found no significant changes in atmospheric chemistry, but these were based on rough estimates of the intensity of a typical microburst event. In fact, only a single monoenergetic microburst of 100

el cm–2 sr–1 s–1 was used in their simulation. We use an automated relativistic microburst detection algorithm [O'Brien et al., 2003, JGR; Blum et al., 2015, JGR; Douma et al., 2017, JGR] on low-altitude SAMPEX HILT >1 MeV electron flux observations. This algorithm provides both event detection and precipitating intensity measurements. This database of relativistic microbursts reveals that both the fluxes and frequency of microbursts are much higher than previously thought. During a 6 hour storm we are likely to see 0.0513 microbursts per second with a mean flux of 1,733.5 cmcm–2 sr–1 s–1 and a median flux of 963 cm–2 sr–1 s–1 of > 1

MeV electrons. We test the seasonal range of atmospheric impacts using this latest microburst information as input forcing to the Sodankylä Ion and Neutral Chemistry model (published in Seppälä et al., 2018, GRL). A modelled 6 h microburst storm increased mesospheric HOx by 15-25%/800-1,200% (summer/winter) and NOx by 1,500-2,250%/80-120%. Together, these drive 7-12%/12-20% upper mesospheric ozone losses, with a further 10-12% longer-term middle mesospheric loss during winter. Our results suggest that existing electron precipitation proxies, which do not yet take relativistic microburst energies into account, are likely missing a significant source of precipitation that contributes to the atmospheric ozone balance.

C2.3-0008-18 ROLE OF EQUATORIAL FOUNTAIN FOR THE DELAYED RESPONSE OF THERMOSPHERE O1D 630.0 NM DAYGLOW OVER THE DIP EQUATOR DURING AN X-CLASS FLARE

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This paper reports, for the 'first time', the delayed response of O1D 630.0 nm dayglow emissions over Trivandrum (8.5o N, 77o E, 0.5o N dip lat.), a geomagnetic dip equatorial station in India, to the X class solar flare event of July 30, 2005. The dayglow measurement has been made using dayglow photometer operating at three wavelengths. The Equatorial Electrojet (EEJ) induced magnetic field, measured using a proton precession magnetometer, showed a magnetic crochet of 90 nT enhancement during this flare with a time delay of 7.2 minutes. Noteworthy observation is, unlike to the conventional belief, the O1D 630.0 nm dayglow over the dip equator exhibits a fourfold enhancement during the noontime flare after a time delay of 45 minutes. These observations show that the thermospheric O1D 630.0 nm dayglow emission over the dip equatorial region is primarily driven by the electrodynamics, rather than the direct solar control. This finding is new, unique and very important for the studies related to plasma-neutral coupling and also modeling the equaorial thermosphere-ionosphere region.

C2.3-0009-18 UPPER AND MIDDLE ATMOSPHERIC RESPONSE TO HARD X-RAY/GAMMARAY IONIZATION: INVESTIGATION WITH OBSERVED AND SIMULATED IONIZATION IMPULSES OR SPIKES

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A significant part of the celestial and terrestrial sources of radiation is the X-rays (soft and hard) and γ-rays, which modify the ionosphere and middle atmosphere of earth by ionization of the neutral molecules. The sources of such ionizing radiation and hence the modulating effects on upper and middle atmosphere may vary in a large range of time scales, starting from few milliseconds for GRB, SGR bursts etc.to few minutes and hours (solar flares). The usual signature of such events is the sudden enhancement of free electrons and ions and gradual decay of those due to atmospheric recombination processes. The Very Low Frequency (VLF) propagation between a pair of transmitter and receiver is effected by such atmospheric modulation and has been studied for decades. The investigation of such VLF response is very informative in terms of both determining the atmospheric chemistry and dynamics as well as the source characteristics. Exact understanding of such modulations is challenging, owing to the fact that the VLF radio wave propagation is multi-parametric in nature and can only be described by rigorous theory, like mode theory of propagation in earth-ionosphere waveguide. In-situ computer simulation starting from ionization rate determination, chemistry evolution and application of programs like Long Wave Propagation Capability (LWPC), based on mode theory, is a viable option. Most simplest ionizing profile in time, such as a spike or ionization impulse is an ideal candidate to start with. Here we present the study of the effect of spike like ionization profiles on the atmosphere and VLF propagation, with both an observed SGR X-ray burst and numerically simulated sources. Numerical investigation with various source and propagation characteristics enables us to explore how the response should vary and also the possibility that whether an actual ionizing X-ray or gamma ray source with arbitrary complicated time profile may be approximated by series of such consecutive spike sources.

C2.3-0010-18 IMPACT OF INTERACTIVE CHEMISTRY OF STRATOSPHERIC OZONE IN PALEOCLIMATE AND GLOBAL WARMING SIMULATIONS

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Several series of numerical simulations on paleoclimates and global warming conditions were performed by using an Earth System Model of the Meteorological Research Institute of the Japan Meteorological Agency to investigate the impact of interactive chemistry of stratospheric ozone on the climate system including the surface conditions. The stratospheric ozone profile can be modulated by the changes of solar insolation at the top of the atmosphere due to variations of orbital parameters of the Earth, and CO2 concentration through associated temperature changes. Time slice runs over 100 years for the Mid-Holocene (MH; 6 kyr B.P. solar insolation and 280 ppm CO2 concentration), Last Glacial Maximum (LGM; 21 kyr B.P. and 185 ppm), PreIndustrial period (PI; 1850 C.E. and 285 ppm), and abrupt quadrupled CO2 concentration (4xCO2; 1850 C.E. and 1140 ppm), were done under interactive ozone chemistry to obtain quasi-equilibrium climates and compared with those of the corresponding experiments with a prescribed ozone profile for the PI condition, respectively.

Comparisons of the results of interactive ozone chemistry calculations for MH and PI with those of the corresponding experiments in CMIP5, in which the ozone distribution was prescribed to the 1850 C.E. level, show that the contribution of the interactive ozone chemistry in a quasiequilibrium state reveals a significant anomaly of up to +1.7 K in the Antarctic region for the annual mean zonal mean surface air temperature (Noda et al., 2017; JGR). This impact on the surface climate is explained by a similar mechanism to the cooling influence of the Antarctic ozone hole in spring but opposite in sign, through the Southern Annular Mode variations and associated weakening of equatorward ocean surface current and sea ice retreat. Seasonal variation in solar insolation modulated with the variations of Earth's orbital parameters has the predominant role in the interactive chemistry in the MH experiment with similar values of CO2 concentration compared with the PI condition.

Comparisons of the simulations for LGM and PI conditions also show the impact of interactive chemistry of stratospheric ozone with significant anomaly of +0.5 K (approximately 20 %) in the tropics and up to +1.6 K in high-latitudes for the annual mean zonal mean surface air temperature, compared with those of the corresponding experiments with a prescribed ozone distribution for the PI simulations in CMIP5 (Noda et al., 2018; under revision). In the tropics, this mitigation of global cooling is related to longwave radiative feedbacks associated with circulation-driven increase in lower stratospheric ozone and related increase in stratospheric water vapor. The relationships are opposite signs to and consistent with those of 4xCO2 simulation. In high-latitudes, the polar amplification of the mitigation of cooling is associated with the sea ice retreat that is the same sign to and consistent with our previous MH simulation.

Biases of sea surface temperature in both MH and LGM simulations in CMIP5 models with the prescribed ozone are reduced in our simulations by using interactive ozone chemistry. We recommend that climate models include interactive sea ice and ozone distribution that are consistent with paleo solar insolation.

C2.3-0011-18 RECENT ADVANCES AND OUTSTANDING ISSUES IN SOLAR EUV IRRADIANCE

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Solar EUV spectral irradiance is a necessary piece in the understanding of the thermosphere, ionosphere, geosphere system. We are currently in a time where there are several missions measuring the solar EUV over multiple wavelength ranges, with different spectral resolutions and cadences, and even from different locations in the solar system. I will present an overview of the observations from TIMED-SEE, SDO-EVE, and GOES-16 EXIS in Earth orbit and MAVEN-EUVM in Mars orbit. These missions have addressed many of the questions originally posed when the TIGER program started. I will take a look at the limitations of the current measurements and the still open questions regarding the important EUV input to the upper atmosphere. In addition, I will also discuss the planned future of solar EUV irradiance monitoring.

C2.3-0012-18 TROPICAL MIDDLE ATMOSPHERE OZONE RESPONSE TO THE SOLAR ROTATIONAL CYCLE IN OBSERVATIONS AND CHEMISTRY-CLIMATE SIMULATIONS

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Solar spectral irradiance fluctuations associated with the Sun's 27-day rotational cycle can significantly influence ozone variability in the tropical middle atmosphere. In the stratosphere, previous observational studies based on different instruments and time periods revealed however large disparities in the magnitude of the ozone response to the 27-day solar signal. For the mesosphere, only few observational estimates of the ozone response to the 27-day solar cycle are available. This is partly due to the relative paucity of ozone measurements and the considerable amplitude of the ozone diurnal variations at these altitudes which both make the detection of solar signals in ozone difficult. The results presented here summarize the main findings of two studies that used satellite ozone data (UARS-MLS, Aura-MLS and ENVISAT-GOMOS) and chemistry-climate simulations of LMDz-REPROBUS and HAMMONIA models in order (i) to understand the discrepancies in previous estimates of the stratospheric ozone solar rotational signal and (ii) to quantify the mesosphere/lower thermosphere ozone response to the solar rotational cycle. Observational ozone response to solar irradiance variations are identified and quantified from linear correlation and regression methods combined with non-parametric statistical tests. Observational results are then compared with the results from chemistryclimate model simulations which are driven with realistic and/or idealized solar irradiance forcings. The analysis of stratosphere MLS ozone data and their comparison with LMDzReprobus results show that the dynamical variability modulates the ozone solar rotational signal, which partly explain the discrepancies found in previous observational studies. This dynamical variability masking effect can be overcome by considering long timeseries; we found that a minimum of a 3 year time window is needed for the 1 uncertainty estimate of the ozone solar rotational signal to drop below 50%. The analysis of mesosphere/lower thermosphere GOMOS data allowed us to derive the first observation-based night-time ozone response to the solar rotational cycle in the range [50,110] km. The vertical distribution of this ozone response exhibits

a maximum at 80 km and an abrupt increase above 100 km. Although qualitatively consistent with GOMOS observations, the results from HAMMONIA simulations significantly underestimates the magnitude of the ozone response. Possible causes for these discrepancies will be discussed.

C2.3-0013-18 STUDY OF LONG TERM EFFECTS OF SOLAR UV AND X-RAY RADIATIONS ON VLF SIGNAL CHARACTERISTICS.

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We study long term effects of high energy solar UV and X-ray radiations on the Very Low Frequency (VLF) signals which propagate through the earth-ionosphere wave-guide. We used the transmitted signal at 24 KHz from NAA (Cutler, Maine) which is received at Moore Observatory in Brownsboro, Kentucky between 2007-2014. To study long term effects of UV and X-ray radiations we used solar X-ray and solar UV data of the same period. We consider diurnal peak amplitude of the VLF signal on each day and compare it with solar UV and X-ray radiation components. We found that the correlation coefficient of diurnal peak VLF signal amplitude with both solar X-ray and UV radiations is 0.7, which indicates a strong relationship between the VLF signal amplitude and solar radiation components. We carry out the same analysis with average VLF signal amplitude during day and night time separately and found that the correlation coefficient to be high with day time data while it is very weak with night time VLF signal amplitude.

C2.3-0014-18 SPORADIC VLF AMPLITUDE PERTURBATIONS IN THE HIGH LATITUDE D-REGION IONOSPHERE

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The propagation of very low frequency (VLF) radio waves permit us to study the response of the lower ionosphere (60-90 km) to sporadic space weather events such as solar proton events (SPEs) and energetic electron precipitation. In this study, we use the 37.5 kHz VLF signal transmitted from NRK (Iceland, L=5.5) recorded at Sodankylä (Finland, L=5.5) since 2010 till 2016. We compare the observed variations in the VLF amplitude measurements with changes in AE index, solar wind velocity, solar proton events and nitric oxide (NO) concentration. The analysis was divided in to positive and negative variations of the VLF perturbations with respect to the quiescent level. We found that the positive variations are mainly associated with SPEs and NO concentration enhancements. The observed large negative daytime perturbations are currently unexplained

C2.3-0015-18 ABOUT COSMIC FACTOR COUPLING WITH CLOUDLESS DAYS AND OZONE CONTENT VARIATIONS BY OBSERVATIONS FROM ABASTUMANI

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We consider possible coupling of geomagnetic disturbances and galactic cosmic rays (GCRs) flux changes with inter-annual and long-term variations of the cloudless days and total ozone content (TOC) observed at Abastumani Astrophysical Observatory during 1957-1993. The observations were carried out during cloudless conditions which allows us to investigate TOC and cloud covering possible coupling with cosmic factors. According to these data the annual and seasonal mean TOC and GCRs flux have negative trends. The tendency of decrease of the TOC is greater for geomagnetically disturbed days, which is evident for planetary geomagnetic indices Ap8 and Ap12. The TOC and corresponding number of cloudless days, observed on geomagnetically disturbed days, show their seasonal peculiarities. The TOC and GCRs flux decreases mainly during strong geomagnetically disturbed days (Ap50), except summer, when in June, in spite of GCRs flux decreases, there is a tendency of its increase and decrease in the number of cloudless days. The observed sensitivity of TOC inter-annual distribution on cosmic factor are important for the troposphere-stratosphere coupling processes which may influence inter-annual variations of dayand night-time cloud covering processes. The different behavior of TOC at spring equinox and summer time on magnetically disturbed days could be coupled with different inter-annual distributions of numbers of cloudless days and nights and the presence of semi-annual variations in it. It is also noted that the observed cloud covering and ozone content sensitivity on cosmic factors is important for climate change. Acknowledgement: This study is supported by Georgian Shota Rustaveli National Science Foundation Grant no. FR17-357.

C2.3-0017-18 OBSERVATION OF COMBINED EFFECTS OF LUNAR OCCULTATION OF A SOLAR FLARE DURING THE GREAT AMERICAN TOTAL SOLAR ECLIPSE OF 2017

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The Great Amerian Total Solar Eclipse of August 2017 had a pleasant surprise stored for VLF observers in that some of the locations could witness VLF amplitude perturbation due to the eclipse superposed by a C 3.0 flare activity partly blocked by the lunar disc. We analyse one such observation and compare it with a similar observation we had in 2010 during the annular solar eclipse over India when the VLF amplitude variation clearly recorded a C1.3 flare being partly occulted by the lunar disc. We also studied other paths during TCE2017 where the flare was fully blocked. In both the cases, the flare increased the amplitude significantly on the top of the general dip profile due to the Eclipse. We discuss how we reproduced the observed signal variation and computed the spatio-temporal variation of the electron number density.

C2.3-0018-18 MID-LATITUDE IONOSPHERIC RESPONSE TO THE SUPER GEOMAGNETIC STORM OF MARCH 2015

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We have shown the response of the mid-latitude D-region ionosphere to the super geomagnetic storm of 17th March, 2015 using radio remote sensing technique. This geomagnetic storm, resulted from the coronal mass ejection on 15th March, was the strongest storm of 24th solar cycle. We analysed radio signal of the NAA transmitter at 24.0 kHz from four receiving stations across the north Atlantic region in Europe. The storm enhanced the entire diurnal signal during the course of the storm. The amplitude of the radio signal recovered to its pre-storm level almost after two weeks. We have observed similar type of response in all the propagation paths. We estimated the enhancement of electron density in the D-region ionosphere during this period with the help of a radio propagation model.

C2.3-0019-18 A EUV REFERENCE DATA SET FOR SOLAR CYLCLE 24 (2008-2018) BASED ON ISS-SOLACES AND OTHER INSTRUMENTS

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In 2017 the SolACES Team published the Level 4 EUV data set, consisting of approximately 1600 spectra, ranging from 16 - 56 nm, over the total ISS-SOLAR-SolACES mission time (2008 - 2017). Even though the measurement cadence of spectral data acquisition is roughly only once a month, additional solar EUV spectra could be generated from ionization chamber measurements, by a modelling process. By combining true spectral measurements and spectra based on ionization chamber measurements, a total of about 1600 solar EUV spectra were accumulated during the mission time of 9 years.

The calibrated SolACES spectra are combined with data from other experiments to fill up the (time) gaps caused by the orbital and logistical conditions of the International Space Station. The extended data set covers almost one full solar cycle in the spectral range from 17 nm to 134 nm, and is intended to be used as a standard data set for solar cycle 24.

SPACE STUDIES OF THE UPPER ATMOSPHERES OF THE EARTH AND PLANETS INCLUDING REFERENCE ATMOSPHERES (C)

SMALL SATELLITE MISSIONS FOR AERONOMY AND IONOSPHERE STUDIES (C2.4)

C2.4-0001-18 SMALL SATELLITE MISSIONS: CREATING A NEW OPPORTUNITIES FOR THE COMMUNITY

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Our community stands at a critical juncture. We have the opportunity to embrace the new capabilities offered to us by lower cost, more widely available, access to space or we can choose the more familiar path of doing "business as usual". With the revitalization of the space program brought about by commercial participation and the greater number of nations that can access space, we can now begin to develop a systematic understanding of the Sun-Earth system. That critical juncture consists of two elements: 1) can we embrace new technologies?

2) can we work together in a broad, trans-national, multidisciplinary way to address gaps in our understanding? The advantage of a collaborative and diverse system is that we gain many different perspectives on this complex system that enable us to better constrain our models. Models have many free parameters and/or parameterized processes. They also have limitations on their ability to specify the state vectors of the upper atmosphere and their drivers. I stress models because, I would assert, we are not able to address a fundamental question: do we have a complete understanding of the physics that drives the system? It may be that our parameterizations of some processes hide the fact that we aren't aware of some of the processes. Some of these questions can be best addressed by combining spaceand groundbased instruments to test hypotheses about mechanisms and processes. I will describe some of the many ways that groundand space-based techniques can be used to explore the ionosphere and, in particular, why cubesats and other small satellites are so important. By combining our approaches and incorporating the space-, groundand modelingcommunity into the design of scientific investigations, we can advance our understanding of this amazing physical system.

C2.4-0002-18 DOPPLER SCANNING WITH GAS FILTERS (DSGF): A GATEWAY TO OBSERVING UPPER ATMOSPHERE DYNAMICS

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A technique for measuring upper atmosphere winds and temperature was describe by Gordley and Marshall (2011) and presented at the 2012 COSPAR meeting in Mysore, India. The method, called the Doppler Wind and Temperature Sounder (DWTS), images gas filtered earth limb emission, from low earth orbit, perpendicular to the orbit velocity vector. The change in signal due to the effective Doppler scanning by the gas filter as the limb scene passes through the FOV can be used to infer temperature and wind components. Although a major advance over current methods, the DWTS wind and temperature come from limb observations that are intrinsically limited to 100 km or more in horizontal resolution along the observation path. This talk briefly reviews the DWTS technique and then demonstrates how the DSGF limb observations can be extended with nadir observations to mitigate the limb resolution problem. The result is the ability to retrieve the upper atmosphere wave dynamics in 3 dimensions with horizontal resolution of 10 to 20 km and vertical resolution ranging from 3 to 8 km over the altitudes from cloud-top to 100 km. This now enables quantification of the key dynamical mechanisms connecting the lower to upper atmosphere.

Gordley, L. L., Benjamin T. Marshall, "Doppler Wind and Temperature Sounder: A new approach using gas filter correlation radiometry", JARS, Vol 5, 2011.

C2.4-0003-18 SOSWEET-SOUP (SOLAR, SPACE WEATHER EXTREME EVENTS AND STRATOSPHERIC OZONE ULTIMATE PROFILES) DUAL CONSTELLATION MISSION

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SoSWEET-SOUP is an innovative small satellites constellation which aims to measure on complementary platforms the solar influence on climate, namely on one part solar activity and spectral variability and, on the other, the different components of the Earth radiation bud- get, energy input and energy re-emitted at the top of the Earth atmosphere, with a particular focus on the UV part of the spectrum and on the ozone layer, which are most sensitive to solar variability. The far UV (FUV) is the only wavelength band with energy absorbed in the high atmosphere (stratosphere), in the ozone (Herzberg continuum, 200-220 nm) and oxygen bands, and its high variability is most probably at the origin of a climate influence. A simultaneous observation of the incoming FUV and of the ozone (O3) production, would bring an invaluable information on this process of solar-climate forcing. Space instruments have already measured the different components of the Earth radiative budget but this is, to our knowledge, the first time that all instruments will be operated simultaneously on coordinated platforms. This characteristic guarantees by itself obtaining new significant original scientific results.

SoSWEET-SOUP is an evolution of the SUITS/SWUSV and SUMO proposed missions, acknowledging the scientific advantages of associating a constellation of 10 to 12 small satellites of some 20 to 30 kg (12 "U" or so nanosatellites) on equatorial orbits (+/- 20° in latitude) to a small polar satellite of 100 to 120 kg on a OneWeb like platform for an almost continuous solar following (a polar orbit is also essential to the understanding of the relation between solar UV variability and stratospheric ozone on arctic and antarctic regions).

SoSWEET-SOUP definition's options are still under assessment but will include, on the polar satellite, SUAVE (Solar Ultraviolet Advanced Variability Experiment), an optimized heavyduty thermally stable SiC telescope for FUV (Lyman-Alpha) and MUV (200-220 nm Herzberg continuum) imaging (sources of variability, extreme events detection), and SOLSIM (SOLar Spectral Irradiance Monitor), a newly designed double-monochromator instrument covering the 170-340 nm ultraviolet spectral range and in within a limited mass-power budget. Other instruments include a small coronagraph, UV and ozone radiometers, Earth radiative budget assembly, Electron-Proton detectors and a vector magnetometer. The constellation of small satellites includes, on its side, precise ozone profiles measurements (miniGOMOS experiment with dual Sun and stars occultations) and detailed energy radiative budget monitors. Science objectives, mission profiles and model payloads will be presented and opportunities of missions and potential collaborations discussed.

C2.4-0004-18 PRELIMINARY RESULTS OF ADVANCED IONOSPHERIC PROBE ONBOARD FORMOSAT-5 SATELLITE

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A remote sensing satellite, FORMOSAT-5, was launched by a SpaceX Falcon 9 launch vehicle from Vandenberg Air Force Base Space Launch Complex 4E at 2:51 25 August 2017 CST into a 98.28° inclination sun-synchronous circular orbit at 720 km altitude along 1030/2230 local time sector. Advanced Ionospheric Probe (AIP) is a piggyback science payload developed by National Central University for FORMOSAT-5 satellite to explore space weather/climate and seismic precursors associated with strong earthquakes. The AIP is an all-in-one plasma sensor that measures ionospheric plasma concentrations, velocities, and temperatures in a time-sharing way and is capable of measuring ionospheric plasma irregularities at a sample rate up to 8,192 Hz over a wide range of spatial scales. Validation on retarding potential analyzer mode has been performed in Space Plasma Simulation Chamber at lab, in a flight test on sounding rocket, and during in-orbit checkout phase of the FORMOSAT-5 satellite. No significant hysteresis on measured current-voltage curves indicates that the AIP grids are almost free of contamination and could make an accurate measurement of ionospheric plasma parameters. Meanwhile, some typical ion density profiles measured by the FORMOSAT-5/AIP in night-side orbits with a geographic latitude coverage from -60° to 60° will be presented. Ion density maxima near equator and mid-latitude troughs near 40°-60° geographic latitude are helpful to identify AIP performance in the future.

C2.4-0005-18 EXTENDING FORMOSAT-5 ADVANCED IONOSPHERE PROBE OBSERVATIONS WITH CUBESATS

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The Advanced Ionosphere Probe (AIP) aboard the FORMOSAT-5 mission is an all in one in-situ plasma sensor combining retarding potential analyzer, ion trap, ion drift meter, and planar Langmuir probe modes in a time-sharing manner, providing measurements of ion density, temperature, composition, and drift velocity, as well as electron temperature. Launched in August 2017 into a 720 km Sun-synchronous repeating orbit, AIP is actively providing observations of the aforementioned parameters in the low to mid latitudes around 22 hours local time. The coverage provided by FORMOSAT-5 AIP will be extended through the upcoming INSPIRESat-1 and IDEASSat (Ionosphere Dynamics Explorer and Attitude Subsystem Satellite) CubeSat missions. The spacecraft are respectively 6U+ and 3U CubeSats carrying the Compact Ionosphere Probe (CIP) - a miniaturized version of AIP, as payload. Both spacecraft are being developed with international partners as part of the International Satellite Program in Research and Education (INSPIRE) consortium, with IDEASSat being developed by National Central University in Taiwan and funded in part by the National Space Organization (NSPO). With both spacecraft operational in high inclination Sun synchronous orbits following the expected IDEASSat launch in 2020, comprehensive in-situ measurements of ionospheric variability and irregularities can be obtained to further extend the AIP ionospheric observations to high latitudes, additional local times and altitudes.

C2.4-0006-18 FAR-EXTENDED HYDROGEN EXOSPHERE OBSERVED BY PROCYON/LAICA

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The hydrogen exosphere constitutes the uppermost atmospheric layer of the Earth, and its shape may reflect the last stage of the atmospheric escape process. The distribution of hydrogen in the outer exosphere remains unobserved because outer geocoronal emissions are difficult to observe from within the exosphere. In this study, we used the Lyman Alpha Imaging Camera (LAICA) onboard the Proximate Object Close Flyby with Optical Navigation (PROCYON) spacecraft, located outside the exosphere, to obtain the first image of the entire geocorona that extends to more than 38 Earth radii. The observed emission intensity distribution can be reproduced using our analytical model that has three parameters: exobase temperature, exobase density, and solar radiation pressure, which implies that hot hydrogen production in the magnetized plasmasphere is not the dominant process shaping the outer hydrogen exosphere. However, the role of the magnetic effect in determining the total escape flux cannot be ruled out. In this report, we show the first high-quality, and wide-field-of-view (FOV) image of Earth's hydrogen corona obtained by the first interplanetary microspacecraft. Hydrogen geocorona has not been observed by wide FOV imager since Apollo 16 in 1972, which observed only up to 10 R of FOV. The field of view of our observation is 10 times wider than that in past. Furthermore, since the advancement in deep UV detection technology in the last four decades is very large, the improvement in data quality is also very large. In fact, our newly obtained data strongly support a different picture for geocorona distribution. More specifically, we found that the observed ecliptic north-south symmetrical distribution can be reproduced by a simple analytic model and is not consistent with past results. Our result strongly suggests a combination between a compact science instrument and a flexible interplanetary microspacecraft allows us to measure important scientific observables not readily accessible with conventional large-scale spacecraft missions.

C2.4-0007-18 ADDRESSING CLIMATE ISSUES WITH SMALL SATELLITES: RADIATIVE BALANCE AND TEMPERATURE

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Atmospheric temperatures result of the radiative balance between Earth emission and Solar irradiance. To resolve such an issue it is required to insure global measurements of vertical temperature profiles, IR Earth emissions and solar irradiance on a long term basis. IR emissions and UV-Visible solar flux are related to composition and albedo that need to be performed simultaneously with temperature because of their space and time variability. Solar irradiance required to be observed on the UV part of the spectrum that exhibit the largest changes and having the largest atmospheric impact. Actual instruments are not numerous and suffer from discontinuities. Such measurements can be performed by miniaturized instruments and conducted on board small satellites. A possible strategy consist in having a constellation to insure a global survey. Continuity can be access with successive instruments if instrument drifts can be reduced.

C2.4-0008-18 DEVELOPMENT OF PHYSICS-BASED GLOBAL MODELS OF THE THERMOSPHERE AND IONOSPHERE FOR SATELLITE DRAG DETERMINATION

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Accurate determination of the properties of the upper atmosphere is vital for orbit prediction. The drag experienced by objects in low Earth orbit (LEO) is primarily dependent on neutral species density and to a lesser extent wind velocity. However, recent research at UNSW Canberra suggests that charged species may affect drag more strongly than previously believed. These quantities can be computed using physics based models, such as the Global Ionosphere Thermosphere Model (GITM) developed at the University of Michigan. This presentation details progress in modelling the LEO environment using GITM for various solar and geomagnetic conditions.

The influences that various improvements to the physical models in GITM have on thermospheric and ionospheric conditions are investigated. The effects of changes to models which describe thermal conductivity, NO cooling and plasmasphere transport on densities and velocities in the thermosphere are assessed. Various levels of solar and geomagnetic activity are considered. Results are compared with the empirical NRLMSISE-00 and IRI-2012 models. Moreover, the results are also compared with accelerometer measurements from the CHAMP satellite.

GITM is applied to predict thermosphere and ionosphere conditions relevant to the Buccaneer CubeSat. This satellite has an elliptical, quasi-sun synchronous orbit which allows investigation of spacecraft environment interactions across a range of altitudes. Circumstances in which charged drag is likely to become important for this satellite are identified. Outcomes from this research will contribute to precise orbit reconstruction and propagation, charge drag determination and manoeuvring using differential drag on planned UNSW satellite missions, including M1 and M2.

C2.4-0009-18 EARTH ENERGY IMBALANCE EXPLORER (EAGER)

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In the science community there is growing need to measure the Earth's energy imbalance (EEI). We propose the EArth enerGy imbalance ExploreR (EAGER) mission, which will - for the first time - determine the EEI through measuring both incoming Total Solar Irradiance (TSI) and Solar Spectral Irradiance (SSI) as well as the outgoing thermal and reflected solar radiation at the TOA with the same instrument type. To further ensure the highest possible accuracy and stability for the EEI observations, in-flight calibration of the solar observations will be enabled through applying very stable DARA-type TSI sensors in combination with transfer filters as a reference for the SSI observations, complemented by ionisation chambers for the calibration in the EUV wavelength range. Similarly, for the Earth observations, the fast bolometric sensors will be calibrated by a stable Earth-pointing DARA instrument. Ultimately, using the DARAtype TSI as calibration facility in space will allow us to determine the EEI with the required precision.

C2.4-0010-18 THE OCCULTATION WAVE LIMB SOUNDER (OWLS) ON INSPIRESAT-3

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Solar occultations served as an early work-horse for characterizing the temperature and density of Earth's thermosphere because of the technique's capability of making self-calibrated measurements of thermospheric density from roughly 90 to 400 km. However, solar occultations have been abandoned in recent decades, and few, if any, satellite-borne solar occultation instruments designed specifically for characterizing the thermosphere have ever flown. Meanwhile, few other methods have been proven capable of profiling the 120-300 km region of the thermosphere, leading some authors to label this region the "Thermospheric Gap" due to its lack of measurements. The Occultation Wave Limb Sounder (OWLS) instrument scheduled to fly on the INSPIRESat-3 small-sat aims to fill the Thermospheric Gap by making solar occultation measurements from 90 to 400 km, spanning from the mesopause to the exobase. OWLS is capable of measuring major neutral species (O2, N2 and O) density and temperature at 20 km vertical resolution below 150 km, and 5 km resolution above 150 km. In addition to simply filling the Thermospheric Gap, a primary focus of the OWLS mission is to understand how gravity waves propagate and dissipate in the thermosphere, addressing a Key Science Goal of the 2013 NAS Solar and Space Physics Decadal Survey. OWLS will achieve its science goals with two ultraviolet channels. One channel is a full-disk integrated far ultraviolet spectrograph for measuring density, temperature and abundance from 90-250 km at high absolute accuracy and 20 km vertical resolution, using methods proven in the early 1970s. The second channel is an extreme ultraviolet (EUV) imager with bands at 20 and 30 nm for measuring density, temperature and abundance from 150-400 km at <5 km vertical resolution, using technology proven on the

Solar Dynamics Observatory and methods proven recently for EUV photometers at both Earth and Mars. This talk will describe the OWLS science objectives, instrumentation, measurement principles, and anticipated observations.

C2.4-0011-18 THE LOW-LATITUDE IONOSPHERE/THERMOSPHERE ENHANCEMENTS IN DENSITY (LLITED) MISSION

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The Low-Latitude Ionosphere/Thermosphere Enhancements in Density (LLITED) CubeSat mission is a funded mission through NASA HTIDs program. It is a 3-year grant with CubeSat delivery at 20 months and a 1-year on-orbit mission life. The mission is to provide both ionosphere and thermosphere measurements related to the Equatorial Ionization Anomaly (EIA) and the Equatorial Temperature and Wind Anomaly (ETWA). The EIA and ETWA are two of the dominant ionosphere/thermosphere interactions on the low-latitude duskside. While the EIA has been extensively studied both observationally and with modeling, the ETWA is less well known since observations are infrequent due to a lack of suitably instrumented spacecraft at appropriate altitudes. LLITED will, for the first time, provide coincident high resolution measurements of the duskside ionosphere/thermosphere at lower altitudes that will characterize and improve our understanding of the ETWA, provide insight into the coupling physics between the ETWA and EIA, and increase our knowledge of the duskside dynamics that may influence space weather.

The LLITED mission will consist of two 1.5U Cubesats in a high-inclination circular orbit, with an orbit altitude between 350 and 450 km. The cubesats will maintain a 1/4 to 1/2 orbit separation to each other in order to observe any temporal changes as the ETWA evolves. The bus and subsystems are provided by The Aerospace Corporation. Both CubeSats will host three payloads: an ionization gauge (IG), planar ion probe (PIP), and GPS radio occultation sensor (GPSRO). The Aerospace Corporation is providing the IG and GPSRO sensors and EmbryRiddle is providing the PIP. The products provided are in-situ neutral pressure/density, in-situ plasma density, and slant TEC. The observations from LLITED will be combined with other available data, such as the remote sensing observations of ICON, to provide a comprehensive and compelling dataset of the ETWA.

C2.4-0012-18 THE MULTI-NEEDLE LANGMUIR PROBE SYSTEM FOR EXPLORATION OF THE GLOBAL IONOSPHERE

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We present the University of Oslo (UiO) multi-Needle Langmuir probe (m-NLP) system developed for small satellites. The scientific driver for this measurement technique, originally invented for sounding rockets, is to investigate plasma structuring due to instability/turbulence processes. The system had acquired flight heritage on a number of sounding rocket missions before we developed a miniaturized version for cubesats. The m-NLP system is additionally capable of monitoring the spacecraft potential, and combined with an electron emitter, we may control the platform potential. Controlling the platform potential is indeed a demanding task for high quality measurements onboard small spacecraft. The m-NLP system was put on eleven of the European Union QB50 spacecraft. We developed a further enhanced version for NorSat-1, which was launched into a polar, Low-Earth Orbit on July 14th, 2017 from Baikonur, Kazakhstan. NorSat-1 carries the multi-needle Langmuir probe (m-NLP) instrument which is capable of sampling at a rate up to 1 kHz, thus offering unprecedented opportunity to continuously resolve ionospheric plasma density structures down to a few meters. The satellite crosses the equatorial and Polar Regions twice every 90 minutes, providing a wealth of data, that we will use to monitor turbulent regions disturbing Global Navigation Satellite System (GNSS) signals as input for ionosphere space weather forecast models. We are involved in several new projects under way. Our aim is to equip a fleet of LEO satellites to continuously monitor the GNSS disturbance regions around the Earth.

C2.4-0013-18 FIRST RESULTS FROM VELOX-CI GPS RADIO OCCULTATION MEASUREMENTS

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Global Positioning Systems (GPS) Radio Occultation (RO) is a robust atmospheric remote sensing technique that can derive vertical profiles of the Earth atmosphere. GPS receivers on Low Earth Orbiting (LEO) satellites are common platforms for hosting the RO experiment. Through the relative motion between the GPS satellite and the LEO satellites, the signals emitted from the GPS satellites pierce through the Earth's atmosphere and get refracted. The refracted GPS signal is then picked up by the receivers on LEO satellites. The atmosphere induces bending and attenuations to the GPS signal, which can be translated to useful atmospheric information such as the refractivity, temperature, pressure and humidity. These measurements can then be assimilated into current weather models to assist weather and climate studies.

Most GPS RO missions, such as CHAMP, SAC-C, TerraSAR-X, COSMIC, adopt the BlackJack series receivers developed by NASA's Jet Propulsion Laboratory (JPL), employ open-loop (OL) tracking when required. The OL tracking method can deal with the severe refractivity gradients that are commonly observed in the lower troposphere. Multiple RO payloads have been launched recently by many government with more commercial missions to be launched in the near future, however the data resources are still quite sparse for climate study. On the other hand, the commercial off-the-shelf (COTS) receivers have the advantage of low cost and short development time. And the COTS receivers are also commonly used to perform orbit determination and relative positioning in other missions.

VELOX-CI was launched on Dec. 16, 2015 into a near equatorial orbit. It is the second micro satellite of Satellite Research Center (SaRC) at Nanyang Technological University. VELOX-CI carried out a total of 136 RO measurements, and collected 448 hours of GPS data with the lowest penetration altitude of 6 km. In this study we present VELOX-CI RO results for troposphere refractivity analysis and ionosphere electron density analysis. We also evaluated the VELOXCI COTS receiver's precise orbit determination performance as a reference of possible error source. The RO results are compared against ground-based measurement, numerical weather model as well as other co-located satellite measurements from COSMIC

and TIMED-SABER. The troposphere refractivity profiles are compared with the integrated global radiosonde archive (IGRA) radiosonde data, ECMWF ERA5 product, and COSMIC and MERRA measurements. The ionosphere profiles are compared with ionosonde data from multiple locations, COSMIC and IRI. In this talk, we present several findings from the VELOX CI mission, which may help with the development and data processing of similar RO missions.

C2.4-0014-18 A NEW COMPACT AND LOW COST LANGMUIR PROBE AND ASSOCIATED ONBOARD DATA HANDLING SYSTEM FOR CUBESAT

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A new compact and low cost Langmuir Probe and associated onboard data handling system are being developed at Instituto Nacional de Pesquisas Espaciais for launching on board one of the future 2U CubeSat missions. The system is a simplified and compacted version of the Langmuir Probe payloads launched on board several Brazilian SONDA III rockets and also developed for the Brazilian scientific satellites SACI-1 and SACI-2. The onboard data handling system will have the dual functions of preprocessing the data collected by the Langmuir Probe and acting as the interface between the experiment and the on board computer. The Langmuir Probe sensor in the form of two rectangular stainless steel strips of total surface area of approximately 80cm^2 will be deployed soon after the injection of the CubeSat into orbit. A sweep voltage varying linearly from 0V to 3.0V in about 1.5 seconds and then remaining fixed at 3.0V for 1 second will be applied to the LP sensor to obtain both the electron density and electron temperature. A high sensitivity preamplifier will be used to convert the sensor current expected to be in the range of a few nano amperes to a few micro amperes into a varying potential. In order to cover the large dynamic range of the expected sensor current the preamplifier output will be further amplified by a logarithmic amplifier before being sampled and sent to the data handling system. The data handling system is projected to handle 8 analog channels and 4 digital words of 8 bits each. The incoming data will be stored in a RAM and later sent to the on board computer using a serial RS422 communication protocol. The interface unit will process the telecommands received from the on board computer. The interface is also projected to do FFT analysis of the LP sensor data and send the averaged FFT spectral amplitudes in place of the original unprocessed data. The system details are presented here.

C2.4-0015-18 DERIVATION OF IONOSPHERE IRREGULARITY FROM TOTAL ELECTRON CONTENT DATA MEASURED BY CUBESAT CONSTELLATION

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The study of ionosphere irregularities has been a scientific interest over the years. This irregularities shows the plasma density variation which can occur rapidly. Practically, this irregularities can affect the performance in the radio communication from satellite to the ground. Many complex factors can contribute to the irregularity in the ionosphere, such as geographic factor and space weather condition. Geographically, the variation of plasma density varies by latitude, longitude, height from the ground and the observation time. Apparently, the fluctuation of plasma density mostly occur in the low latitude 0 - 300 after sunset. Large depletion in the TEC number indicates the phenomenon of plasma bubble which located from the lower ionosphere to the top side of ionosphere. This article will discuss about the observation of ionosphere by SPATIUM, a 2U CubeSat project developed jointly by Kyushu Institute of Technology, Japan and Nanyang Institute of Technology, Singapore. SPATIUM suggests a mission to do scientific study of ionosphere using a satellite carrying a precise chip scale atomic clock (CSAC). This paper presents the basic algorithm to derive the ionosphere irregularity will be derived from the SPATIUM observation data.

C2.4-0016-18 PETITSAT - A 6U CUBESAT TO EXAMINE THE LINK BETWEEN MSTIDS AND IONOSPHERIC PLASMA DENSITY ENHANCEMENTS

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The midand low-latitude ionosphere is home to a variety of plasma density irregularities, including depletions (bubbles), enhancements (blobs), and small-scale scintillation, which result in the distortion of radio wave propagation. Recent observations from the C/NOFS satellite suggest that multiple mechanisms are responsible for forming plasma density enhancements, with wave action in the thermosphere as a significant driver of the enhanced densities. Indeed, statistical analysis of enhancements observed from satellites resembles the statistics of MediumScale Traveling Ionosphere Disturbances (MSTIDs) with respect to seasonal variability and solar activity. In order to investigate the link between these two phenomena, both in-situ data of the plasma enhancement and remote data of the MSTID at the magnetic footpoint are required. petitSat is a CubeSat mission designed to provide in situ measurements of the plasma density, 3D ion drift, as well as ion and neutral composition. The instrument suite includes a combined retarding potential analyzer and cross-track drift meter and a neutral mass spectrometer. This instrument suite will provide comprehensive information about the fluctuations in plasma, as well as changes in the neutral profile. petitSat will launch into a 51 deg inclination orbit at 400 km (consistent with an International Space Station deployment),

allowing for numerous conjunctions with the Boston University All-Sky Imager network and GPS receivers from the International Global Navigation Satellite Systems (GNSS) Service (IGS) network over the mission lifetime.

C2.4-0017-18 DORIS OBSERVATIONS FROM LEO FOR 3D SPACE WEATHER

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Study of the upper and lower atmosphere has advanced to the point where a compelling need has emerged for global real-time specification of the most important observations as inputs to climate and other high-resolution assimilative models. For the ionosphere, plasmasphere and magnetosphere this is the local free electron density (ED); for the troposphere it is the local water vapor content (WVC). Currently, available data describes only the synoptic (few to tens of degrees) ionospheric features, but future needs require mesoscale (tens to hundreds of km) description. We describe a system concept for a DORIS receiver to be flown on a future constellation of weather satellites that would provide precise real-time global specifications of ionosphere 3D electron density profile (EDP) and troposphere WVC, as well as ionospheric scintillation maps at two length scales. We emphasize the ionospheric feature sizes that could be resolved - 100 km scale or less horizontally - and how the data sets obtained could help illuminate the transition from persistent to turbulent structures.

C2.4-0018-18 AN EQUATORIAL SATELLITE CONSTELLATION FOR SPACE WEATHER MONITORING AND NOW-CASTING OVER THE SINGAPORE REGION.

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The Regional Ionosphere Mapping and Autonomous Uplink (RIMAU) mission is a constellation of six CubeSats in an equatorial orbit, making Radio Occultation (RO) measurements of the atmosphere and in-situ Ionospheric measurements to characterize the ionosphere over equatorial South-East Asia in near real time. RIMAU builds on the success of the VELOX-CI mission which carried a COTS NOVATEL GPS receiver and have been operating successfully since December 2015. The Satellite Research Centre at Nanyang Technological University in Singapore has designed, built, tested and operated 7 satellites so far ranging from 1U cubesat to 135 kg VELOX-CI microsatellite. RIMAU will carry GPS receivers for RO and an Ionospheric payload consisting of a planar Langmuir probe, retarding potential analyser and Ion trap/drift meter. RIMAU-1 is scheduled to be in operation by 2020 with the full constellation scheduled for flight by 2021. A secondary objective of RIMAU is to provide a Low Earth Orbiting nanosatellite platform for communication with remote sensors in the region. RIMAU-I will demonstrate communication with remote water sensors monitoring water pollutants and uplink from ground based GPS sensors to adjust the sampling rate for the Ionospheric probe during periods of high scintillation. Understanding the occurrence and impact of Ionospheric irregularities is critically needed for equatorial countries like Singapore. Forecasting Ionospheric plasma bubbles and their day-to-day variability is one of the long-standing frontier challenges in space physics. In this paper, we present a novel idea to combine ground based and space based Ionospheric observations to monitor in near-real time the Ionosphere over the Singapore region to characterize Ionospheric disturbances and their impact on communication and navigation systems. The main data products from these measurements will be vertical profiles of the Total

Electron Content (TEC) in the ionosphere, atmospheric temperature and humidity profiles in the troposphere. RIMAU TEC measurements will be combined with ground based TEC measurements from 60 GPS receivers in the SE Asia region, operated by the Earth Observatory of Singapore to produce 3D maps of the Ionosphere. The outcomes from the study will be a space weather 'now-cast' system for the region, which has applications to minimize impacts to a number of critical applications, such as point positioning and real-time kinematics (i.e., the location of moving vehicles), which are particularly relevant to the aviation and maritime industry and the emerging autonomous vehicle industry.

C2.4-0019-18 A COMPACT GAMMA SPECTROMETER FOR SPACE MISSIONS WITH MINIATURIZED SATELLITES

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New gamma detection technologies provide opportunities for revolutionary new science to be done from space. For example, Gamma-Ray Burst detections associated with gravitational waves are among the most important scientific goals to achieve over the next few years. To date, the number of space missions looking for gamma interactions along with calorimetric measurements is quite limited due to high costs and the wide energy ranges of the Physics involved. However, the widespread diffusion of space missions based on miniaturized satellites (i.e. CubeSats) makes a different approach possible. A constellation of compact and low weight gamma spectrometers can be a valid option for a new era of experiments in space. A direct application might be the detection of Terrestrial Gamma-Ray Flashes (TGF) triggered by lightning or thunderstorms originating in the Earth's atmosphere. The characteristic signatures (i.e. Energy range and time evolution) of such events have been measured by AGILE and FERMI: we think that a TGF dedicated mission will improve understanding of the physics behind lightning initiation along with a refined knowledge of the dynamics of particle acceleration in the atmosphere. In particular, the time resolution and dead time limitations of current detectors could be overcome.

In this work, we describe a possible array made of several independent gamma detectors: each unit is composed of a 1-inch Cerium Bromide scintillating crystal coupled to a compact photomultiplier tube (Hamamatsu R11265U-100). Due to limited power budget, a custom multichannel front end board is used to readout, operate and control the system. The proposed detector array has been designed to fit inside 1U of a CubeSat where two arrays could be deployed on a 3U-CubeSat. We will describe the characterization of the basic unit in terms of energy calibration, energy, and time resolution. The main characteristics of the photodetector in use, such as linearity and gain versus applied voltage and more in general, working parameters as a function of the temperature, as well as a complete characterization of the scintillating crystal, will be also a topic of this work.

C2.4-0020-18 SENSITIVITY OF THE OPAL INSTRUMENT FOR GRAVITY WAVE DETECTION

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Understanding the Earth's lower thermosphere (altitude range 90km-140km) is of high interest to the space science community because of competing forcing due to solar heating above and episodic wave forcing from below. The NSF sponsored OPAL(Optical Profiling of the Atmospheric Limb) mission is designed to measure the temperature profile in this region by observing day-time integrated line of sight of the O2 A-band (760nm) emission on the limb. The OPAL instrument, on a 3U CubeSat (10 cm x 10 cm x 30 cm), has an altitude resolution of 1km from tangent altitudes of 80-160 km and is expected to be launched from the International Space Station (ISS) (400 km altitude). To investigate the instrument's ability to detect space weather signatures (i.e. solar storms and gravity waves) in the lower thermosphere, A-band emission data we have developed a suite of models that simulate the flight track of the satellite, the attitude of its optical systems, as well as the expected atmospheric O2 A-band observations that will be seen by the instrument. These models combine in a virtual CCD image that is used to develop and test different OPAL running modes for gravity wave detection. We will present development and integration of the models that resulted in thresholds for gravity wave observations by OPAL.

C3.1-0001-18 ATMOSPHERIC STUDIES BY SPACE MISSIONS IN THE SOLAR SYSTEM AND BEYOND

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The solar system objects with atmospheres have been studied with dedicated space missions since the beginning of the space exploration age. Earth's close neighbours, Venus and Mars have in particular been privileged targets of space missions, most recently with ESA's Venus Express and Mars Express and with NASA's Mars Odyssey, MSL, MRO and MAVEN, among other. These spacecraft have given important insights on the origin and characteristics of the atmospheres of the terrestrial planets and in particular on their very different evolution from that of our own planet in terms of habitability (Coustenis and Encrenaz, 2013, "Life Beyond Earth", Cambridge Univ. Press). In the outer solar system, following in the footsteps of the Voyager missions, recent large space missions - usually involving international collaboration (like Galileo, Cassini-Huygens, or Juno) -, have determined with precision the properties of the dense and extended giant planets atmospheres, but also revealed among their satellites new possible habitats in icy moons with atmospheres harboring organic chemistry and water vapour, associated with internal liquid water oceans and available energy sources. Current investigations look at different physical processes, such as greenhouse effects and environmental conditions, to find answers for the differences we observe in the large variety of gaseous envelopes within the solar system and how this diversity can inform us on what we can expect in other planetary systems. Applying our findings in the solar system to exoplanets and exomoons with atmospheres may help us better interpret current and future observations of space missions and ground-based measurements. At the same time, our understanding of the solar system and our own origins may benefit from such new information.

C3.1-0002-18 SPECTRAL ALBEDO OF VENUS CLOUDS IN THE UV AS MEASURED ONBOARD THE VEX ORBITER

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Venus clouds possess high spherical albedo (70-80%) in the visible spectral range, and the planet disk looks very bright and homogeneous. On the other hand, the ultraviolet (UV) albedo is 2-3 times lower and the clouds appear to be very contrasted. The dark spots point out to presence of some cloud components that absorb solar radiation at wavelengths from 250 to 400 nm. One of molecules is sulfur dioxide (SO2), which varies from 0.1 to 1 ppm at the cloud top [1, 2]. Other candidates are also sulfur-bearing species, sulfur Sx with different valences [3], OSSO [4], and even FeCl3 [5]. So far, there was no published precise measurement of Venus albedo in spectral range 200-400 nm that would allow retrieval the unknown UV absorbers of Venus clouds.

In the present work we perform data processing from two spectrometers that measured UV albedo of Venus clouds onboard the Venus Express (VEX) orbiter in 2006-2014. The UV channel of SPICAV operated at 115-320 nm [6], while the UV-VIS channel of VIRTIS covered 300-1000 nm [7]. We have selected a few tens of simultaneous nadir observations with similar pointing that allows us combining the clouds reflectance spectra at 200-400 nm. At the moment, spectral and absolute radiance calibrations are being performed for correct merging of spectra between two spectrometers.

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C3.1-0003-18 CIRCULATION OF VENUSIAN ATMOSPHERE AT 90-110 KM BASED ON APPARENT MOTIONS OF THE O2 1.27 MICROMETER NIGHTGLOW FROM VIRTIS-M (VENUS EXPRESS) DATA

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In the atmosphere of Venus at 90-110 km altitudes in the transition region between the superrotation and the subsolar-antisolar circulation, tracking of the O2(a1g) 1.27μm nightglow is practically the only method of studying the dynamics. The nightglow images were obtained by VIRTIS-M on Venus Express from 2006 to 2008. The horizontal wind speed can be obtained by tracking the displacement of the bright morphological features at given pairs of images. The resulting global mean velocity vector field covers the nightside between latitudes 75°S - 0°N and local time 19 h - 5 h. The mean zonal and meridional components are asymmetrical between the morning and the evening side in terms of direction and magnitude. The zonal wind speed in the eastward direction from the morning side exceeds the westward (evening) by 20-30 m/s, and the streams "meet" at 22±1 h. The meridional component is predominantly poleward on the morning side, ranging from 0 to -50 m/s, and changes to equatorward at mid-latitudes. The influence of underlying topography was suggested in some cases: above mountainous regions flows behave as if they encounter an "obstacle" and "wrap around" highlands. Instances of circular motion were discovered, encompassing areas of 500-4000 km.

C3.1-0004-18 SULFURIC ACID VAPOR IN THE ATMOSPHERE OF VENUS AS OBSERVED BY THE VENUS EXPRESS RADIO SCIENCE EXPERIMENT VERA

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The main cloud deck within Venus' atmosphere, which covers the entire planet between approx. 50 and 70 km altitude, is believed to consist mostly of liquid sulfuric acid. Below the main clouds, the temperature is high enough to evaporate the H2SO4 droplets into gaseous sulfuric acid forming a haze layer which extends to altitudes as deep as 35 km. Gaseous sulfuric acid in the lower atmosphere is responsible for a strong absorption of radio waves as seen in Mariner, Pioneer Venus, Magellan and Venera radio occultation observations. These radio wave absorption measurements can be used to derive the amount of H2SO4 in Venus' atmosphere. The radio science experiment VeRa onboard Venus Express probed the atmosphere of Venus between 2006 and 2015 with radio signals at 13 cm (S-band) and 3.6 cm (X-band) wavelengths. The orbit of the Venus Express spacecraft allowed to sound the atmosphere over a wide range of latitudes and local times providing a global picture of the sulfuric acid vapor distribution. We present absorptivity and H2SO4 profiles derived from Xand S-band signal attenuation for the time of the entire Venus Express mission. More than 600 H2SO4 profiles show the global sulfuric acid vapor distribution covering the northern and southern hemisphere on the dayand night side of the planet. A distinct latitudinal H2SO4 gradient and a southern northern symmetry are clearly visible. Observations over 8 years allow to study also long-term variations. Indications for temporal H2SO4 variations are found, at least at northern polar latitudes. The results are compared with observations retrieved by other experiments (VIRTIS, SPICAV) onboard Venus Express as well as with previous observations like Mariner, Pioneer Venus and the Magellan spacecraft.

C3.1-0005-18 SIMULATIONS OF VERTICAL PROFILES OF SULFUR MONOXIDE AND SULFUR DIOXIDE IN VENUS' MESOSPHERE

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Sulfur dioxide (SO2) plays many important roles in Venus' atmosphere. It is a precursor for the sulfuric acid that condenses to form Venus' global cloud layers and is likely a precursor for the unidentified UV absorber, which, along with CO2 near the tops of the clouds, appears to be responsible for absorbing about half of the energy deposited in Venus' atmosphere [1]. Published simulations using standard photochemistry [2,3] indicate the mixing ratio of SO2 should decrease roughly monotonically with increasing altitude as the source for SO2 is the troposphere. Observations, however, have consistently found an inversion layer in the upper mesosphere (above about 85 km altitude) where the mixing ratio of SO2 increases with increasing altitude [4,5,6]. Simulations using condensed H2SO4 as the medium for transporting sulfur from the lower mesosphere to the upper mesosphere have succeeded in replicating the upper mesosphere SO2 inversion layer [2,7], but these simulations either have required assumptions that stretch significantly the boundaries of known laboratory data or their calculated gaseous H2SO4 abundance has significantly exceeded the observational upper limit on gaseous H2SO4 [8]. S8 remains as a viable alternative medium by which sulfur can be transported from the lower mesosphere to the upper mesosphere but there are significant uncertainties in the proposed mechanism due to lack of laboratory data [7]. Two new approaches show promise as alternative explanations for the upper mesosphere SO2 inversion layer.

The Caltech/JPL photochemical model [9] was used for the numerical simulations. For these simulations, the 1-d continuity equation was solved simultaneously for all species over 58-110 km altitude. Vertical transport via eddy diffusion was set based on observations, as were the lower boundary conditions for HCl, CO, and OCS. Solar fluxes were based on measurements obtained by SORCE SOLSTICE and SORCE SIM [10,11]. For solar zenith angle (SZA)dependent simulations, calculations were run to steady-state using the solar flux expected for a specified local time on Venus' equator.

Calculated SZA-dependent SO2 profiles illustrate the upward shift with increasing SZA of the altitude at which optical depth unity is reached for the wavelengths where SO2 absorbs strongly [12]. These calculations represent the chemistry that would be expected if horizontal transport is neglected and the chemistry is allowed to equilibrate between vertical transport of mass and photons.

Comparing the calculated photochemical and transport lifetimes [12], photo-dissociation effectively stops at smaller SZAs at lower altitudes and the SO2 mixing ratio is approximately frozen at the mixing ratio where the photo-dissociation and transport lifetimes are equal. This "quenching," analogous to that occurring in temperature-dependent processes, results in a profile where the SO2 mixing ratio increases by a factor of two from 70 to 80 km altitude near the terminator. This agrees qualitatively, but not quantitatively, with observations.

Another possibility that has received only preliminary study is that compounds of S-Cl-O [13] may be sufficiently long-lived in the mesosphere to transport sulfur from the lower mesosphere to the upper mesosphere.

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C3.1-0006-18 SULFUR CHEMISTRY AND CLOUDS ON VENUS

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Sulfur dioxide SO_2 is the most abundant minor species in the lower atmosphere of Venus with mixing ratio of 130 ppm. Chemistry is initiated in the lower atmosphere by production of free sulfur in $SO_2 + CO \rightarrow CO_2 + SO$ followed by $SO + SO \rightarrow SO_2 + S$. S recycles between free sulfur S_X (x = 1 to 8) and OCS with no net loss, so that mixing ratio of OCS + xS_X is constant and equal to 20 ppm. Photolyses of S_3 and S_4 stimulate this exchange as well. OCS + CO is also constant at 35 ppm below 35 km. Downward flow of H_2SO_4 + CO from the middle atmosphere is another source of chemistry in the lower atmosphere. Krasnopolsky and Pollack (1994) proposed two processes with a net reaction $SO_3 + 2\ OCS \rightarrow CO_2 + CO + SO_2 + S_2$ that is probably a substitute of a more complicated reaction system. The chemical kinetic model by Krasnopolsky (2013) that involves the above chemistry and this reaction, predicts vertical profiles of OCS, CO, H_2SO_4, S_3, and S_4 that agree with the spacecraft and ground-based observations. A very slow reaction $S + HCl \rightarrow SH + Cl$ originates hydrogen and chlorine chemistries in the lower atmosphere. They result in formation of hydrogen sulfide H_2S decreasing from 150 ppb near the surface to 30 ppb at 47 km. The predicted H_2 abundances are 3.5 and 8.5 ppb, respectively. The most abundant chlorine product is SO_2Cl_2 with mixing ratio of 3.5 ppb at 28-47 km. Formation of sulfuric acid in a narrow layer near the cloud tops is a key feature of Venus' photochemistry that greatly reduces abundances of SO_2 and H_2O above the clouds. Delivery of SO_2 and H_2O through this bottleneck determines the chemistry and its variations above the clouds. Small variations of eddy diffusion near 60 km result in variations of SO_2, SO, and OCS at and above 70 km within a factor of 30 and do not require volcanism. Variations of the SO_2/H_2O ratio at the lower boundary have the similar effect. The photochemistry does not predict significant sources and sinks of sulfur and chlorine species above 75 km, and the increase in the mixing ratios of SO_2 + SO, HCl, and HF to 100 km in some observations does not conform the element conservation. Along with the ClCO cycle, S

$+ O_2 \rightarrow SO + O$ is the basic process of O_2 removal.

H_2O-H_2SO_4 system was modelled in the Venus clouds by Krasnopolsky (2015). Gao et al. (2014) and Parkinson et al. (2015) calculated microphysics and particle size distributions at various levels in the clouds and haze. Krasnopolsky (2016) predicted aerosol sulfur at 10% of mass loading in the lower cloud layer, in accord with the Vega gas chromatograph and mass spectrometer measurements. Data on $FeCl_3$ as the mode 1 particles in the lower and middle cloud layers and the solution of 1% $FeCl_3$ in sulfuric acid in the mode 2 particles in the upper cloud layer as the NUV absorber have been updated as well. The controversial detections of chlorine in the middle cloud layer and phosphorus in the lower cloud layer by the Vega X-ray radiometer (Andreichikov et al. 1987) may be explained by condensation of $AlCl_3$ and H_3PO_4, respectively, but require independent confirmation.

C3.1-0007-18 INTERACTION OF SOLAR-RELATED EFFECTS AND STATIONARY GRAVITY WAVE ABOVE APHRODITE TERRA ACCORDING TO VMC/ VENUS EXPRESS WIND FIELDS

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A set of UV (365 nm) images obtained by the Venus Monitoring Camera onboard Venus Express spacecraft was used to study the circulation of the atmosphere at upper boundary of clouds (70±2 km). 172000 displacement vectors (257 orbits) were obtained by digital wind tracking technique for observation period from 2006 to 2014. This data set allows studying both variation of the wind speed vs. latitude and longitude (correlation with surface topography) and dependence on local time. The zonal speed decrease was found above Aphrodite Terra. It has a solar-related character and strongly connected to the local noon. We studied the shape of the minimum wind speed structure (dependence of wind speed vs. longitude and latitude). It has an elongated shape in latitude. It was found that it repeats a contour of Aphrodite Terra at noon. The shape is conserved at least up to 30°S. In the same time, the wind speed increases by approximately 5 m/s to 30°S, and the area of minimum zonal speed shifts in direction of superrotation. The Sun influence manifests itself in the region of the stationary gravity wave existence above Aphrodite Terra as the mean zonal flow deceleration in near equatorial latitudes (0-30°S). The zonal speed minimum is observed at noon above highest region of Ovda Regio (western part of Aphrodite Terra). Outside the Aphrodite Terra, the Sun influence does not manifest itself. The structure above highlands of Aphrodite Terra observed at noon may be a result of the stationary wave which generated by Aphrodite Terra and possible higher stability of the atmosphere, as a result of Solar heating, allow gravity waves to reach the upper clouds where they break and decelerate the mean zonal wind. J.-L. Bertaux, I.V. Khatuntsev and

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C3.1-0008-18 CONTRIBUTIONS OF THE CURIOSITY ROVER TO THE UNDERSTANDING OF THE MARTIAN ATMOSPHERE

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NASA's Curiosity Mars rover landed within Gale crater in August 2012 to assess the habitability of Mars in the past and present through investigations of the geology, geochemistry, and environment. A number of instruments on the rover study the atmosphere, including the grayscale Navigation Cameras (Navcam), the color Mast Cameras (Mastcam), the ChemCam spectrometer in passive mode, the Rover Environmental Monitoring Station (REMS), and the Sample Analysis at Mars (SAM) quadrupole mass spectrometer (QMS) and tunable laser spectrometer (TLS). Measurements span three Mars years. In addition, records of pressure, air and ground temperature, UV flux, wind, and relative humidity have hourly or better resolution over the full martian day. The results have improved our understanding of the evolution of the atmosphere as well as processes at scales from local to planetary.

Volume mixing ratios and isotopic ratios are determined with unprecedented precision. Some isotopes of Kr and Xe may be products of spallation or neutron capture in the regolith. Isotopic fractionation in H, C, O, N, and noble gases provides evidence of substantial atmospheric loss to space. D/H in water evolved from Hesperian clay minerals is intermediate between the present value and that of very early Mars, suggesting that a larger exchangeable water inventory existed at the time that the clay minerals formed in an ancient lake and groundwater system within the crater. Systematic measurements of methane show a repeating annual cycle that requires an active and seasonally variable source of methane, as well as transient spikes that remain unexplained. Column water vapor exhibits a seasonal behavior similar to that of orbiter measurements, but mixing ratios measured at the surface are depressed at night, consistent with temperature-dependent adsorption by surface materials. Curiosity's instruments do not have the sensitivity to directly measure this adsorption. The surface reaches the frost point for a few nights each winter, but frost has not been detected.

The pressure record reflects annual exchange with the polar caps; tidal modes as modulated by atmospheric dust heating; Northern Hemisphere equator-crossing baroclinic eddies; small dips due to dust-free vortices and dust devils; and, fluctuations from wind-induced dynamic pressure. Slope-driven circulations from the crater rim and central mound dominate the wind measurements, but local topography is observed to modify wind speed and direction. Winds also are inferred from observations of grain

and bedform motion in sand deposits, and from ventifacts. Dust optical depth peaks in both middle and late southern summer and is mini- mal through southern winter. Atmospheric dust within the crater varies similarly, but more smoothly, moderated by the rate of mixing vertically in the crater and horizontally with outside air. Local dust lifting results from gusts and vortices. Dust aerosol particle size is positively correlated with optical depth. The Aphelion Cloud Belt brings elevated water ice cloud opacity and increased cloud activity in southern winter, with inter-annual variability. Cloud detections are greatest in the morning with a secondary peak in mid-afternoon. Water ice crystal shapes are constrained from photometric analyses of all-sky imaging.

C3.1-0009-18 ATMOSPHERIC AND AERONOMY INVESTIGATIONS BY ESA'S MARS EXPRESS

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Mars Express remains one of ESA's most scientifically productive missions whose publication record now exceeds 1000 papers. Characterization of the geological processes on a local-toregional scale by HRSC, OMEGA and partner experiments on NASA spacecraft has allowed constraining land-forming processes in space and time. Recent results suggest episodic geological activity as well as the presence of large bodies of liquid water in several provinces (e.g. Eridania Planum, Terra Chimeria) in the early and middle Amazonian epoch and formation of vast sedimentary plains north of the Hellas basin. Mars Express observations and experimental teams provided essential contribution to the selection of the Mars-2020 landing sites. More than a decade-long record of the atmospheric parameters such as temperature, dust loading, water vapor and ozone abundance, water ice and CO2 clouds distribution, collected by SPICAM, PFS and OMEGA spectrometers as well as subsequent modeling have provided key contributions to our understanding of the martian climate. ASPERA-3 observations of the ion escape covering complete solar cycle have revealed important dependencies of the atmospheric erosion rate on parameters of the solar wind and EUV flux. The structure of the ionosphere sounded by the MARSIS radar and the MaRS radio science experiment was found to be significantly affected by the solar activity, the crustal magnetic field, as well as by the influx of meteorite and cometary dust. MARSIS and ASPERA-3 observations suggest that the sunlit ionosphere over the regions with strong crustal fields is denser and extends to higher altitudes as compared to the regions with no crustal anomalies. The ionospheric plasma expands to higher altitudes where it contacts with the solar wind plasma. Reconnection of solar magnetic field lines carried by the solar wind with field lines of crustal origin opens channels through which the ionospheric plasma escapes to space, producing strong and narrow cavities in the density. The situation is very different on the night side where the ionosphere has patchy structure. Such patchy ionizations are observed in the regions where field lines have a dominant vertical component. Through these patches the ionospheric plasma from the dayside penetrates and supplies the nightside ionosphere. Mars Express provides unique observation capabilities amongst the flotilla of spacecraft investigating Mars. The mission has been extended till the end of 2020. The observation program proposed for 2019-2020 includes both augmenting the coverage and extending long-time series, as well as new elements and potentially new opportunities for discoveries. It will be boosted by collaboration and synergies with NASA's MAVEN, ESA-Roscosmos Trace Gas Orbiter and other missions. The talk will give the mission status, review the recent science highlights, and outline future plans.

C3.1-0010-18 CLIMATOLOGY LEGACY OF THE MARS EXPRESS MISSION

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Mars Express has continuously monitored the Martian environment from orbit since January 2004 (a total of more than seven Martian years) and is planned to continue for several more years. Among the numerous and important outcomes of the mission is thus a unique ensemble of climatology datasets. The datasets are unique because of 1) the very diverse payloads and 2) the non sun-synchronous polar orbit which has allowed, year after year, to observed atmospheric phenomena at various local times and seasons. The Martian environment have been remotely observed at many wavelengths: radar (ionosphere), radio (temperature and ionosphere), thermal infrared (temperatures, aerosols, clouds, water vapor), near infrared (frost, aerosols, water vapor,fluorescence), visible, and UV (ozone, temperatures, aerosols, airglow). The Mars Express team is now working to make the Mars Express "legacy" high level dataset available to the science community in the most convenient way on the ESA Planetary Science Archive.

C3.1-0011-18 INTERANNUAL VARIABILITY IN THE 'SOLSITICIAL PAUSE' IN MARTIAN PLANETARY WAVE ACTIVITY

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Planetary waves have long been observed in the winter hemisphere of Mars, for example in the Viking Lander 2 surface pressure record, and are simulated in Mars global circulation models (MGCMs). Some of these waves are trapped near to the surface and give rise to the day-to-day variability, or weather, seen in the lower atmosphere. Large amplitude wave activity lasts from autumn to spring, but recent assimilations of spacecraft observations have led to the suggestion that wave activity near the surface falls to a subsidiary minimum directly around the winter solstice, a phenomenon called the 'solsticial pause' (Lewis et al. 2016). This behaviour is in contrast to waves higher in the atmosphere, above about 20 km, where activity can peak close to winter solstice.

We have conducted a nine-Mars Year (MY) consistent reanalysis of the martian atmosphere covering the period MY 24-32 and making use of data from three different spacecraft. Remotelysensed measurements of temperature, dust opacity, water and ozone from NASA's Mars Global Surveyor (MGS) and Mars Reconnaissance Orbiter (MRO) and ESA's Mars Express (MEx) were assimilated into a continuous model simulation. One of the most striking features of the reanalysis is the year-to-year variation in the martian dust loading, in particular during Northern Hemisphere winter. We establish that the solsticial pause is a robust, repeatable feature in both hemispheres and discuss its interannual variability.

Lewis, S.R., Mulholland, D.P., Read, P.L., Montabone, L., Wilson, R.J., Smith, M.D., 2016. The solsticial pause on Mars: 1. A planetary wave reanalysis. Icarus 264, 456–464.

C3.1-0012-18 LARGE-SCALE TRAVELING WEATHER SYSTEMS IN MARS' SOUTHERN EXTRATROPICS

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Between late autumn and early spring, the middleand high-latitudes within Mars' atmosphere support strong mean equator-to-pole temperature contrasts and an accompanying mean westerly polar vortex. Observations from both the MGS Thermal Emission Spectrometer (TES) and the MRO Mars Climate Sounder (MCS) indicate that such strong mean baroclinicitybarotropicity supports intense, large-scale eastward traveling weather systems (i.e., transient synoptic-period waves). Such extratropical weather disturbances are critical components of the global circulation as they serve as agents in the transport of heat and momentum, and generalized scalar/tracer quantities (e.g., atmospheric dust, water-vapor and ice clouds). These weather systems also interact with other large-scale atmospheric circulation components such as the quasi-stationary (i.e., forced Rossby) modes and the global thermal tidal modes. The character of such traveling extratropical synoptic disturbances in Mars' southern hemisphere during late winter through early spring is investigated using a high-resolution Mars global climate model (Mars GCM). The climate model includes a complex water-ice cloud microphysics package, one that produces simulation results that compare relatively well with the planet's current water cycle. The Mars GCM imposes interactively-lifted and radiatively-active dust based on a threshold value of the surface stress. The model exhibits a reasonable "dust cycle" (i.e., globally averaged, a dustier atmosphere during southern spring and summer occurs). Compared to the northern-hemisphere counterparts, the southern synoptic-period weather disturbances and accompanying frontal waves have smaller meridional and zonal scales, and are far less intense. Influences of the zonally asymmetric (i.e., east-west varying) topography on southern large-scale weather are investigated, in addition to large-scale up-slope/down-slope flows and the diurnal cycle. A southern storm zone in late winter and early spring presents in the western hemisphere via orographic influences from the Tharsis highlands, and the Argyre and Hellas impact basins. Geographically localized transient-wave activity diagnostics are constructed that illuminate dynamical differences amongst the simulations and these are presented.

C3.1-0013-18 A COUPLED ATMOSPHERE-HYDROSPHERE GLOBAL CLIMATE MODEL OF EARLY MARS: REPRODUCTION OF A 'COOL AND WET' SCENARIO FOR THE FORMATION OF WATER CHANNELS

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Martian water channels are considered evidence of a climate warm enough to allow the existence of long-term fluvial systems on early Mars during the Noachian and Hesperian boundary (3.853.6 Ga). Quantitative inferences of water channel formation from climate models are crucial to develop an accurate understanding of the early Martian environment. We present the results of a 3-dimensional Paleo Martian Global Climate Model (PMGCM) assuming the CO2/H2O atmosphere under the 'Faint Young Sun' (solar luminosity of 75% of the current value), with surface pressures between 0.5 and 2 bars. The PMGCM also has a hydrologic cycle module, which includes ocean thermodynamics, water vapor advection/convection/condensation/precipitation processes, and surface fluvial activities (e.g. fluvial and sediment transport).

The simulation with a surface pressure exceeding 1.5 bars indicated that as per the PMGCM, the early Martian surface environment would have been 'cool' (between 'warm' and 'cold'); namely, the mean surface temperatures were high enough (> 273 K) during spring to autumn, to allow seasonal melting of snow-ice deposits, and low enough (< 273 K) during winter to produce considerable snow precipitation and accumulation. The PMGCM also indicated a 'wet' surface environment characterized by precipitation and seasonal melting of snow/ice (neither 'dry' nor 'permanent frozen' states), and enough fluvial sediment transport in the southern low-mid latitudes to reproduce Martian valley networks within a relatively short time (less than 10 million years). We suggest that a moderate climate, that is, 'cool and wet' conditions lying between 'warm and wet' and 'cold and frozen,' is preferable to explain the fluvial activity on early Mars, which does not need to consider non-climatic mechanisms such as warming by meteorite impacts.

C3.1-0014-18 EXOMARS 2016 TRACE GAS ORBITER STATUS REPORT

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The ExoMars programme is a joint activity by the European Space Agency(ESA) and ROSCOSMOS, Russia. It consists of the ExoMars 2016 mission, launched 14 March 2016, with the Trace Gas Orbiter, TGO, and the Entry Descent and Landing Demonstrator, EDM, named Schiaparelli, and the ExoMars 2020 mission, to be launched in July 2020, carrying a Rover and a surface science platform. TGO arrived at Mars on 19 October 2016 and was inserted into a near equatorial, highly elliptical 4 sol period capture orbit. Two orbits in late November were dedicated to instrument calibration and initial science observations, where an excellent performance of all instruments could be confirmed. In January 2017 the orbital plane was changed to its final inclination of 74 degrees and the period was reduced to one Sol. Early March 2017 an additional two orbits were scheduled for instrument tests and observations, after which a long period of aerobraking commenced. The final near circular 400km altitude orbit, with a 2 hour period, is expected to be reached in April 2018 when instrument commissioning and initial scientific observations will start. The TGO scientific payload consists of four instruments. These are: ACS and NOMAD, both being spectrometers for atmospheric measurements in solar occultation mode and in nadir mode, CASSIS, a multichannel camera with stereo imaging capability, and FREND, an epithermal neutron detector for search of subsurface hydrogen. The mass of the TGO is 3700 kg, including fuel and the mass of EDM was 600 kg. The EDM was carried to Mars by the TGO and was separated three days before arrival at Mars but unfortunately failed during the last stage of the descent. This presentation will cover a brief description of the Trace Gas Orbiter mission, the present status and the planned future activities.

C3.1-0015-18 THE NOMAD INSTRUMENT ON BOARD EXOMARS TGO: FIRST RESULTS FROM THE SCIENCE PHASE

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The NOMAD ("Nadir and Occultation for MArs Discovery") spectrometer suite [1] on board the ExoMars Trace Gas Orbiter (TGO) has been designed to investigate the composition of Mars' atmosphere, with a particular focus on trace gases, clouds and dust. The detection sensitivity for trace gases is considerably improved compared to previous Mars missions, compliant with the science objectives of the TGO mission. This will allow for a major leap in our knowledge and understanding of the Martian atmospheric composition and the related physical and chemical processes.

The instrument will conduct a spectroscopic survey of Mars' atmosphere in ultraviolet (UV), visible and infrared (IR) wavelengths covering large parts of the 0.2-4.3 μm spectral range. NOMAD is composed of 3 channels: a solar occultation only channel (SO - Solar Occultation) operating in the infrared (2.3-4.3 μm), a second infrared channel (2.3-3.8 μm) capable of doing nadir, but also solar occultation and limb observations (LNO - Limb Nadir and solar Occultation), and an ultraviolet/visible channel (UVIS - UV visible, 200-650 nm) that can work in the three observation modes. NOMAD offers an integrated instrument combining a flight-proven concept and innovations based on existing and proven instrumentation: SO is a copy of the Solar Occultation in the IR (SOIR) instrument [2] on Venus Express (VEx), LNO is a modified version of SOIR, and UVIS has heritage from the development in the context of the Humboldt lander.

NOMAD will provide vertical profiling information for atmospheric constituents at unprecedented spatial and temporal resolution. Indeed, in solar occultation, the vertical resolution is less than 1 km for SO and UVIS, with a sampling rate of 1 s (one measurement every 1 km), and occultations will range from the surface to 200 km altitude. NOMAD will also provide mapping of several constituents with an instantaneous footprint of 0.5 x 17 km^2 (LNO channel) and 5 km^2 (UVIS channel) respectively, with a repetition rate of 30 Martian days.

Preliminary results will be presented and discussed, covering observations recorded during cruise, Mars orbit insertion, the Commissioning Phase and first few weeks of the Science Phase.

[1] Vandaele. et al, Planet. Space Science, 119, 233-249 (2015) [2] Nevejans et al., Applied Optics, 45(21), 5191-5206 (2006)

C3.1-0016-18 SATURN AT 1-10 KM RESOLUTION: CASSINI IMAGING DURING THE FINAL YEAR

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During Cassini's last year of existence, the spacecraft took numerous images of Saturn's northern hemisphere at 1-10 km resolution. The spacecraft was in a high-inclination orbit, so the image sequences were usually scans from the north pole to the equator. In the southern hemisphere, ring shadows interfered with the illumination of the planet. The spacecraft made its first dive between the rings and the planet on April 26, 2017 and took its final plunge into Saturn's atmosphere on September 15, 2017. Between those two dates, the Imaging Science Subsystem (ISS) imaged Saturn on two separate polar passes, with about 80 wide-angle images per pass. At closest approach, which was near the equator, the resolution was about 1 km per pixel. Such resolution was available before April using the narrow-angle camera. Here we present a sample of those images and their possible scientific significance.

Optically thin filamentary clouds are a common feature. The individual filaments are traceable for thousands of km. Given the clouds' low relative motion and their fine scale structure, we conclude that the horizontal diffusion coefficient is extremely small. We compare these clouds with similar clouds on Earth.

Scarp-like clouds, which represent an abrupt change in cloud altitude, are also common. They are optically thick and cast prominent shadows, enabling one to estimate the height of the scarp. The scarps usually follow lines of constant latitude and often are coherent for thousands of km and persist for years.

Ensembles of cyclones and anticyclones 2000-3000 km in diameter can travel together, despite their being at slightly different latitudes and therefore subject to slightly different ambient zonal velocities. We find that at high northern latitudes the cyclones and anticyclones persist for years, in agreement with del Rio-Gaztelurrutia et al. [Icarus 302, 499-513, 2018].

Based on methane-band imaging, the cloud tops of the anticyclones are high and those of the cyclones are low. Shading from oblique illumination indicates that the cloud tops of the anticyclones are dome-shaped.

C3.1-0017-18 OBSERVATIONS OF TITAN'S DETACHED HAZE 2005 - 2017

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Spacecraft images and stellar occultation measurements of Titan throughout the UV-Visible range reveal a local maximum in brightness or extinction optical depth at altitudes from about 250 - 500 Km above Titan's surface. The appearance in images is of a distinct haze layer, 'detached' from and above the main haze that extends to the surface. We now know that the optical appearance can be attributed to a deficit in the haze density just below the apparent altitude of the detached haze. The detached haze was first seen in Voyager images in 1981 (K. Rages and J. Pollack, Icarus, 55, 50-62, 1983, doi: 10.1016/0019-1035(83)90049-0). With hundreds of images of Titan and several UV occultations observed by Cassini ISS and UVIS instruments we now have a time history of the haze over a significant fraction of a Titan year. These show seasonal behavior of the altitude and amplitude of the detached haze that has only been recognized in retrospect as likely due to the breakup of the meridional circulation near equinox in the stratosphere and mesosphere. Some details of the observations are still not adequately explained by models. The detached haze disappeared after mid-2012 and began to reappear weakly and intermittently in 2016. These observations drive new models for Titan's circulation and haze microphysics. Future observational work will focus on the latitude distribution of the haze morphology, probes to deeper layers via longer-wavelength observations, and details revealed at higher spatial resolution.

C3.1-0018-18 PROFILES OF TITAN'S HIGH-ALTITUDE HAZE FROM MULTIPLE OCCULTATIONS

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Haze in Titan's upper atmosphere were observed in Cassini UVIS stellar occultations. Pointing motion, however, impaired the analysis process and only three occultations have been published to date. Most of the occultations are usable, but require special treatment. To address the problem, an innovative analytic method for correcting the effect of pointing motion has been developed using forward modeling of the Cassini/UVIS instrument spectral response function. The Markov Chain Monte-Carlo (MCMC) method has been applied to the analysis by including pointing in the state vector as parameters in the spectral fitting process. In addition to haze, LOS (line-of-sight) abundances of twelve other hydrocarbon and nitrile species are obtained in the analysis. Reduction of high-altitude haze profiles for thirteen occultations has been obtained, most of which have never been analyzed because of pointing motion. The new results provide a 2-D (highly interpolated) regional map of the haze abundance in Titan's upper atmosphere.

C3.1-0019-18 HELIUM 584Å AND H LYMAN-ALPHA AIRGLOW IN GIANT PLANETARY ATMOSPHERES: MODELING, OBSERVATIONS, AND IMPLICATIONS

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The atmosphere of the outer planets is mainly composed of H2 and neutral atomic helium. The study of He 584 A and H Lyman-alpha brightnesses is interesting as the EUV and FUV (Extreme and Far Ultraviolet) planetary airglow have the potential to yield useful information about mixing and other important parameters in their thermospheres. Time variation, asymmetries, and polar enhancement of the airglow are also possible and analysis of the public archived NASA mission data sets (i.e. Voyager and Cassini) can help solve some of the outstanding problems associated with these phenomena. The comparison of observations with results from sophisticated photochemical and radiative transfer models can also help ameliorate unexplained differences in the dynamical processes operating within planetary upper atmospheres. Powerful analysis techniques allow us to extract information on atmospheric mixing, temperatures, and temporal changes due to the solar and seasonal cycles from the variations in distribution and intensity of airglow emissions that result. The presentation will discuss the implications of interpretations from a comparison of modeling and observations in giant planetary atmospheres.

C3.1-0020-18 ANALYTICAL AND NUMERICAL STUDIES IN RADIO OCCULTATION EXPERIMENTS

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Since the 60's, radio occultation geometry has proven to be a powerful opportunity for sounding remotely planetary atmospheres. The basic idea behind this methodology is to analyze the changes in the Doppler frequency of a radio link between a transmitter and a receiver, when they are mutually occulted by a media of non-unity index of refraction. In the literature, there are different approaches devoted to the retrieval of the refractive profile from the Doppler variations. Let's mention, i) the analytic formulation of the Abel inversion which is only employed for spherically symmetric atmospheres, and ii) the ray tracing method which is a numerical integration of the fundamental equations of optics and which is well suited for atmospheres with more complicated shapes. In this context, we discuss the benefits of a new formalism based on a full reformulation of the fundamental equations of optics. This new approach provides a very comprehensive description of the light trajectory inside a media which is mainly shaped by a gravitational potential. We show how the first order effects on the light ray trajectory due to various perturbations can be obtained from this formalism. We derive the effects due to an oblate atmosphere and apply the solution to real radio occultation experiments carried out by the Cassini mission at Saturn. The validity of the proposed approach is assessed comparing the results with other studies available in the literature.

C3.1-0021-18 THE STUDY OF ATMOSPHERES OF EXOPLANETS: STATUS AND PERSPECTIVES

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The study of the atmospheres of exoplanets is at the verge of a new revolution. After the detection of thousands of planetary systems, most of the physical parameters obtained so far are still restricted to orbital parameters, mass and size of these objects, which is notoriously insufficient to characterize the systems due to multivalue retrievals from inverse models. Constraining the atmospheric structure and composition has been possible only for a dozen of planets, from IRAC, Spitzer, HST or ground based telescopes. The James Webb Space Telescope, to be launched in 2019, is expected to observe many more exoplanets transits and eclipses, as well as direct observations when possible, with exquisite signal to noise [1]. Today, the current knowledge of the exoplanets corpus has unveiled a large variety of systems, not known in our Solar System, which would even have been thought impossible 15 years ago: hot Jupiters, warm Neptunes, Superearths, etc. Our Solar System is definitely not the common standard for planets in the Universe, and anthropocentrism has once again be defeated, urging for more open mind approaches to understand exoplanetary systems. New missions will be needed to address this scientific goal [2]. Nevertheless the great details available from our Solar System planets is still of great use as a template to validate models before extrapolation, or as a "ground truth" model to test observation retrieval. The possibility to infer the history of Solar System atmospheres on Venus, Mars or Earth has also profound implications on the research of exoplanets. The new era of interpretation of planetary atmospheres will have to combine expertise from:

Stellar physics, to know as accurately as possible the stellar environment, activity and history of the exoplanets.

Planetology: spectroscopy of planetary atmospheres has developed a corpus of expertise by 50 years of space observations on planets, including Earth, which can be deployed to study the new worlds

Spectroscopy: as traditional spectroscopic databases for hot temperature molecules are challenged by the needs of exoplanet modelling, the breakthrough in spectroscopic analysis came with ab initio models accurate enough to provide complete molecular spectroscopic data for hot bands observed in the near infrared and for various molecules [3]

Big data analysis: new methods of calculations including Artificial Intelligence algorithms are emerging to deal with the huge database and the complexity of models [4]

The era of exoplanetology is only starting to emerge and we can expect in the next decades new revolutions in the science of planets, with new missions and instruments like the future ESA/M4 ARIEL mission [5].

[1] EXPLORING THE UNIVERSE WITH JWST: 49th ESLAB symposium, 12-16 Octobre 2015, ESTEC, Noordwijk, Pays-Bas. 2015. [2] Echo - Exoplanet Characterisation Observatory; Tinetti and Drossart editors, Springer, 2015 ISBN 978-94-024-0836-2 [3] J. Tennyson et al. The ExoMol database: Molecular line lists for exoplanet and other hot atmospheres (2016). Journal of Molecular Spectroscopy, Vol. 327, p. 73-94. [4] Ingo P. Waldmann Artificial Intelligence in planetary spectroscopy, EPSC Abstracts Vol. 11, EPSC2017-240, [5] Tinetti G. et al.,The Science of ARIEL, EPSC Abstracts Vol. 11, EPSC2017-713, 2017 European Planetary Science Congress 2017 2017 European Planetary Science Congress 2017

C3.1-0022-18 CLIMATES OF HIGH OBLIQUITY TERRESTRIAL PLANETS

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Ongoing discoveries of terrestrial exoplanets suggest that these planets might span a wide range of climatic regimes and atmospheric circulations, which will strongly impact their habitability. Here, we use an idealized moist general circulation model in aquaplanet configuration to characterize the atmospheric circulations of terrestrial planets with high obliquities. We increase the obliquity from earth-like values of 23.5° up to 90°. This not only provides for a systematic exploration of the impact of obliquity on a planet's climate, but also includes the range of obliquities experienced by Mars' orbit in the past.

Because obliquity impacts the seasonal distribution of insolation, our simulations have a seasonally varying insolation forcing. High obliquity climates show interesting features, which are not necessarily predictable a priori. For instance, while for obliquities larger than 54° more energy is delivered at the poles than at the equator, the annual mean surface temperatures produce equator-to-pole temperature gradients that are much flatter than the insolation. This points to the importance of atmospheric energy transport, which is primarily accomplished during the warm seasons by strong and broad cross-equatorial Hadley circulations that transport energy from the summer to the winter hemisphere.

Seasonal precipitation patterns also feature interesting peculiarities. In Earth-like low obliquity cases net precipitation (the difference between precipitation and evaporation) is primarily balanced by mean moisture flux convergence in the tropics and eddy moisture flux convergence in the extratropics. In high obliquity cases, however, storage effects become increasingly important in the polar regions because of rapid temperature changes. More specifically, as polar temperatures drop quickly from their maximum values around the summer solstice, the water vapor in the atmospheric column rapidly condenses out, producing large amount of precipitation there. At lower latitudes, precipitation is primarily associated with seasonally migrating convergence zones within the Hadley circulation. As the solstice-season cross-equatorial Hadley cells become broader with increasing obliquity, peak precipitation becomes progressively more separated from their poleward boundary and from widely used diagnostics, such as the lowerlevel moist static energy maximum and the energy flux equator. This emphasizes the need for more robust theories that are broadly applicable to climates more exotic than Earth's.

C3.1-0023-18 PROBING PLANETARY ATMOSPHERES USING POLARIMETRY

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Our solar system shows a large variety of atmospheric polarization properties of its components, ranging from the inner to outer planets, planetary rings, and moons, comets, asteroids, dust; even the sun, Earth and Moon. The unique signatures arise from the particular scattering media of the various solar system objects, from clouds in the equatorial region of Jupiter or on Venus, to the thick, highly polarizing haze on Titan and the poles of Jupiter, and Rayleigh scattering by molecules on Uranus and Neptune. Planetary atmospheres have unique polarimetric signatures that vary with the state of the atmosphere. Changes in the clouds/thermal filed can be brought about by endogenic dynamical processes such merger of vortices; global, planetary scale upheavals, and external factors such as celestial collisions (such as D/Shoemaker-Levy 9 impact with Jupiter in 1994, etc.); or from the outbreak of planetary disturbances (such as the storms and cloud outbreaks on Jupiter and Saturn) and also measured via limb polarization in methane bands, thereby probing the atmosphere. Although the range of phase angles available from Earth for outer planets is restricted to a narrow range, limb polarization measurements provide constraints on the polarimetric properties. For example, at the equator, much of the observed reflected radiation is due to the presence of clouds and therefore, low polarization. Polar asymmetry exists between the two poles, while the planetary disk is unpolarized on both Jupiter and Saturn. Jupiter is known to exhibit a strong polar limb polarization and a low equatorial limb polarization due to the presence of haze particles and Rayleigh scattering at the poles. In contrast, at the equator, the concentration of particulates in the high atmosphere might change, changing the polarimetric signature and aurorae at both poles. The polarimetric maps, in conjunction with thermal maps and albedo maps, can provide constraints on modeling efforts to understand the nature of the aerosols/hazes in Jovian atmosphere. Saturn exhibits limb polarization, like Jupiter, and its ring system too. Multiple scattering in planetary atmospheres manifest in circular polarization; Venus and Mars allow the probing their clouds and dust respectively. I will discuss the probing of planetary atmospheres via polarimetry and use it as a reference for other planetary systems. Some of our observations are acquired by a global network of amateur planetary imagers astronomers. Details/results of these studies will be presented to optimize the observing strategy of planetary atmospheres, to understand the diversity in our solar system, and other planetary systems.

C3.1-0024-18 ANALYSES OF WAVE VARIATIONS IN VENUS' CLOUD-LEVEL ATMOSPHERE SIMULATED WITH A MIDDLE ATMOSPHERE GCM

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We use a Venus middle atmosphere general circulation model (GCM) to assess the role that propagating waves play in generating the cloud-level winds and temperature structure. Measurements at cloud altitudes are characterized by waves with a wide variety of periods and wavelengths, including gravity waves, thermal tides, Rossby waves, and Kelvin waves. However, the origin and importance of different waves, their interactions, and their variability over time are not well understood. We have developed a middle atmosphere model, based on the FMS code, with a lower boundary raised relative to the surface to just below cloud altitudes (40 km altitude or 4 x 105 Pa), to focus on the dynamics of the cloud-level atmosphere. The model upper boundary altitude is around 95 km (3 Pa). In these simulations, we use a Newtonian cooling radiation scheme, based on the Held-Suarez formulation for relaxation of temperature to a specified radiative equilibrium. Since the lower atmosphere is not simulated directly in this model we have introduced a simple linear friction within the first 2 km from the lower boundary to maintain zonal and meridional winds within observed values. We simulate waves which are assumed to be propagating upwards from the lower atmosphere by introducing wave forcing near the lower boundary of the model. In this study, we investigate the effects of propagating Kelvin and Rossby waves. We perform sensitivity tests in which we modify wave forcing parameters, to determine the influence of the different waves on the cloud-level atmosphere. We validate our results by comparison with available observations, including probe measurements and observations from the Venus Express and Akatsuki missions.

C3.1-0026-18 THE ESCAPE OF O AND C FROM THE EARLY MARTIAN ATMOSPHERE DUE TO ION PICK UP

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We present loss rates of O and C from the early Martian atmosphere due to ion pick up for four points in time in its history corresponding to 1, 3, 10, and 20 times the present solar EUV flux. Based on density profiles of the background atmosphere of O and C and on the profiles of suprathermal O and C produced by dissociative recombination, ionization rates are estimated and the trajectories of these newly created ions are calculated by means of a hybrid code, taking into account the interaction with the magnetized solar wind. The impact rate of ions entering the atmosphere as well as the ion escape rates are determined.

Moreover, we compare these ion loss rates to the corresponding rates of suprathermal O and

C. We found that ion pick up loss becomes comparable with neutral escape rates and that the former dominates the escape for 20 EUV. This suggests that up to about 1 Gyr after Mars' origin, the main loss mechanism is ion pick up process, whereas loss due to suprathermal atoms was more efficient during later times.

C3.1-0027-18 VOLATILE ORGANIC COMPOUNDS STABILITY AT EXOPLANETARY ATMOSPHERES

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The last decades of exoplanet research have revealed that exoplanets are very common and diverse in their orbital and bulk properties. With the possibility of obtaining spectra of the atmosphere of exoplanets now on the technological horizon, characterizing the atmospheres of extrasolar planets is a new frontier in exoplanetary science. There has been a growing interest on determining what properties of atmospheric chemistry are indicative of the presence of a biosphere. Some molecules, like molecular oxigen and ozone have been proposed as possible determining evidence of the presence of life; however, their detectability fluctuates, and they are capable of being produce abiotically, leading to the possibility of false positives. Species such as toluene, isoprene and other terpenoids are reactive volatile organic compounds (VOCs). They are emitted in significant amount by trees and other vegetations. Also, it can be quite reactive under atmospheric conditions, with short chemical lifetimes (minutes-hours). So, the emission of biogenic VOCs can play an important role in the photophysics and photochemistry of the atmosphere, affecting the oxidative capacity of the atmosphere. To understand the molecular stability of VOCs in the atmosphere, we have measured the absolute photoionizing cross-section of these molecules, using an ionizing chamber and ion-trap spectrometer, with UV, EUV and soft X-ray radiation (3-300 eV) from the Toroidal Grating Monochromator (TGM) beamline of the Brazilian Synchrotron Light Laboratory (LNLS), to simulate the radiation field of different types of stars and astrophysical situations. The ionizing chamber has four ion-collectors, two guard-electrodes, a repeller and a pair of secondary electron deflectors in a cylindrical symmetry. We used a Logarithmic Ammeter to measure ion current. It was determined the optimized voltage of the ion collector as 20 V from the plateau of ion current versus applied potential curve, through the ionization of argon, nitrogen and xenon with pressures between 10−8 and 10−6

torr. In our preliminary results, we have determined photoionizing cross-section of toluene at energies of 100 eV and 280 eV produces. Also, these results sugest that the photofragmentation of toluene at these energies produces high rates of double ionizied fragments.

C3.1-0028-18 PHOTOCHEMISTRY IN SATURN'S RING-SHADOWED ATMOSPHERE: PHOTOCHEMICAL AND HAZE PRODUCTION

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After 13 years of observing Saturn, Cassini explored for nearly a half Saturnian year. During this epoch, in addition to seasonal solar inclination changes, the ring shadow has moved from covering much of the northern hemisphere to covering a large swath of the southern hemisphere. The intensity of both ultraviolet and visible sunlight penetrating through the rings varied depending on Saturn's axial tilt relative to the Sun and the optical thickness of each ring system, i.e. the rings act like semi-transparent venetian blinds. This effect magnifies the effect of axial tilt alone and acts to turn off photochemistry and haze generation, an effect seen with the presence of a bluish northern atmosphere in 2004 and color change to blue in the southern hemisphere after equinox. We report on the impact of the oscillating ring shadow, seasonal axial tilt, and solar flux, on photochemistry of hydrocarbons and phosphine in Saturn's stratosphere and upper troposphere. The impact on the abundance of long-lived photochemical products leading to haze formation and on disequilibrium species is explored. We will also present analysis of Cassini's CIRS, UVIS, and VIMS datasets that provide an estimate of the evolving haze content. Specifically, we will examine how the region inside Saturn's famous hexagonal jet stream evolves over time from a relatively clear atmosphere to hazy atmosphere and how the jet stream acts like a barrier to transport, thus isolating Saturn's north polar region from outside influences. Lastly, an estimate of the impact of ultraviolet ring-shine on photochemistry is provided.

The research described in this paper was carried out in part at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

C3.1-0029-18 SULFURIC ACID VAPOR ABSORPTION AT MILLIMETER WAVELENGTHS: IMPLICATIONS FOR VENUS OBSERVATIONS

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Powerful radio telescope arrays such as the Atacama Large Millimeter/Submillimeter Array (ALMA) can be valuable tools for measuring the millimeter-wavelength emission of Venus. Past observations from such arrays have indicated significant diurnal variations in observed brightness temperature. Proper interpretation of this variation in brightness requires the development of radiative transfer models informed by laboratory measurements of gas absorption under Venus conditions. To this end, a laboratory campaign has been undertaken to characterize the opacity of sulfuric acid vapor at millimeter wavelengths. The highest abundance of sulfuric acid vapor at Venus is found in the sub-cloud region, so the laboratory measurements have been carried out at conditions close to those found in this region. Absorption measurements are made using a stainless steel, gold-plated semi-confocal open resonator which is housed in a pressure vessel. This configuration is itself housed in a temperature chamber capable of reaching temperatures relevant to the sub-cloud region of Venus. Measurements of sulfuric acid vapor absorption pressure-broadened by up to 3 bars of carbon dioxide between 2 mm and 4 mm wavelengths have been made at 533 and 550 Kelvins. Multiple sources of error in thes measurement have been taken into account to determine the effective sensitivity of the system. Initial results suggest that sulfuric acid vapor absorption at millimeter wavelengths follows a collisionally-broadened Van Vleck-Weisskopf lineshape model. This lineshape model relies on measured and calculated rotational lines tabulated in the JPL Spectral Line Catalog. In contrast, the centimeter-wavelength absorption of sulfuric acid vapor as measured by Kolodner and Steffes (1998) is higher than that predicted by lineshape theory, and a best-fit expression had to be developed to accurately model it. This suggests the possibility that the microwave absorption of sulfuric acid is similar to that of water, consisting of contributions from the spectral lines of the molecule and a continuum absorption feature. Future measurements in this laboratory campaign will determine the absorption of sulfuric acid vapor between 7.5 mm and 1 cm to form a more accurate opacity model. This data can be combined with previous data on the millimeter wavelength opacity of sulfur dioxide (Bellotti and Steffes 2015) to develop accurate radiative transfer models for interpretation of results from radio telescopes and provide further insight into the aforementioned variability of millimeter-wavelength emission from Venus.

C3.1-0030-18 PROPOSAL ON THE DEVELOPMENT OF A LASER RADAR UTILIZED TO DETECT MAR'S DUST AEROSOL

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Sandstorms on Mars are an important kind of atmospheric phenomenon. In the growing boom of Mars exploration, the monitoring and scientific research of the sandstorm climate is of great significance. In this paper, the development plan of micro laser radar for detection of dust aerosols from a Mars orbiter has been outlined. Compared with the telemetry of visible light camera, it can not only collect information for the origin of sandstorm and its spreading, but also obtain the detailed data for dust aerosols including column concentration, particle size distribution, total amount of dust, and so on. In the schematic design of the radar, under relatively low power consumption(12W), its detection sensitivity of aerosol size, spatial resolution and vertical resolution of aerosol reach 53nm, 1km, 30m, respectively.

C3.1-0031-18 SPECTRO-POLARIMETRY OF PLANETARY ATMOSPHERES: RADIATIVE TRANSFER SIMULATIONS AND INSTRUMENT CONCEPT

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Planetary atmospheres are characterized based on their gaseous composition as well as the aerosols or clouds in the atmosphere. Spectroscopy generally gives information about the gaseous composition of the planets whereas polarimetry is known to be sensitive to the scatterer present in the atmosphere (like aerosols and clouds). Combined together, the spectropolarimetry gives complete information about the atmosphere of a planet. We are developing an Acousto-Optic Tunable Filter (AOTF) based near - infrared (1 - 1.7 µm) spectro-polarimeter for ISRO's upcoming Mars and Venus missions. We also aim to observe Earth's spectropolarimetric signatures from a Geo-stationary platform.

The atmosphere of Mars contains tiny amounts of water vapour which combined with ubiquitous Martian dust, forms clouds at high altitudes (30-50 km). We show with the help of a radiative transfer model as to how a limb viewing spectro-polarimeter can reveal the process of condensation in Martian atmosphere. We show the polarization signatures of dust and clouds and expected level of water vapour absorption in Martian limb. Since Mars atmosphere is largely un-explored as far as polarization studies are concerned so we expect a good scientific gain from such an experiment. In the similar context, we intend to study the scattered polarization from Venus' sulphuric acid clouds. We aim to study the polarization within a strong CO2 absorption band which would possibly provide information about the vertical structure of the clouds in Venusian atmosphere. We also plan to study the spectro-polarimetric signatures of Earth from a Geo-stationary platform. This study would provide us with a global view of scattered polarization from Earth. Since Earth is a known habitable planet with an active - weather system, it would be possible to study the bio-signatures such as O2 and H2O and also characterize the changing cloud cover with the help of scattered polarization. This study would prove to be a benchmark for the future characterization of habitable zone extra-solar planets.

In this paper, we present the spectro-polarimetric (simulated) signatures from Mars, Venus and Earth atmosphere along with unique concept design of the instrument, which is under development at ISRO.

C3.1-0032-18 INFLUENCE OF THE STRUCTURE AND COMPOSITION OF MARTIAN SURFACE ON VISIBILITY THE FEATURES OF ATMOSPHERIC TRACE GASES IN MID-INFRARED SPECTRA - THE RESULTS OF NUMERICAL SIMULATION AND ANALYSIS OF SOME AVAILABLE PICTURES OF MARS

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The presented work is directly connected with the measurements of the stereoscopic camera CASSiS (The Colour and Stereo Surface Imaging System) a part of payload of ExoMars Trace Gas Orbiter (TGO) of the ESA mission in which researchers and engineers from SRC - PAS are engaged. The CASSiS camera will give us the opportunity of analysis the structure and locations on the surface of Mars of the possible sources of trace gases e.g. methane. Identification and monitoring of minor species in the atmosphere are performed from orbiter by spectrometric instruments (e.g. NOMAD, ACS). The existence of trace gases, in particular methane on Mars is a topic of special interest because of their influence on climate and as a potential signature of past or present life development on Mars. There are various types of features on Martian surface that could be connected with methane release e.g. mud-volcanos in Utopia and Acidalia, Gusev Crater, Arabia Terra, Valles Marineris and rims of big craters. The processes making possible emission of methane occur in diverse places on Mars in sedimentary and igneous rocks and probably are originated in different ways. Maybe in high temperature geothermal reactions or connected with ancient activity of micro-organism, during degassing of volcanic magma or in low-temperature processes in serpentinized rocks. The way of generation the trace gases depends on the structure and composition of the soil and on physical state of the atmosphere. The recorded spectra appear as a result of a combination of different light-matter interactions, such as scattering, reflection, absorption and emission. These processes may act several times, each in a way that depends on the composition, temperature and pressure of the atmospheric gases and on the physical and chemical parameters of the material of the surface, and dust in the atmosphere. The main issue in the interpretation of the measured Martian spectra is how to discriminate between surface and atmospheric contribution to the spectral features. The character of these features can change drastically according to specific conditions, for example because of variations in mineralogical composition and in dimensions of the grains. The elaborated model provides estimates of the spectral reflectance/emittance and total radiance from Martian surface and atmosphere in the Mid-infrared spectral range. We perform analysis of common effects of the surface and atmosphere contains trace gases on radiance spectra. We take into account the spectral signatures of the surface and the atmospheric trace gases (first of all methane) in various physical conditions. From the pictures done by HIRISE instrument we select the examples of diverse shapes of the surface with various subtle structures of the soils. These various kinds of surfaces are spectrally described by an appropriate reflectance or emissivity of minerals and rocks (e.g. the serpentinized rocks) for selected locations. Spectral reflectance and emissivity of the modelled regions we calculate from n,k with Mie and Hapke theories or we use the values measured in the laboratory. The physical properties of the atmosphere is characterized by its thermodynamical parameters and absorbing and scattering properties.We discuss the possible visibility of spectral features of methane in radiance spectra. We hope that interpretation of data from TGO will benefit from our simulation of the spectra we expect will be acquired by NOMAD and ACS.

C3.1-0033-18 ENVISION: UNDERSTANDING WHY OUR MOST EARTH-LIKE NEIGHBOUR IS SO DIFFERENT

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Why are the terrestrial planets so different? Venus should be the most Earth-like of all our planetary neighbours: its size, bulk composition and distance from the Sun are very similar to those of Earth. Its original atmosphere was probably similar to that of early Earth, with abundant water that would have been liquid under the young sun's fainter output. Even today, with its global cloud cover, the surface of Venus receives less solar energy than does Earth, so why did a moderate climate ensue here but a catastrophic runaway greenhouse on Venus? How and why did it all go wrong for Venus? What lessons can be learned about the life story of terrestrial planets in general, in this era of discovery of Earth-like exoplanets? Were the radically different evolutionary paths of Earth and Venus driven solely by distance from the Sun, or do internal dynamics, geological activity, volcanic outgassing and weathering also play an important part?

Following the primarily atmospheric focus of Venus Express, we propose a new Venus orbiter named EnVision, submitted in October 2016 in response to ESA's M5 call for Medium-size missions for its Science Programme, for launch in 2029. EnVision will focus on Venus' geology and geochemical cycles, seeking evidence for present and past activity. The payload comprises a state-of-the-art S-band radar which will be able to return imagery at spatial resolutions of 1 - 30 m, and capable of measuring cm-scale deformation; this is complemented by subsurface radar, IR and UV spectrometers to map volcanic gases, and by geodetic investigations.

C3.1-0034-18 PROPAGATION OF TRANSIENT PERTURBATIONS INTO A PLANET'S EXOSPHERE: MOLECULAR KINETIC SIMULATIONS

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Atmospheric perturbations such as gravity waves, or perturbations due to the atmospheric interaction with an incident plasma, can affect the composition and the structure of planets' upper atmosphere. Our goal is to study how these perturbations dissipate and propagate into an atmosphere, in particular in the exobase region, which is the transition region between the collisional and collisionless regions. We present results of molecular kinetic simulations describing the evolution of density and temperature in a multi-component atmosphere, in the case of Mars in particular. Results show that atmospheric perturbations' propagation is dependent on the collision rate, and therefore propagates differently depending on the species.

SPACE STUDIES OF THE UPPER ATMOSPHERES OF THE EARTH AND PLANETS INCLUDING REFERENCE ATMOSPHERES (C)

PLANETARY UPPER ATMOSPHERES, IONOSPHERES, AND MAGNETOSPHERES (C3.2)

C3.2-0001-18 MAGNETOSPHERE OF MERCURY: THE VIEW FROM MESSENGER

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MESSENGER's three close fly-bys and 4 years of observations from orbit have revealed that Mercury possesses a highly dynamic and complex magnetosphere. Despite the low altitude of its magnetopause, induction currents in Mercury's highly conducting iron core resist compression of the dayside magnetosphere by the solar wind, even during coronal mass ejection impacts. However, the dayside magnetosphere sometimes disappears during periods of strong southward interplanetary magnetic fields. Mercury's surface-bounded exosphere is maintained by sputtering and other surface interactions that eject neutrals from the regolith. Prospects for understanding Mercury's coupled magnetosphere - exosphere - solid planet as a system with the measurements to be returned by ESA's BepiColombo mission in 2025 will be discussed.

C3.2-0002-18 THE SOLAR WIND INTERACTION WITH MERCURY

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The magnetosphere of Mercury has many interesting features. It is small compared to Earth's, making it respond to solar wind changes on short time scales. The planet also has a tenuous atmosphere, where the exosphere reaches all the way down to the surface. Another factor that will affect the solar wind interaction is the large core of the planet. Here we model the magnetosphere of Mercury using a hybrid plasma solver (ions as particles, electrons as a fluid). The solar wind interaction with Mercury is studied and we present the general morphology of the plasma interactions, both close to the planet and on a larger scale, for different solar wind conditions. In particular we also examine particle precipitation and the turbulent foreshock region. We compare with earlier modeling work, with observations by MESSENGER and discuss implications for BepiColombo.

C3.2-0003-18 WAVE IMPACTS ON THE VENUS UPPER ATMOSPHERE (ABOVE THE CLOUD TOPS): DATASETS AND RECENT GCM MODEL SIMULATIONS

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The upper atmosphere of Venus has been observed for many decades by multiple means of observations (e.g. ground-based, orbiters, probes, fly-by missions). The European Space Agency Venus Express (VEX) orbiter and more recently the Japanese mission, Akatsuki, have been providing illuminating observations of the Venusian atmosphere. From past and present observations there is evidence of wave activity contributing to Venus' atmospheric dynamics and variability. Systematic studies with theoretical models can help better understand the underlying physical processes. The presented work will discuss parameter space guided by observations for characterizing planetary-scale waves (Rossby and Kelvin) and small-scale gravity waves, and their implementation within numerical models. For the first time, a whole atmosphere nonlinear gravity wave parameterization of Yiğit et al. [2008, JGR] is implemented into the Venus Thermospheric General Circulation Model (VTGCM) [Bougher et al. 1988, Icarus; Brecht et al. 2011, JGR]. In conjunction, model simulations utilizing the parameter space will be conducted, thereby demonstrating the impact of planetary waves and gravity waves upon Venus' upper atmosphere.

C3.2-0004-18 WAVE STRUCTURES IN THE UPPER ATMOSPHERE OF MARS AND VENUS AS SEEN BY THE RADIO SCIENCE EXPERIMENTS ON MARS EXPRESS AND VENUS EXPRESS

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Atmospheric waves play a crucial role in all stably stratified planetary atmospheres. They contribute significantly to the redistribution of momentum, energy and dust between the different atmospheric regions.

In the Martian thermosphere, thermal tides have been observed e.g. by radio occultation or accelerometer measurements on MGS. Recently, the NGIMS instrument on MAVEN reported gravity waves in the thermosphere of Mars. On Venus, thermospheric waves have been observed by in situ measurements in the polar region, and by the VIRTIS instrument on Venus Express.

The radio science experiment VeRa on Venus Express used the radio subsystem of the spacecraft to retrieve refractivity profiles in the atmosphere and ionosphere of Venus. Venus Express was equipped with a dedicated onboard ultrastable oscillator, which allowed to conduct the measurements in a oneway radio link mode. The refractivity profiles are used to retrieve profiles of temperature, pressure and neutral number density in the troposphere and mesosphere of Venus (40 - 90 km) and electron density profiles in the ionosphere. More than 900 profiles with a high vertical resolution could be retrieved between 2006 and 2014.

The Mars Express Radio Science Experiment (MaRS) uses the same radio occultation technique to retrieve atmospheric profiles in the lower atmosphere of Mars (a few hundred metres above the surface to 40 km) and electron density profiles in the ionosphere. MaRS uses a twoway radio link mode, stabilized by a hydrogen maser on Earth. So far, the MaRS data set comprises more than 800 profiles and the mission is still ongoing.

Both experiments use two coherent frequencies (XS-band) for their investigations. These two frequencies are required to discriminate between plasma density fluctuations in the ionosphere and Doppler related frequency shifts caused by spacecraft movement.

Planetary scale waves have been detected in the Martian ionosphere. These large scale waves propagate from the lower atmosphere upwards and lead to altitude changes of the main ionospheric peaks as a function of planetary longitude. These waves can be identified as thermal tides influenced by the Martian topography.

Small scale wavelike structures have also been detected in the ionosphere of Mars and Venus below the main ionospheric layers and in the topside of the ionosphere. The observed features can be classified by a careful analysis of the observed electron density fluctuations in combination with simulations based on ray tracing methods and comparisons with atmospheric model predictions. An ionospheric time stepping model (Ion-A2) is used to study the observed electron density fluctuations.

Acknowledgments

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C3.2-0005-18 MODELING OF OBSERVATIONS OF THE OH NIGHTGLOW IN THE VENUSIAN MESOSPHERE

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Airglow emissions, such as NO and O2, have been observed previously on Venus. Airglow emissions provide insight into chemical and dynamical processes that control the composition and energy balance in the upper atmosphere. The OH airglow emission has been observed previously only in the Earth's atmosphere which was discovered (Meinel 1950) in high-resolution spectra of the Earth's atmosphere and were successfully modeled by Pickett et al. (2006). Similarly, Venus airglow emissions have been unambiguously detected in the wavelength ranges of 1.401.49 and 2.63.14 m in limb observations by the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) on the Venus Express (VEX) spacecraft. These emissions are attributed to the OH (20) and (10) Meinel band transitions as well (Piccioni et al., 2008).

We have used a 1-D photochemical model derived from the Caltech/JPL KINETICS model (Parkinson et al., 2010; Pickett et al., 2006; Allen et al., 1981) and the Venus Thermospheric General Circulation Model (VTGCM) 3-D finite difference hydrodynamic model of Venus' upper atmosphere (Bougher et al., 1988) to model the OH nightglow in the Venusian mesosphere. This is done by treating the vibrationally excited states of OH for v = 1- 9 as separate chemical species, analogous to Pickett et al. (2006) for the Earth. Two chemical pathways for production are considered and vibrationally OH is produced via both these reactions. Subsequently, collisional quenching of OH proceeds via a single quantum collisional cascade, where CO2 is the dominant (only) quenching agent considered.

Our model calculations predict a layer that is very consistent with the analysis of VEx VIRTIS observations. We discuss the results of modeling the OH nightglow and compare with observations, also making connections with the O2 nightglow (cf. Soret et al. 2011, 2012; Brecht et al., 2011)

C3.2-0006-18 STATISTICS AND ENERGETICS OF LIGHTNING ON VENUS

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The existence of lightning on Venus has been studied by numerous space missions for over 50 years. The Soviet Venera landers detected radio waves due to lightning during the descent of the landers and while on the surface. Venera 9 even detected an optical signature with its visible spectrometer. The Pioneer Venus (PVO) orbiter also detected radio waves determined to be from lightning, but only while on the nightside because of excessive noise in the electric antenna caused by the sun. These signals exhibited a decrease in amplitude at higher altitudes, implying a source from below, i.e. lightning in the clouds. Most recently, Venus Express (VEX) detected whistler-mode waves in the Venus ionosphere with its dual fluxgate magnetometer. The entire 8.5+ year dataset has been analyzed with over 2200 signals identified. Signal lengths range from one second to more than one minute. These longer signals are likely due to multiple bursts as the spacecraft passed over a storm. The majority of the signals were detected when VEX was around 250 km, approximately 3% of the time it was near this altitude. In order to demonstrate that the whistlers detected by VEX originate below the ionosphere, we first need to calculate the Poynting vector, which is difficult for two reasons: VEX had no electric field sensor and it did not take measurements of the electron density in the lower ionosphere where these signals were observed. Thus, we have employed the VIRA electron density model, which allows us to estimate the Poynting flux of the waves. Since the model was developed during the PVO era, when the solar EUV was more intense, we have scaled it to match the solar cycle conditions during the VEX campaign. With the three components of the magnetic field and an estimate of the electron density, we can statistically show that the whistler-mode waves observed by Venus express do indeed originate from the atmosphere below. Next, we estimate the energy of the bursts and compare Venus lightning rates to terrestrial lightning and rates.

C3.2-0007-18 OVERVIEW OF THE OBSERVED VENUS SOLAR WIND INTERACTION

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The Venus-solar wind interaction was initially probed in detail by the Pioneer Venus Orbiter, but the combination of the PVO orbit and the time period of the mission left us with a somewhat ideal but biased view favoring a robust ionospheric obstacle picture. The more recent Venus Express mission provided an opportunity to probe both unexplored regions of the interaction as well as conditions when the ionosphere was weakened by low solar activity. This provided in effect a natural 'experiment' departing from the nearly classical unmagnetized planet interaction. We describe some of the contrasts and similarities revealed by the different timings and circumstances of these two missions.

C3.2-0008-18 ASYMMETRIES IN THE MAGNETOSHEATH FIELD DRAPING ON VENUS' NIGHT SIDE

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Draping features of the interplanetary magnetic field around non-magnetic bodies, especially Venus, have been studied in detail in numerical simulations and also from observations. Existing analytical and numerical work for non-perpendicular IMF and solar wind velocity direction show a kink in the draped fieldlines in the near magnetosheath on the quasi-parallel side of the bow shock. Here, long-term magnetic field data from the Venus Express mission (2006-2014) are analyzed in the near night-side region of the magnetosheath, searching for differences in the draping pattern between the quasi-paralleland quasi-perpendicular side of the shock. From these MAG data, the kink in the fieldlines occurring only on the quasi-parallel side is clearly identified from the change of sign in the field component parallel to the solar wind velocity. Furthermore, an asymmetry in the deflection of the out-of-plane field component due to the slipping of the fieldlines over the planetary obstacle is also found, which confirms predictions from numeral studies and from earlier work.

C3.2-0009-18 HIGHLIGHTS FROM IMAGING ULTRAVIOLET SPECTROSCOPY OF THE MARS ATMOSPHERE WITH MAVEN/IUVS

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The Mars Atmosphere and Volatile EvolutioN (MAVEN) mission's Imaging Ultraviolet Spectrograph (IUVS) observes Mars in the far and mid ultraviolet (110-340 nm), investigating lower and upper atmospheric structure and indirectly probing neutral atmospheric escape. The instrument is among the most powerful spectrographs sent to another planet, with several key capabilities: separate Far-UV Mid-UV channels for stray light control; a high-resolution echelle mode to resolve deuterium and hydrogen emission; internal instrument pointing and scanning capabilities to allow complete mapping and nearly continuous operation; and optimization for airglow studies. After two Earth years in orbit (one Mars year), IUVS has assembled a large quantity of data and provided insights on present-day processes at Mars including dayglow, nightglow, aurora, meteor showers, clouds, and solar-planetary interactions. In this presentation, we will highlight key results obtained by IUVS, including: (1) mapping of thermospheric composition, structure, and variability; (2) long-term tracking of H escape, O escape, and D/H ratios, and (3) detection and mapping of diffuse auroral emission. We will present an overview of these results and a discussion of their implications for understanding Mars atmospheric dynamics and evolution.

C3.2-0010-18 MARS NITRIC OXIDE NIGHTGLOW AND ITS IMPLICATIONS FOR THE VARIABLE UPPER ATMOSPHERE CIRCULATION

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On the dayside thermosphere of Mars, solar extreme ultraviolet radiation dissociates CO2 and N2 molecules. O(3P) and N(4S) atoms are carried by the day-to-night hemispheric transport. They descend in the nightside mesosphere, where they can radiatively recombine to form NO(C2). The excited molecules rapidly relax by emitting UV photons in the and bands. These emissions are thus indicators of the N and O atom fluxes transported from the dayside to Mars' nightside and the descending circulation pattern from the nightside thermosphere to the mesosphere, as well as impact of waves and/or tides in this region (e.g., Stiepen et al., 2017).

These emission have been discovered at Mars by the Mars Express SPICAM instrument (Bertaux et al., 2005 ; Cox et al., 2008 ; Gagné et al., 2013 ; Gérard et al., 2008 ; Stiepen et al., 2015) and modeled by the MGTCM (Bougher et al., 1990) and the LMD-MGCM (González-Galindo et al., 2009). Recently, the IUVS instrument on board MAVEN spacecraft accumulated a large dataset of nightside disk images and vertical limb scans (Stiepen et al., 2017) during two consecutive martian years covering several seasonal conditions. For the first time, observations cover a full night disk, extending previous studies in both time and space coverage.

We will present results concerning the variability of the brightness and altitude of the emission with season (solar longitude and latitude) and geographical position (longitude, local time). We will present results on local time behavior in polar regions, especially a dawn-dusk asymetry in the emission. We show the possible impact of atmospheric waves structuring the emission longitudinally and indicating a wave-3 structure in Mars' nightside mesosphere close to the equator. We will also show the results of a search for local time control of the wave-3 pattern in equatorial emissions. We provide possible interpretation for local and global changes in the mesosphere dynamics. In particular, quantitative comparison with calculations of the LMDMGCM show that the model globally reproduces the trends of the NO nightglow emission and its seasonal variation but also shows large discrepancies that can be interpreted as a computed transport too efficient toward the night winter pole.

C3.2-0011-18 DATA AND MODEL COMPARISONS OF THERMOSPHERIC DENSITY STRUCTURES NEAR THE DAWN AND DUSK TERMINATORS AT MARS

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Using 1.5 Mars years of neutral density data collected by the neutral mass spectrometer on the NASA MAVEN spacecraft, we reconstruct an average Martian thermosphere between 160 and 220 km, 35ºS-35ºN latitude with a local time resolution of 15 minutes (3.75º). The results indicate the presence of several stationary features in both atomic oxygen, argon, and carbon dioxide number densities near the dusk and dawn terminators. The most significant feature near dusk is centered at a local solar time of 19.5 and has a magnitude of between 50-100% relative to the surrounding background densities. Near dawn, a night-time density enhancement occurs at a local solar time of 5 and has an amplitude between 50-200% relative to the surrounding densities. In both cases, the enhancements are observed during different seasons and across all altitudes analyzed in this study. The enhancement amplitude increases with height in most cases. The observed enhancements are interpreted to be a result of night-time adiabatic heating caused by converging winds. The approximate location of these large-scale features agree with past predictions made by global circulation models. In particular, the MGITM model predicts a prominent post-dusk enhancement consistent with that observed in the statistical analysis of MAVEN data. In this paper, we compare the MGITM modeling results and observations of neutral density enhancements in the Martian night-side.

C3.2-0012-18 GRAVITY WAVES IN THE MARTIAN UPPER ATMOSPHERE AS OBSERVED BY MAVEN AND STUDIED BY GENERAL CIRCULATION MODELS

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Gravity waves (GWs) are ubiquitous features of all known planetary atmospheres. They have been extensively studied in Earth's upper atmosphere [Yiğit and Medvedev, 2015] and their importance for the Martian atmospheric dynamics is increasingly appreciated [Medvedev et al., 2013]. GWs are primarily produced via weather processes in the lower atmosphere. They propagate upward and dissipate due primarily to nonlinear interactions, molecular diffusion and thermal conduction in the Martian middle and upper atmosphere. Recent observations conducted by the Mars Atmosphere Volatile EvolutioN (MAVEN) mission demonstrate substantial GW activity in the Martian thermosphere, which can be studied by global scale models. This work reviews past and recent observations of GWs in the upper atmosphere [e.g., Yiğit et al, 2015] and uses three-dimensional general circulation modeling technique, incorporating a whole atmosphere GW parameterization [Yiğit et al, 2008], to interpret these observations.

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C3.2-0013-18 COMPARISONS BETWEEN MAVEN/NGIMS THERMOSPHERIC WINDS AND M-GITM MODEL SIMULATIONS: PROCESSES DRIVING WINDS

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The MAVEN (Mars Atmosphere and Volatile Evolution) mission is currently providing systematic observations of the Martian upper atmosphere (Jakosky et al., 2015, SSR). The NGIMS (Neutral Gas and Ion Mass Spectrometer) instrument on MAVEN is producing a new dataset of thermospheric neutral wind measurements (e.g., Bougher et al., 2016, Fall AGU). These are the first in-situ observations of thermospheric winds at Mars, and as such, provide a unique opportunity to add to our understanding of the dynamics of the Martian upper atmosphere. Furthermore, when these wind observations are compared to model simulations, the processes driving the winds (and their variations) in the upper atmosphere can be examined and better understood. Here, the Mars Global Ionosphere-Thermosphere Model (M-GITM) (Bougher et al., 2015, JGR) is utilized for these data-model comparisons.

NGIMS has the capability to measure horizontal winds in-situ along orbit passes from periapsis up to 200 km (Bougher et al., 2016). With this method, wind velocities can be determined for both cross-track and along-track flow (relative to the spacecraft ram direction). Horizontal winds can be measured up to 350 m/s with an accuracy of 30 m/s for cross-track winds and 100

m/s for along-track winds. Using spacecraft geometry, cross-track and along-track velocities are then converted to zonal and meridional velocities. Examining mean (longitudinally averaged)

winds over time allows seasonal and other trends in thermospheric winds to be more readily observable. Currently, the neutral wind datasets (i.e., mostly 5-orbit campaigns occurring once each month) span over half a Martian year.

A preliminary comparison with M-GITM simulations has shown that the NGIMS wind measurements in many cases do not match the simulated thermospheric winds in speed, direction, or both. The M-GITM model is currently primarily driven by solar EUV forcing at thermospheric altitudes. Thus, it is likely that for cases where simulated and observed winds are similar, EUV heating is the primary mechanism driving the thermospheric winds. Otherwise, non-solar driven processes may be responsible. In fact, gravity waves are thought to have large thermal and dynamical impacts in the thermosphere, and are expected to significantly modify the thermospheric structure and circulation (e.g. Medvedev and Yiğit, 2012, GRL). Presently, a whole atmosphere spectral nonlinear gravity wave parameterization (Yiğit et al., 2008, JGR) is being incorporated into M-GITM and tested to identify the relative importance of gravity wave impacts (i.e., momentum and energy deposition) during these MAVEN wind campaigns. Initial gravity wave simulations will be presented and compared to solar only driven simulations conducted previously.

C3.2-0014-18 ELEVATED ATMOSPHERE ESCAPE OF HYDROGEN FROM MARS INDUCED BY HIGH ALTITUDE WATER: DUST STORM INFLUENCES

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Seasonal variability in Mars upper atmospheric hydrogen has been shown to be responsible for a 10-100x increase in escape of H to space in Mars Southern Summer. Competing explanations for the enhanced escape include the presence of a thermospherically generated hot hydrogen component, required by some observations of the corona, and an increase in the altitude of the hygropause, which can allow water at altitude to supply H to the upper atmosphere much more efficiently in Southern summer. In previous work, we explored the high-altitude water hypothesis using a 1D photochemical model. Here, we extend this modeling work to incorporate more realistic conditions for Mars Southern Summer, surveying a variety of dust conditions from clear to global dust storm. We will present an analysis of the competing influence of dust opacity, which tends to shield lower atmospheric water, and atmospheric heating, which allows water to penetrate to higher altitudes. In particular, we will address the question of whether the 2007 global dust storm caused a large enhancement in H escape, above and beyond what would be expected in Southern Summer alone.

C3.2-0015-18 IN-SITU OBSERVATION OF MARTIAN NEUTRAL EXOSPHERE: RESULTS FROM MENCA ABOARD INDIAN MARS ORBITER MISSION

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MENCA is a quadrupole based neutral mass spectrometer, working in mass range 1-300 amu with unit mass resolution, aboard the first Indian Mars Orbiter Mission (MOM). The analysis of the data from MENCA has revealed unambiguous detection of the three major constituents which are amu 44 (CO2), amu 28 (which has both contributions from CO and N2) and amu 16 (atomic O), as well as a few minor species. Since MOM is in a highly elliptical orbit, the MENCA observations pertain to different local times, in the low-latitude region. MENCA observations have revealed significant orbit-to-orbit variability in densities of the three constituents. During the evening hours, the transition from CO2 to O dominated region is observed near 270 km, which is significantly higher than that at sub-solar point. The mean evening time exospheric temperature derived using these observations is 271±5 K. These observations corresponding to the Martian evening hours would help to provide constraints to the thermal escape models. We have also studied the altitude profiles of argon-40 (Ar) in the Martian exosphere using MENCA from four orbits during December 2014 (Ls = 250-257°), when MOM's periapsis altitude was the lowest. The upper limit of Ar number density corresponding to this period is 5 × 105 cm3 (250 km), and the typical scale height is 16 km, corresponding to an exospheric temperature of 275 K. However, on two orbits, the scale height over this altitude region is found to increase significantly making the effective temperature >400 K. Neutral Gas and Ion Mass Spectrometer (NGIMS) observations on the Mars Atmosphere and Volatile Evolution (MAVEN) mission also indicate that the change in slope in Ar density occurs near the upper exosphere (around 230- 260 km). These observations indicate significant suprathermal CO2 and Ar populations in the Martian exosphere. Significant wave-like perturbations are observed but only on certain days when suprathermal population is seen. These results will be presented and discussed along with some new analysis.

C3.2-0016-18 LATEST RESULTS FROM THE MAVEN RADIO OCCULTATION SCIENCE EXPERIMENT (ROSE)

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A new observing capability was acquired by MAVEN for its extended mission - radio occultations. Observations by the MAVEN Radio Occultation Science Experiment (ROSE) provide vertical profiles of ionospheric electron density with vertical resolution on the order of 1 km, vertical range that can extend to 1000 km altitude, and measurement uncertainties on the order of 3000/cm3. Typically, two pairs of occultations are observed during each week in which occultations are geometrically possible. This cadence is limited by MAVEN's allocated DSN time.

MAVEN performs two-way radio occultations at X-band frequencies on occultation ingress and egress. This capability was demonstrated in a trial campaign in February 2016, and routine operations began in July 2016, shortly before the formal start of MAVEN's Extended Mission 2 in October 2016. Over 60 occultations have been observed to date. These observations are focused on the ionosphere, although data from which neutral temperature-pressure profiles can be obtained are also collected.

Radio occultation electron density profiles complement MAVEN's other ionospheric measurements, such as LPW electron densities, by covering altitudes below MAVEN's periapsis. The main ionospheric peak is usually below MAVEN's periapsis altitude and the lower ionospheric layer is always below MAVEN's periapsis altitude. Furthermore, these observations can provide an independent calibration for MAVEN's in situ density measurements. The MAVEN ROSE electron density profiles can be interpreted and analyzed in the context of simultaneous MAVEN observations of the solar irradiance, solar wind, and magnetospheric conditions, which will enhance research into how the state of the ionosphere is affected by these highly-variable external forcings. The topside ionosphere is of particular interest as a reservoir of escaping volatiles.

C3.2-0017-18 CHARACTERISTICS OF SOLAR X-RAY FLARES AND THEIR EFFECTS ON THE IONOSPHERE AND HUMAN EXPLORATION TO MARS: MGS RADIO SCIENCE OBSERVATIONS

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Responses of solar X-ray flares were observed in a layer of the Martian ionosphere at altitudes of 110 km from 35 electron density profiles obtained by radio science experiment onboard Mars Global Surveyor (MGS) during solar cycle 23. Of the 35 profiles recorded during flare periods, 10 were associated with X-class flares, 13 with M class, 10 with C class, and 2 with B class flares. Their flare E-peak densities vary with solar X-ray flux, Solar Zenith Angle (SZA), Solar Longitude (Ls), Universal Time (UT) and latitude. Ionospheric Electron Content (IEC) and E-peak electron production rates of these flare profiles are estimated in the E region ionosphere. We found a maximum increase of 200%, 140%, 90% and 20% in the time series of IEC for X, M, C and B-class flares respectively. The IEC of flare profiles also increase at high latitude region. The peak altitudes and peak densities of flare profiles behave like a Chapman layer at high SZA. The dependence of flare E-peak electron production rate with Ls is fitted by a sinusoidal function. We have also calculated biological doses 0.1 - 1.0 x 10-1, 1 - 8 x 10-3, 1

6 x 10-4 and 0.4-1 x 10-4 Gy for X, M, C and B-class flares respectively to study the human risk for exploration to Mars. Among 10 X-class flares X14.4 is a strong solar flare that gives highest dose, which is potentially lethal for humans.

C3.2-0018-18 PROCESSES DRIVING MARS ION ESCAPE VARIATIONS IN LIGHT OF BOTH MARS EXPRESS AND MAVEN MEASUREMENTS

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In this review talk we focus on the ion escape from Mars due to the solar wind interaction and do not consider processes and channels resulting in neutral escape. Mars Express ion measurements for more than a solar cycle (14 years) provide sufficient statistics to establish the dependence of the ion escape rate on the solar wind density, solar wind velocity, and solar UV flux as independent parameters. Also the ion escape rate variations due to position of magnetic anomalies with respect to the Sun can be established. The long duration of the Mars Express measurements provided opportunities to characterize the escaping ion fluxes during several rare extreme solar wind conditions. We compare the Mars Express findings with MAVEN results obtained for a shorter period.

The local acceleration processes resulting in ion escape are relatively well understood. The planetary ions are accelerated by the convective electric field, polarization electric field due to electron pressure gradients ("polar wind"), and the Hall electric field. However, what defines the total escape rates on the global scale is not clear. Is it the total energy transferred from the solar wind or the supply of ions from the ionosphere? Based on the review of the Mars Express and MAVEN measurements we attempt to answer these fundamental questions.

C3.2-0019-18 ON THE REPEATABILITY OF THE MAGNETICALLY CONTROLLED DENSITY STRUCTURES IN THE MARTIAN IONOSPHERE

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The Mars Advanced Radar for Subsurface and Ionosphere sounder (MARSIS) aboard the Mars Express spacecraft regularly detects the magnetically controlled density structures (MCDS) in the Martian ionosphere. In this paper, we examined the repeatability of these MCDS using long-term (more than a decade) MARSIS observations over a strong magnetic anomaly region. Instead of a conventional echogram analysis, we adopted a peak density echogram (PDE) analysis since the former may miss some vertical and oblique echoes if their peak frequencies are smaller than the frequency at which an echogram is constructed. The results of the present study suggest that the MCDS are in fact formed persistently on all dayside periapsis passes. However, clear discontinuities are observed on the hyperbola shape in a PDE display that appear at different locations on different orbital passes. In addition, the apices of the hyperbolas associated with an MCDS are observed at different latitudes on different orbital passes. From these results, we infer that the locations and shapes of MCDS are disturbed by some timevarying external factors so that some parts of the MCDS cannot give specular reflections. Nearly similar features are observed with the nightside MCDS but they occur only 60% of the passes. We surmise that wave dynamics associated with tides and gravity waves etc. might be responsible for altering the shape and location of MCDS, both on the dayside and nightside. The results of the present study are discussed in the light of the current understanding on the generation of MCDS.

C3.2-0020-18 MARTIAN MAGNETOTAIL TOPOLOGY WITH RESPECT TO UPSTREAM IMF

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The canonical picture of the magnetotail of unmagnetized planets consists of draped interplanetary magnetic fields (IMF) forming opposite-directed lobes, separated by the central plasma sheet. Mars possesses localized crustal fields, which make its magnetotail configuration more complicated. DiBraccio et al. [2018] shows that the Martian magnetotail has a twist from the expected location based on nominal IMF draping patterns. Magnetohydrodynamic (MHD) simulation results suggest that field lines connected to the planet that populate portions of the tail cause the twist. To validate the picture of a hybrid Martian magnetotail with observations, we compare the tail topology determined from MHD simulations and from data collected by the Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft, in particular how each topology responds to the upstream IMF. Despite limited data coverage, the high-occurrence rate pattern for open field lines varies similarly

w.r.t Eest/West IMF from MAVEN data and MHD simulations. It suggests that Martian crustal fields have a global effect on the magnetosphere configuration and supports the picture of a hybrid magnetotail at Mars.

C3.2-0021-18 OVERVIEW OF THE RESPONSES BY THE MARS UPPER ATMOSPHERE AND SPACE ENVIRONMENT TO THE SEPTEMBER 2017 SOLAR FLARE AND ICME EVENTS

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The deep Solar Cycle (SC) 23 minimum and the modestly active SC 24 maximum have produced generally weaker solar events and heliospheric conditions. Surprisingly, on September 10, 2017 late in the declining phase of SC 24, some of the strongest solar activity erupted from active region (AR) 12673, including an X-class solar flare and a fast coronal mass ejection (CME). Associated with this activity are the solar energetic particles (SEPs), which may be accelerated locally at the flare site or by the moving shock front propagating ahead of the CME. Although

AR 12673 was not centrally facing Mars (it was located about 67 degrees east in heliolongitude from the Sun-to-Mars line), the solar events impacted the local space weather environment. To name a few, some of the effects include flare heating of the upper atmosphere, flare-related enhancements of ion and neutral densities, high fluxes of SEP ions and electrons impacting the atmosphere and the surface, bright emissions of a diffuse (global) aurora, deep draping of the interplanetary magnetic field, and compression of the ionosphere due to the impact of the ICME and related shock. In this presentation we will give an overview of the observations at Mars obtained from various Mars missions, including MAVEN, MSL, and MEX. Numerical results from the Wang-Sheeley-Arge (WSA)-Enlil-cone model system together with observations at Earth/L1 and STEREO-A will also be presented to provide a more global heliospheric context of the event period.

C3.2-0022-18 MHD SIMULATIONS OF THE IMPACT OF THE SEPTEMBER 2017 MAJOR SOLAR FLARE AND ICME EVENTS ON MARS

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We study the impact of the September 2017 extreme solar flare and interplanetary coronal mass ejection events on Mars using a sophisticated multi-species MHD model. The flare impact is examined by coupling with the Mars Global Ionosphere-Thermosphere Model. A great challenge of the study is that MAVEN was mostly inside the Martian bow shock during the events, and thus no direct solar wind measurement was available. To carry out reasonable simulations, we first simulate the events using steady-state assumptions with rough solar wind estimates. Although these simplistic time-stationary runs are able to capture the general features observed by MAVEN, they cannot represent the details of the large perturbations associated with the events. To describe the time variation during the space weather events, we estimate upstream solar wind conditions by fitting steady-state MHD model results to MAVEN observations in the sheath region. The obtained solar wind proxies are then used to drive a time-dependent MHD simulation. It is found that the data-model comparison is greatly improved, especially in the magnetosheath region. We are able to reproduce many detailed structures observed by MAVEN during the period despite the fact that no direct measurement of the solar wind is available. This model-data agreement confirms the validity of the derived upstream solar wind conditions. Using the time-dependent results, we examine in detail the impact of the events on the Martian system, including three plasma boundaries (Bow Shock, induced magnetosphere and ion composition boundaries) and ion loss rates. It is found that these plasma boundaries vary dramatically during the ICME and total planetary ion loss rates are enhanced by more than an order of magnitude.

C3.2-0023-18 LOSS OF THE MARTIAN ATMOSPHERE TO SPACE: PRESENT-DAY LOSS RATES FROM MAVEN OBSERVATIONS AND INTEGRATED LOSS THROUGH TIME

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Observations of the Mars upper atmosphere made from the Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft have been used to determine the loss rates of gas from the upper atmosphere to space for a complete Mars year. Loss rates for H and O are sufficient to remove 2-3 kg/s to space. By itself, this loss would be significant over the history of the planet. In addition, loss rates would have been greater early in history due to the enhanced solar EUV and solar wind. Integrated loss would have been as much as 0.8 bar CO2 or 23 m global equivalent layer of H2O; these losses are likely to be lower limits due to the nature of the extrapolation of loss rates to the earliest times and due to additional loss likely to have been driven by solar storms. Combined with the lack of surface or subsurface reservoirs for CO2 that could hold remnants of an early, thick atmosphere, these results suggest that loss of gas to space has been the dominant process responsible for changing the climate of Mars from an early, warmer environment to the cold, dry one that we see today.

C3.2-0024-18 JUNO AURORAL OBSERVATIONS AND THEIR SURPRISING IMPLICATIONS

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The Juno spacecraft carries with it a suite of instruments for both in situ and remote sensing observations of Jupiter's aurora and its response to variations in the polar magnetosphere. Observations by the particle instruments (JEDI and JADE) measure the energetic electron and ion distributions locally at the spacecraft, while the magnetometer (MAG) provides the instantaneous magnitude and orientation of Jupiter's magnetic field. Spectral imagers (UVS and JIRAM) perform remote sensing of H2 ultraviolet and H+ near-infrared auroral emissions to give context for the particles and fields instruments to help untangle the complex processes occurring in Jupiter's giant magnetosphere. Antennas (Waves) perform remote sensing and in situ measurements of complex jovian auroral radio emissions. Here we will present important and surprising results from the many successful perijoves to date.

C3.2-0025-18 SATURN'S MAGNETIC FIELD DURING THE CASSINI GRAND FINALE

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During the Cassini Grand Finale orbits at Saturn the focus of the magnetometer investigation was determination of the internal planetary magnetic field as well as the rotation rate of the deep interior. The unique geometry of these orbits provided an opportunity to measure the internal magnetic field at closer distances to the planet than ever encountered before. The surprising close alignment of Saturn's magnetic axis with its spin axis (known about since the Pioneer 11 observations) has been confirmed, however external effects, observed even around periaspse are masking some of the magnetic field signals from the interior. The varying northern and southern magnetospheric planetary period oscillations and field aligned currents at both high and low latitudes are contributing to the magnetic signals observed. An overview of the magnetic field results from the Grand Finale orbits will be described, including confirmation of the extreme axisymmetric nature of the planetary magnetic field, detection of high degree magnetic moments and the behaviour of external magnetic fields.

C3.2-0026-18 THE COUPLING OF SATURN'S ATMOSPHERE AND IONOSPHERE TO THE RINGS

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Cassini's Grand Finale provided a treasure trove of data while flying between Saturn's atmosphere/ionosphere and the D ring. The INMS instrument measured both neutrals and light ions during this time period - observing the most complex mass spectra of the entire mission. The RPWS measured the electron density along track and registered the presence of heavy positive and negative ions. MIMI observed energetic ions as well as an important population of nanometer-sized grains. MAG observed field-aligned currents and characterized the magnetic field geometry. Taken together these data sets characterize the complex chemical and dynamical interconnection of the rings to Saturn's equatorial atmosphere/ionosphere. This presentation will emphasize the structure of the Saturn/ring atmosphere and the chemical coupling of ring material to the equatorial atmosphere of Saturn. It will also attempt to place this within the context of the other measurements that will be more completely covered in separate presentations.

C3.2-0027-18 MONITORING SATURN'S UPPER ATMOSPHERE DENSITY VARIATIONS USING HELIUM 584Å AIRGLOW

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The atmosphere of Saturn is mainly composed of H2 and neutral atomic helium. The study of He 584 Å brightnesses is interesting as the EUV (Extreme UltraViolet) planetary airglow have the potential to yield useful information about mixing and other important parameters in its thermosphere. Resonance scattering of sunlight by He atoms is the principal source of the planetary emission of He 585 Å. The helium is embedded in an absorbing atmosphere of H2 and since it is heavier than the background atmosphere, it's concentration falls off rapidly above the homopause. The scattering region (i.e. where the absorption optical depth in H2 is less than 1) generally lies well above the homopause. As the eddy diffusion coefficient, Kz, increases in the middle atmosphere, more helium is mixed into the scattering region and thus the reflected intensity increases.

Specifically, He emissions come from above the homopause where optical depth tau=1 in H2 and therefore the interpretation depends mainly on two parameters: He mixing ratio of the lower atmosphere and eddy mixing profile, Kz. The occultations of Koskinen et al (2015) give Kz with an accuracy that has never been possible before and the combination of these occultations and airglow analyses can therefore can provide estimates of the mixing ratio in the lower atmosphere.

Using Cassini UVIS data and powerful modeling and analysis techniques, we can address longstanding questions regarding the He mixing ratio in Saturn's atmosphere and upper atmosphere density variations using the He 584Å airglow. We discuss ongoing efforts to determine the mixing ratio of He and constrain dynamics in the upper atmosphere of Saturn.

C3.2-0028-18 UNDERSTANDING CALLISTO'S INTERACTION WITH THE JOVIAN MAGNETOSPHERE: A CASE STUDY OF THE GALILEO C10 FLYBY

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We apply a combination of data analysis and hybrid modeling to study Callisto's interaction with Jupiter's magnetosphere during the Galileo C10 flyby on 17 September 1997. This encounter took place while Callisto was located near the center of Jupiter's current sheet. Therefore, induction in Callisto's subsurface ocean and magnetospheric field line draping around the moon's ionosphere both made nonnegligible contributions to the observed magnetic perturbations. The induction signal during C10 was obscured by plasma currents to a significant degree, in contrast to previously studied Callisto flybys. Our analysis reveals that at large distances to Callisto, its magnetic environment was dominated by field line draping, leading to the formation of Alfvén wings. Closer to the surface and in Callisto's wake, Galileo encountered a quasi-dipolar "core region" that was partially shielded from the plasma interaction and was dominated by the induced field. When exiting this core region, the spacecraft crossed a rotational discontinuity where the magnetic field vector rotated by approximately 50°. The hybrid model is able to quantitatively explain numerous key features of the observed magnetic signatures, especially the transitions between drapingand dipole-dominated regimes along the C10 trajectory. The model also reproduces the electron number density enhancement by 3-4 orders of magnitude detected in Callisto's wake, requiring a substantial ionosphere to surround the moon during C10. For flybys with nonnegligible plasma currents, comprehensive knowledge of the incident flow conditions and properties of Callisto's atmosphere is required to refine existing constraints on the subsurface ocean (conductivity, thickness, and depth) based on magnetic field data. These findings are highly relevant for the upcoming JUpiter ICy moon Explorer (JUICE) mission, which will include multiple Callisto flybys.

C3.2-0029-18 COMETARY NEUTRAL SPECIES: WHAT CAN WE LEARN FROM THE ROSETTA MISSION AND MODELING?

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The European Space Agency's Rosetta spacecraft was in orbit around comet 67P/ChuryumovGerasimenko from August 2014 to September 2016. Rosetta carried several instruments to investigate the comet's nucleus and surrounding neutral gas, dust, and plasma environment. Part of the payload was the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA) that consisted of two mass spectrometers and a pressure sensor. ROSINA was designed for in situ measurement of the neutral gas, both in composition and in absolute abundance.

Comets are surrounded by an extended neutral gas and dust coma. As they journey around the Sun on eccentric orbits the production of volatiles from sublimation of ices in the nu- cleus undergoes strong variations. ROSINA observations in combination with sophisticated time-dependent models have shown that the neutral gas coma is very heterogeneous. This heterogeneity is driven in large parts by the complex shape of the nucleus and the varying illumination conditions associated with the comet's rotation and variation in heliocentric distance. Furthermore, the oblique rotation axis of the nucleus led to seasons, i.e., different evolutionary histories of the northern and the southern hemispheres.

In this presentation we will address some of the major findings of ROSINA and discuss their implications on the formation and thermal evolution of comet 67P/Churyumov-Gerasimenko.

C3.2-0030-18 ENERGETIC NEUTRAL ATOM IMAGING: INTERACTIONS BETWEEN PLANETARY PLASMA, EXOSPHERE, AND SURFACE

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It is frequently said that 99% of all known matters in the universe is in the plasma state. To understand the universe, understanding of the behavior of the plasma is therefore essential. Traditionally, space plasma has been investigated using in-situ charged particle measurements, or electromagnetic emission (or absorption) lines. Recently, energetic neutral atom (ENA) imaging has open a new channel for space plasma investigations. Energetic neutral atoms are produced from the charge exchange mechanism. When an ion received an electron from neighboring neutral atom, the primary ion becomes an ENA. During the charge exchange process, the energy loss of the primary ion is usually negligible. Due to the neutrality, ENAs do not feel any electromagnetic force. Therefore, we can know the primary ion's velocity distribution function remotely using ENAs.

The ENA imaging has been utilized to not only terrestrial missions, but also to planetary missions. Low energy (1 keV) ENA instruments were carried to Mars, Venus, and the Moon. Interactions of these planets and the solar wind has been investigated. At Saturn, high energy (> keV) ENA imagers were operated to measure the magnetospheric plasma. As future missions, ENA sensors will be inserted to Mercury (with BepiColombo) and to Jupiter (with JUICE). In this review talk, we will overview planetary environments revealed by ENA imaging.

C3.2-0031-18 ON THE RELATIVE ROLES OF THE NEUTRAL DENSITY AND PHOTO CHEMISTRY ON THE SOLAR ZENITH ANGLE VARIATIONS IN THE V2 LAYER CHARACTERISTICS OF THE VENUS IONOSPHERE UNDER DIFFERENT SOLAR ACTIVITY CONDITIONS

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Using an in-house developed one-dimensional photo-chemical model (1D-PCM) which considers production and loss of 11 ions namely, CO+, CO+, C+, N+, N+, He+, O+(2D), O+(2P), O+(4S),

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O+ and NO+, characteristics of the V2 layer in the Venus ionosphere has been studied. It was noted that existing ionospheric model for the Venus ionosphere, such as IonA model, not only over/ under estimated the peak electron density of V2 layer, it also had significant departures from the observations on the solar zenith angle and solar activity control. The IonA model had used VenusGRAM model as input for the neutral density which considers Venus atmosphere consisting of CO2, O, and N2 molecules only. In addition to this, it had oversimplified the ion chemistry by assuming Venus ionosphere to have O+ as the only dominant ion species.

Using VTS3 model which considered profiles of six neutrals (CO2, O, CO, He, N, and N2), we modified IonA model to find that it reproduced the height of V2 peak electron density quite well. The model however still lacked in reproducing observed peak V2 electron density. The ion-house developed 1D-PCM model not only reproduced the observed V2 peak density, the height of the peak V2 layer was also represented well. Our results with 1D-PCM calculations show the role of complex chemical reactions in determining the features of peak altitude and density of V2 layer during different solar activity periods. We surmise that difference between modelled peak altitude of V2 layer by IonA model, and observations was due to the limitations of VenusGRAM neutral density model. It also suggested that the height of peak V2 layer in Venus ionosphere is controlled by neutral density. 1D-PCM calculations showed that the complex chemistry including production and loss reactions of 11 ions could reproduce the variations in the peak density of Venusian ionosphere during different solar activity conditions. This fact further suggests that the ion-chemistry has control over the peak plasma density in the Venus ionosphere

C3.2-0032-18 MGS RADIO SCIENCE ELECTRON DENSITY PROFILES: LONGITUDINAL CHARACTERISTICS

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Early analysis of the first few sets of electron density profiles returned by the radio science experiment aboard MGS spacecraft provided a strong evidence for planetocentric longitude dependence of the photochemical controlled E and F1 layers of the Martian ionosphere. This feature is not seen in the E and F1 layer of the Earth's ionosphere, which too are photochemical. In this study, with the availability of several MGS data sets containing a total of 5600 electron density profiles, we re-examine the longitude dependence of the observed peak parameters (viz. height and density) as well as of other derived parameters, like the electron content and the atmospheric scale height of the E and F1 layers. We find that though there is a lot of variability, the distribution with longitude for each of these parameters is nearly uniform most of time. However, exceptions are periods during late spring and early summer (northern latitudes) when the longitudinal variations indicate the presence of crests/troughs, in the observed as well as in the derived parameters, broadly spread around 0°, 70° and 140° E longitudes. On examining the characteristics of the electron density profiles located at these crests/troughs, we find a large difference between the two sets, with the peak height and peak density showing large excursions. Further, the peak density, electron content and atmospheric scale height show significant relationship with the excursions in peak height. These observations can be explained if there are rapid changes in Mars thermosphere.

C3.2-0033-18 EXOSPHERIC NEUTRAL COMPOSITION DATA SET OF MARS FROM INDIAN MARS ORBITER MISSION

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The raw data of exospheric composition of Mars for the period 24 September 2014 to 23 September 2015 has been utilized to prepare a spread sheet based calibrated and normalised data set. For this, the voluminous data is compressed to select the best values of partial pressures of the atmospheric species covering the mass spectrum between 1 to 100 amu values. Multiple data files were merged to consolidate the data for individual orbits of Mars Orbiter Mission (MOM) for which the Mars Exospheric Neutral composition Analyser (MENCA) payload operated for carrying out the observations. Depending on the height coverage, the total and partial pressure values are further analysed by suitable algorithms considering the rate of change of the pressure values with time. A total of 497 data files contain the MENCA data for the above period pertaining to 149 orbits of MOM. Individual plots of the total and partial pressures with altitude for the height region below 1000 km have provided a statistically significant variation of atmospheric constituents. The anomalous pressure values particularly during the first hour of switching on the quadrupole mass spectrometer have been carefully examined and only the consistent values have been retained. The main constituents with relatively higher partial pressures like H, N, O, H2O, (N2+CO), Ar, CO2 have been studied with their relative variation with height, surface co-ordinates, solar angles and solar activity. Sample results of these profiles are presented.

C3.2-0034-18 MAGNETIC FIELD ENVIRONMENT OF VENUS AND MARS

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The magnetism is a universal parameter and an essential component of any planetary body. The magnetic field of a planetary body is the result of its internal movements taken place in the past and present as well as due to its interaction with the solar wind. The magnetic field imposes constraints on the planetary structure, dynamics and evolution. The magnetic field can be used as a potential tool to understand the interiors of a planetary body. Venus and Mars do not possess a global magnetic field unlike Earth. The absence of an intrinsic magnetic field in Venus is due to the lack of dynamo which is responsible for a strong global magnetic field due to the motion of an electrically conducting and convecting fluid inside the planet. It is believed that Mars had an intrinsic magnetic field is the past but the dynamo stops due to various factors. However, Mars does possess a weak magnetic moment due to the crustal magnetic anomalies. In the absence of a global magnetic field, the solar radiation (dominantly EUV) interacts deep into the atmosphere of Venus and Mars and ionizes large number of neutral atoms and molecules to generate the ionosphere. In the ionosphere of these two terrestrial planets a number of plasma phenomena take place. Some of these phenomena lead to the generation of plasma waves.

In this paper, the scientific understanding of the magnetic environment of Venus and Mars is presented with proposed studies that can be carried out in a future space mission to these planets.

C3.2-0035-18 INTERPLANETARY MAGNETIC FIELD PENETRATION INTO MERCURY'S MAGNETOSPHERE

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In this work we present the results of performing multi-parametric fitting of the paraboloid magnetosphere model (PMM) to magnetometer observational data obtained during a number of MESSENGER orbits around Mercury with the purpose of investigating the interplanetary magnetic field (IMF) coefficient of penetration into the magnetosphere. We analyze cases with multiple IMF states that satisfy the condition that during the inbound and outbound orbit segments the IMF vector is approximately the same; since Mercury's magnetosphere is quite small, any disturbances in the magnetosphere induced by abrupt changes in the IMF propagate rapidly, and the magnetosphere achieves a new meta-stable state shortly. We thus assume that the IMF is nearly constant and the magnetosphere is quasi-stationary during the whole duration of these orbit segments, and fit the PMM parameters (including the IMF penetration coefficient κ) to match the observations.

C3.2-0036-18 NEUTRALS - FORESHOCK ELECTRON IMPACT IONIZATION AT MARS FROM MAVEN SWEA OBSERVATIONS

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Backstreaming electrons emanating from the bow shock of Mars observed by the MAVEN SWEA instrument show a flux fall off with the distance from the shock. This feature is not observed at the terrestrial foreshock. The flux decay is only for electron energy E > 29 eV. A reported recent study indicates that Mars foreshock electrons are produced at the shock in a mirror reflection of a portion of the solar wind electrons. In this context and given that the electrons are sufficiently energetic to stay unaffected by the IMF fluctuations, the observed flux decrease appears problematic. We investigate the possibility that the flux fall off with distance results from the impact of backstreaming electrons with Mars exospheric neutral hydrogen. We demonstrate that the flux fall off is consistent with the electron-atomic hydrogen impact cross-section for a large range of energy. A better agreement is obtained for energy where the impact cross section is the highest. One important consequence is that foreshock electrons can play an important role in the production of pick up ions at Mars far exosphere.

C3.2-0037-18 DENSITIES INFERRED FROM ESA'S EXOMARS TRACE GAS ORBITER AEROBRAKING CAMPAIGN

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The aerobraking phase of TGO, from March 2017 to February 2018, was used to reduce the orbital period from 24 hours to about 2 hours and an apocenter altitude of 1000 km. It was achieved by lowering the orbit perigee to approximately 105-110 km and rotating the solar array to be almost perpendicular to the satellite speed vector in order to enhance the atmospheric drag effect.

Data of the aerobraking phase will be processed to infer total densities. The attitude quaternions are used to correctly orient the spacecraft bus and solar arrays in inertial space, which is necessary to accurately compute the exposed surface in the ram direction. The (engineering) accelerometers provide measurements with a good signal-to-noise ratio at low altitude, close to the pericenter; at the beginning of the aerobraking phase, this results in one acceleration profile per day, whereas up to 12 profiles per day can be obtained at the end of the phase. The calibrated accelerations, essentially due to aerodynamic drag at low altitude, are then used to infer total density using a model for satellite shape and the aerodynamic drag coefficient Cd. The uncertainty in the derived density is the sum of a systematic part due to the uncertainty in Cd, and a noise and bias (not completely resolved after calibration) part due to the accelerometers. Preliminary results of the density calculations will be presented, and comparison to models such as MarsGRAM and MCD. In-situ thermosphere density measurements will be used to infer the global structure and variability of the Martian upper atmosphere, including analyses of atmospheric waves. Comparisons with simultaneous MAVEN atmosphere measurements will also be made in the future.

C3.2-0038-18 PROFILES, SEASONAL AND SOLAR CYCLE VARIABILITY OF ELECTRON DENSITIES IN THE UPPER MARTIAN IONOSPHERE: 11 YEARS OF MARSIS DATA

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Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) onboard the Mars Express (MEX) spacecraft has been providing valuable information about the ionosphere of Mars. Among these are the electron densities local to the spacecraft, obtained from the excitation of local plasma oscillations. This paper provides an overview of electron densities in the upper ionosphere of Mars. We investigated over 1200 orbits, about 360000 ionograms, over the course of 11 Earth years, 5.5 Martian years, which corresponds to a full solar cycle period. The data covers a wide range of SZA, latitude and longitude, with an altitude range between 250 km and 1500 km. The electron density profiles show large fluctuations within each orbit and also for a given altitude and solar zenith angle range. However, the median electron density is almost constant on the dayside at a fixed altitude range, with the exception of a dip at around 30°, at altitudes between 300 and 700 km. Interestingly, a decrease in the electron density similar to the dip we have seen, has been also observed in MAVEN data for lower altitudes. For a fixed SZA range, the median electron density decreases with increasing altitude. Full solar cycle data permit us to study solar cycle and seasonal dependence. Especially at higher altitudes a decrease in the electron densities during the solar minimum is evident. Also, an increase is seen during northern winter in some altitude and SZA ranges compared with northern summer. Crustal fields have a notable effect on the electron densities at lower altitudes: Electron densities are substantially higher above regions of strong fields.

C3.2-0039-18 IONOSPHERIC MAGNETIC FIELD AND CURRENT VARIATIONS OVER THE INSIGHT LANDING SITE

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The InSight lander, scheduled to reach Mars in late 2018, will investigate the interior of Mars using seismic, heat flow, and radio tracking experiments. The InSight Flux Gate magnetometer (IFG), part of the Seismic Experiment for Interior Structure (SEIS), will measure the ambient magnetic field in order to decouple the magnetic field impacts from the seismometer recordings. As the first magnetometer on the surface of Mars, observations from IFG can also be used to investigate the behavior of ionospheric magnetic fields and ionospheric currents above the lander.

Here we use Mars Global Surveyor and MAVEN magnetic field measurements while the spacecraft were in the martian ionosphere above the nominal InSight landing site to investigate the variability in the ionospheric magnetic field and currents. The ionospheric magnetic field can be highly variable, depending largely upon the upstream interplanetary magnetic field and solar wind conditions. From these magnetic field observations, we estimate the ionospheric currents and the expected magnetic perturbations at the surface due to the estimated currents. Ionospheric currents are found to be on the order of μA m−2. These currents would result in a surface level magnetic field perturbation of a few nT, large enough to be easily measured by IFG. This analysis lays the groundwork for future investigations of the variability of ionospheric currents from IFG observations.

C3.2-0040-18 A MODEL ANALYSIS OF THE NORTHERN AND SOUTHERN HEMISPHERIC ELECTRON DENSITY PROFILES AT MARS

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The Mars Express electron density (Ne) profiles near terminators have indicated more complicated structure of the Martian high-latitude ionosphere than previously thought. Some of these profiles over the northern hemisphere show wide and narrow shapes of the main Ne peaks while others over the southern hemisphere have shown anomalous characteristics of the topside plasma distribution. We use our 1-D chemical diffusive model coupled with the Mars - Global Ionosphere Thermosphere Model (M-GITM) to interpret both northern (67oN, 235oE and 66oN, 341oE) and southern (82oS, 180oE) hemispheric Ne profiles. Our model is a coupled finite difference primitive equation model which solves for plasma densities and vertical ion fluxes. The crustal magnetic field at the northern locations is mainly horizontal and does not allow plasma to move vertically. Thus, the primary plasma loss for the topside ionosphere at the northern locations is likely caused by diverging horizontal fluxes of ions, indicating that the dynamics of the upper ionosphere of Mars is controlled by the solar wind. The situation at the southern location is different where the field lines are nearly vertical and open to the access of solar wind plasma through magnetic reconnection with the interplanetary magnetic field. This can lead to the acceleration of electrons and ions during the daytime ionosphere. The downward accelerated electrons with energies >200 eV penetrate deep into the Martian upper ionosphere along vertical magnetic field lines and cause heating, excitation and ionization of the background atmosphere. The upward acceleration of ions resulting from energy input by precipitating electrons can lead to enhance ion escape rate and modify scale heights of the topside ionosphere. The primary source of ionization in the model is due to solar EUV radiation. An extra ionization source due to precipitating electrons of 0.25 keV, peaking near an altitude of 145 km is added in the model to interpret the measured ionospheric structure at the southern location. We find that an upward flux of O2+ of 1.8 x 106 cm−2 s−1 is needed to explain the northern topside electron density profile at 66oN while this value is increased by a factor of two at 67oN. However, the behavior of the topside ionosphere at the southern location is interpreted by the vertical plasma transport simulated by vertical ion velocities, whose values can be interpreted as drift velocities along magnetic field lines. We find that the variation of the topside Ne scale heights is sensitive to magnitudes of upward and downward drifts with an imposed outward flux boundary condition at the top of the model. The model requires an upward flux of more than 107 ions cm−2 s−1 for both O2+ and O+, and drift speeds of 200

m/s to interpret the measured topside ionospheric structure. The model results for both the northern and southern locations will be presented in comparison with the measured electron density profiles. This work is supported by MBRSC, Dubai, UAE.

C3.2-0041-18 THE BEHAVIOR OF THE BUNEMAN INSTABILITY IN DISSIPATIVE PLASMA

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The Buneman instability (BI) [1] plays an important role in many scenarios in space physics and geophysics. It is invoked to explain many phenomena in the Earth's ionosphere [2] and in the solar chromosphere [3]. In double-layer physics as well as in collision-less shock physics, the same instability was found responsible in formation of nonlinear structures [4]. Development of the BI in ionospheric electrojets leads to a formation of plasma density irregularities, which have observational confirmations [5]. Studies of these irregularities have focused attention on the role of BI and other low frequency instabilities. Ionospheric irregularities and related phenomena in the equatorial and high-latitude E-region electrojets have been studied for many years by radars and rockets. It is now generally accepted that the most common irregularities are caused by the BI. In order to full understanding how the instability transforms given local equilibrium of plasma, how the irregularities have been created as well as calculate their level and/or spatial scales and estimate possible saturation mechanisms it is necessary to investigate the evolution of the instability in space and time [6]. In spite the BI is subject of many investigations, this (as well as some other) aspect of the instability remains unstudied. In present investigation the problem of time evolution of initial perturbation excited at the development of the BI in plasma with dissipation is solved. Developing fields are presented in form of wave train with slowly varying amplitude. It is shown that the evolution of the initial pulse in space and time is given by differential equation of third order. The equation is solved and the expression for asymptotic pulse shape is obtained. The expression gives the most complete information on the instability: the space-time distribution of the fields, growth rates, velocities of unstable perturbations, the influence of the collisions/ dissipation on the instability, its character (absolute/convective) etc. All these characteristics of the BI are carried out by analyzing the expression for the space-time distribution of the fields. It is shown with increase in dissipation the BI turns to instability of dissipative type. [1]. Buneman O. Phys.Rev.Let, v.1, p8, (1958); Phys Rev v.115, 503, (1959). [2]. Gogoberidze G. Voitenko, Y. Poedts, S. Goossens, M., Astrophys. J. Lett. 706 (2009) L12. [3]. Izuka S., Saeki K., Sato N., and Hatta Y. Phys. Rev. Lett., 43 1404. (1979). [4]. Tabak M., Phys. Plasmas, 1, 1626, (1994). [5]. Y.S.Dimant, M.M.Oppenheim J. Atmospheric and Solar-Terrestrial Phys, 66, p.1639,(2004). [6]. A. Bers in Basics of Plasma Physics edited by

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C3.2-0042-18 NON-SIMILARITY SOLUTION FOR UNSTEADY ISOTHERMAL FLOW BEHIND A MAGNETOGASDYNAMIC SHOCK WAVE IN A ROTATIONAL AXISYMMETRIC GAS WITH EXPONENTIALLY VARYING DENSITY

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The propagation of cylindrical shock wave in an ideal gas with or without rotational effects in the presence of a constant azimuthal magnetic field for unsteady isothermal flow is discussed. The ambient medium is assumed to have radial, axial and azimuthal components of fluid velocity. Non-similar solutions are obtained for one-dimensional isothermal flow behind a magnetogasdynamic shock wave by taking into account the vorticity vector and its components. The density of the gas, azimuthal and axial components of fluid velocity in the ambient medium are assumed to be varying and obeying an exponential law. The numerical solutions are obtained using the Runge-Kutta method of the fourth order. The effects of Alfven-Mach number; adiabatic exponent gamma and time are obtained. It is shown that in the presence of magnetic field the pressure and density vanishes at the inner expanding surface (piston) and hence a vacuum is formed at the line of symmetry, which is an excellent agreement with the laboratory condition to produce the shock wave. Also, the shock strength increases with increase in time in the absence of magnetic field but in the presence of magnetic field time has reverse affects on the shock strength. The shock waves in conducting perfect gas can be important for description of shocks in supernova explosions, in the study of central part of star burst galaxies, nuclear explosion, rupture of a pressurized vessel, explosion in the ionosphere and for upper atmosphere. Other potential applications of this study include analysis of data from exploding wire experiments and cylindrically symmetric hypersonic flow problems associated with meteors or re-entry vehicles etc. A comparison is made between the solutions in the cases of rotating and non-rotating medium with or without magnetic field. The obtained solutions are applicable for arbitrary values of time. Keywords: Shock wave; Magnetogasdynamics and Electro-fluid Mechanics; Rotating medium, Non-similarity solution.

C3.2-0043-18 DAYSIDE IONOSPHERIC CONDUCTIVITIES AT MARS OVER THE REGION OF CRUSTAL MAGNETIC ANOMALY

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A complex magnetic topology at Mars gives rise to diverging magnetic field cusps and closed magnetic loops with local magnetic conditions similar to those found above Earth's polar region. One of such cusps is located at 82oS and 180oE where the crustal magnetic field is nearly vertical and open to the access of solar wind plasma through magnetic reconnection with the interplanetary magnetic field. This reconnection can allow solar wind electrons to penetrate into the Martian upper atmosphere, causing ionization and heating, which leads to inflate the topside plasma distribution to high altitude and increase the topside electron density scale height. These characteristics of the Martian upper atmosphere at this southern location are confirmed from the Mars Express electron density profile. We use our 1-D chemical diffusive model from an altitude of 100 km to 400 km to interpret the measured electron density profile with the vertical plasma transport simulated by vertical ion velocities and by imposing an outward flux boundary condition. The output of this model and available crustal magnetic field information at Mars are used to estimate the vertical distribution of ionospheric conductivities. We find that the ionosphere is highly conductive in the Martian dynamo region between 100 and 250 km altitude, where plasma -neutral collisions permit electric currents perpendicular to the crustal magnetic field. The magnitudes of Pedersen and Hall conductivities are estimated to be 0.65 - 0.75 S/m, respectively, near the Martian ionospheric peak. We also estimated the magnitude of horizontal ionospheric currents driven by ion and electron motions in the Martian dynamo region. The model results will be presented in comparison with existing estimates of the Martian conductivities and ionospheric currents. We acknowledge support for this work from the Mohammed Bin Rashid Space Center (MBRSC), Dubai, UAE.

C3.2-0044-18 THE MAGNETOSPHERE OF MERCURY UNDER NOMINAL AND FAST SOLAR WIND CONDITIONS IN A GLOBAL HYBRID SIMULATION

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We analyze the interaction of the solar wind with the Hermean magnetic field including the formation of the bow shock, the magnetosheath and the magnetopause in a 3-dimensional global hybrid model. First we present the implementation of the numerical simulation model, where ions are treated as particles moving under the Lorentz force and electrons are a chargeneutralizing fluid. In the hybrid approach ion dynamics are self-consistently coupled with the propagation of the magnetic field by Faraday's law. The undisturbed solar wind flow is injected from the front wall of the simulation domain and the particles can reach the planetary surface, which is the inner boundary. Resistivity profiles of the planetary crust and core can be included as well. The incident solar wind can include, for example, conditions during nominal and highspeed streams and solar wind transient conditions like interplanetary coronal mass ejections. In the analysis we concentrate on how the solar wind plasma gains access to different regions in Mercury's magnetosphere and its boundary layers.

C3.2-0045-18 THE IMPACT OF CALLISTO'S ATMOSPHERE ON ITS PLASMA INTERACTION WITH THE JOVIAN MAGNETOSPHERE

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The interaction between Callisto's atmosphere and ionosphere with the surrounding magnetospheric environment is analyzed by applying a hybrid simulation code, in which the ions are treated as particles and the electrons are treated as a fluid. Callisto is unique among the Galilean satellites in its interaction with the ambient magnetospheric plasma as the gyroradii of the impinging plasma and pickup ions are large compared to the size of the moon. A kinetic representation of the ions is therefore mandatory to adequately describe the resulting asymmetries in the electromagnetic fields and the deflection of the plasma flow near Callisto. Multiple model runs are performed at various distances of the moon to the center of Jupiter's magnetospheric current sheet, with differing angles between the corotational plasma flow and the ionizing solar radiation. When Callisto is embedded in the Jovian current sheet, magnetic perturbations due to the plasma interaction are more than twice the strength of the background field and may therefore obscure any magnetic signal generated via induction in a subsurface ocean. The magnetic field perturbations generated by Callisto's ionospheric interaction are very similar at different orbital positions of the moon, demonstrating that local time is only of minor importance when disentangling magnetic signals generated by the magnetosphere-ionosphere interaction from those driven by induction. Our simulations also suggest that deflection of the magnetospheric plasma around the moon cannot alone explain the density enhancement of 2 orders of magnitude measured in Callisto's wake during Galileo flybys. However, through inclusion of an ionosphere surrounding Callisto, modeled densities in the wake are consistent with in situ measurements.

C3.2-0046-18 VALIDATING SOLAR SOFT X-RAY IRRADIANCE MODELS WITH MODELMEASUREMENT COMPARISONS OF PHOTOELECTRON SPECTRA AT MARS

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Solar x-ray ultraviolet (XUV, 0.1-10 nm) photons are a primary energy input into the upper atmospheres of Earth and other planets, and are distinct from extreme ultraviolet (EUV, 10-120 nm) photons in their capability to penetrate to lower altitudes, creating the E-region of the ionosphere at Earth for example. Predicting XUV photoionization requires spectrally resolved irradiance measurements or models because the cross-sections of many atmospheric constituents are highly structured near 2.5 nm. Although spectral irradiance at the shortest XUV wavelengths has been historically uncertain due to limited measurements, knowledge of the XUV spectrum from 0.2-2.5 nm has been significantly improved by the MinXSS CubeSat, which made full-disk spectral irradiance measurements from May 2016 to May 2017. These measurements have been incorporated into the Synthetic Reference Spectra (SynRef) model which can be driven by a number broadband XUV measurements that have been made nearcontinuously for the past two decades at Earth by SNOE, SORCE and TIMED; and at Mars by MAVEN since October 2014. Due to the lack of other spectrally resolved XUV measurements, directly validating SynRef for times when MinXSS was not making observations is not possible. An indirect method for validating XUV irradiance models is to input them into models for photoelectron

energy spectra and compare the modeled photoelectron energy spectra with measured photoelectron energy spectra. Measurements made by the MAVEN SWEA instrument currently in orbit at Mars provide such an opportunity. This study compares photoelectron measurements made at Mars by SWEA with predictions from SynRef-coupled photoelectron models in order to characterize SynRef over a range of solar activity occurring while MAVEN has been at Mars. This includes the declining phase of Solar Cycle 24, where activity declined from moderate to minimum conditions, and a number of solar flares.

SPACE STUDIES OF THE UPPER ATMOSPHERES OF THE EARTH AND PLANETS INCLUDING REFERENCE ATMOSPHERES (C)

IMPROVED DESCRIPTION OF THE IONOSPHERE THROUGH DATA ASSIMILATION (C4.1)

C4.1-0001-18 REALISTIC IONOSPHERE: A SUITE OF ASSIMILATIVE EMPIRICAL MODELS AND RESOURCES AT LGDC

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The Realistic Ionosphere (RI) [1] objective is to provide an accurate and prompt nowcast of the 3D global plasma density distribution in the subpeak ionosphere using high-frequency (HF) ionospheric sounding technology. It includes several remote sensing, modeling, and computer science resources. A multi-nation coordinated network of ionosondes, the Global Ionosphere Radio Observatory (GIRO) [2], provides near-real-time (nRT) low-latency measured data of the subpeak ionospheric plasma density. In addition to the conventional ionosonde data products like the ionogram-derived autoscaled records of electron density profiles and the standard URSI characteristics (foF2, hmF2, etc.) [3], GIRO acquires skymap-derived measurements of the local tilt of the ionosphere [4], and detects Traveling Ionospheric Disturbances (TIDs) using coordinated operation of its observatories [5]. A global 3D empirical nowcast of the ionospheric plasma density is then computed based on assimilative techniques of smoothly transforming the background International Reference Ionosphere (IRI) climatological model [6] into the optimal match with GIRO measurements. The resulting IRI-based Real-Time Assimilative Model (IRTAM) [7] releases nRT ionospheric weather nowcasts every 15 minutes with a 7.5 minute latency. The TID and local tilt observations are used to incorporate fine-scale description of the plasma structures in the Realistic Ionosphere, a 3D specification of the subpeak ionosphere density distribution. RayTRIX (RayTracing through Realistic Ionosphere eXplorer) uses numerical raytracing [8] to simulate the properties of HF signals propagating in the ionospheric channels specified by IRTAM with added knowledge of TID activity and local tilt of the ionosphere. The Lowell GIRO Data Center (LGDC) maintains a collection of computer software, database engines, and computer infrastructure for computations associated with RI nowcast and warning services, and open international data access for academia, students, radio enthusiasts, and space weather applications. Public service of RI is arranged via LGDC Open Data Portal at http://giro.uml.edu.

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C4.1-0002-18 REAL-TIME MAPPING OF VTEC AND GLOBAL 30-DAY AVERAGE EMPIRICAL VTEC MAPS IN COOPERATION OF IGS' GNSS AND GIRO SENSOR NETWORKS

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Since 1998, the International GNSS Service (IGS) Ionosphere Working Group has been continuously releasing global maps of vertical total electron content (VTEC) in rapid, final, and predicted schedules. The IGS Ionosphere Combination and Validation Center (ICVC) at University of Warmia and Mazury is responsible for an ensemble analysis of the global VTEC maps synthesized independently by several ISG Associate Analysis Centres by applying the observation uncertainty weights determined by validating the VTEC data against the original slant TEC measurements.

This work presents early results from a near-real-time ionosphere mapping system combining ionospheric data from two separate

sensor networks: IGS permanent GNSS receivers providing VTEC measurements and GIRO high-frequency ionosonde sounders providing data for 3D mapping of the bottomside ionospheric plasma density. Near-real-time mapping systems can be considered as a step towards real-time systems, at the moment an extremely important and difficult to solve problem, not only considering mapping process itself, but also data gathering from all over the world, data delivery to the computational center, quality control, validation, mapping and releasing of final product in possibly unnoticeable amount of time. The combination of IGS and GIRO real-time capabilities brings an intriguing possibility of evaluating dynamics of the topside ionosphere and plasmasphere, even though crudely, using only groundbased resources whose real-time performance can be engineered to accomplish below one minute latency of nowcast.

Comparison of the ICVC-released “weather” VTEC maps to their quiet-time “climate” counterpart is a powerful instrument in the space physicist toolbox: such deviation maps allow rapid evaluation of the anomalous near-space plasma dynamics as it responses to a wide variety of effects in the Sun-Earth system, ranging from the forces acting in the outer space to the processes on the surface and even underneath the Earth’s crust. However, development of such global reference quiet-time VTEC maps proved to be a difficult task, given the staggering complexity and dynamics of the constituent subsystems and the intersystem coupling mechanisms. Our approach to the task of building a reference for the deviation maps is to compute daily empirical 30-day running average VTEC. Such averaging is expected to smooth out effects from any ongoing events (that would otherwise distort the presentation of ionospheric/plasmaspheric climate) while still preserving the specifics of the annual cycle. The second objective of presented work is to introduce such global 30-day average empirical TEC maps into GAMBIT Explorer software used to build deviation maps for ionosonde-derived global maps of the bottomside ionospheric plasma.

C4.1-0003-18 INSTANTANEOUS MAPPING OF THE IONOSPHERIC SLAB-THICKNESS WITH IRI-PLAS MODEL

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Improvement to assimilation of ionosonde-derived F2 layer critical frequency foF2 (proportional to the peak electron density NmF2) and total electron content TEC with IRI-Plas model is described. Input of the foF2 critical frequency and hmF2 peak height is internal option of IRI, NeQuick and IRI-Plas models. Input of instant TEC alone by IRI-Plas system allows obtain the instant foF2, hmF2 and 3D electron density profile using the median slab-thicness τ -med obtained as ratio of TEC-ins to NmF2 prediction with CCIR or URSI maps. In conversion of global ionospheric maps GIM-TEC to GIM-foF2 by IRI-Plas, the residual error is determined for each cell of map processed in parallel. The residual error between the TEC-obs data and modelled TEC-mod is proposed to use for estimate of the instant τ -ins. It is found that τ -ins can differ from τ -med by ±20%. When both foF2 and TEC are assimilated by IRI-Plas, the instant τ -ins is obtained automatically equal to the ratio of TEC/NmF2 input. Evaluating τ -ins by IRI-Plas model in process of GIM-TEC assimilation improves accuracy of GIM-foF2 results and produce the instantaneous GIM-τ global maps as a new product for the science and applications.

C4.1-0004-18 ASSIMILATION OF MULTIPLE DATA TYPES TO MODEL REGIONAL IONOSPHERE DURING GEOMAGNETIC QUIET AND STORM DAYS

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Ionosphere NmF2 provided by five ionosondes, and COSMIC; Slant Total Electron Content (STEC) from twenty-seven Global Positioning System (GPS) located over Korea and adjacent areas (200 600 N in latitude and 1100 1600 E in longitude) have been assimilated into International Reference Ionosphere (IRI) empirical model. Ionospheric Data Assimilation Four-Dimension (IDA4D) technique is used to assimilate those measurement data during geomagnetic quiet (March 15-16, 2015) and storm days (March 17-18, 2015) to investigate the performance of IDA4D model ability and ionosphere characteristics. The IDA4D run for multiple assimilation cases by using data from: (1) all GPS; (2) all GPS and five ionosondes; (3) five ionosondes; and (4) all GPS, five ionosondes, and COSMIC. GPS STEC has been assimilated during geomagnetic quiet and storm days as a benchmark. Jeju ionosonde was set aside to provide ground truth of foF2 values. The assimilated results are validated with foF2 values from ionosondes, and STEC from GPS. It was found that assimilation of all GPS STEC data improves the accuracy of IDA4D ionosphere foF2 values. The result also shows that, the average errors of foF2 after assimilation all GPS STEC and ionosonde NmF2 data were smaller than assimilation all GPS STEC data for Beijing, Kokubunji, and Wakkanai stations. Assimilation COSMIC NmF2 together with all GPS and ionosonde NmF2 data further increases the performance of IDA4D over areas not covered by GPS and ionosondes. Ionosphere foF2 from IDA4D shows that negative storm response on the recovery phase of 18 March geomagnetic storm.

Keywords: Ionosphere storm during 17-18 March 2015, Ionospheric Data Assimilation FourDimension (IDA4D), International Reference Ionosphere (IRI), Slant Total Electron Content, NmF2, foF2, negative storm response

C4.1-0005-18 TEC DATA ASSIMILATION INTO NEQUICK 2

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NeQuick 2 is the ionosphere electron density model developed at the Abdus Salam International Centre for Theoretical Physics (ICTP) - Trieste, Italy in collaboration with the University of Graz, Austria. To provide 3-D specifications of the ionosphere electron density for current conditions, different ionosphere electron density retrieval techniques based on the NeQuick adaptation to Total Electron Content (TEC) data and ionosonde measured peak parameters values have been proposed. Recently, a procedure based on the Best Linear Unbiased Estimator (BLUE) has been implemented to incorporate ground and space-based GNSS-derived TEC data into NeQuick, considered as a background model. In the present paper an overview of the mentioned assimilation techniques will be given and the latest development concerning the assimilation of Radio Occultation (RO)-derived TEC data into NeQuick will be presented. As a first step, the results of a simulation experiment will be described to evaluate the relevance of the RO-derived TEC data assimilation in the topside electron density reconstruction. More specifically, it will be shown that the inclusion of RO TEC data can improve the description of the topside profile shape (scale height), but not always allows for a sufficiently accurate reconstruction of the peak density and height. Indeed, it will also be demonstrated how the background model slab thickness can play an important role in the analysis results. Subsequently, using experimental data, specific test cases will be illustrated where the BLUE algorithm is used to assimilate both ground a space-based TEC data. In particular, the effects of assimilating RO TEC data on the reconstruction of the ionospheric electron density at selected locations and epochs will be discussed and interpreted in light of the simulation outcomes. For this purpose, independent ground truth measurements like manually scaled F2 layer peak parameter values will be utilised to evaluate the performance of the proposed assimilation procedure.

C4.1-0006-18 MODELLING THE IONOSPHERE: GLOBAL AND REGIONAL HIGH-RESOLUTION VTEC REPRESENTATION BY MEANS OF B-SPLINES

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The project OPTIMAP is a joint initiative of the Bundeswehr Geoinformation Centre (BGIC), the German Space Situational Awareness Centre (GSSAC), the German Geodetic Research Institute of the Technical University of Munich (DGFI-TUM) and the Institute for Astrophysics at the University of Goettingen (IAG). The main goal of the project is the development of an operational tool for ionospheric mapping and prediction. The software uses geodetic observation techniques that are sensitive to the free electrons within the Earth's ionosphere (GNSS, satellite altimetry, radio occultations, and DORIS) in order to provide representations of the Vertical Total Electron Content (VTEC) with high spatial and spectral resolution. Since the ionospheric observations from space-geodetic missions are distributed rather unevenly over the globe, an appropriate modelling approach has to be developed. Our modelling approach is based on a two-level strategy, with a global modelling part as the first and a regional modelling part as the second level. To be more specific, the global VTEC model suffers from the inhomogeneity of observations and thus contains a moderate spatial and spectral resolution while in areas with a dense measurement distribution, a regional VTEC model with higher resolution is set up. This Two-Level-Model (TLM) is based on B-spline series expansions. The unknown B-spline series coefficients and additional observation dependent unknowns such as GNSS Differential Code Biases (DCBs) are estimated from pre-defined global and regional data sets by means of parallel running Kalman Filter processes for the two levels. In this contribution, we present our two-level modelling approach and the corresponding high-resolution VTEC products with global maps with moderate resolution and regional maps with high resolution.

C4.1-0007-18 PERFORMANCE OF THE IRI AND NEQUICK MODELS ON ELECTRON CONTENT REPRESENTATION: SPACEBORNE RADIO OCCULTATION AND TOPSIDE GPS TEC MEASUREMENTS

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The clarification of the ionosphere's structure and dynamics above the F layer peak is still a challenge for ionospheric model developers due to lack of topside ionosphere-plasmasphere data and measurements. Extension of current ionospheric models (first principal and climatological) to the plasmasphere together with improvement of the plasmasphere's part representation is actual now. During low solar activity and at night time the bottom side ionosphere contributes only about 20% of the ground-based total electron content (TEC), and the dominant contribution comes form the topside (>80%). So, reliable topside electron density representation is therefore of utmost importance for all ionospheric models. In this study we present new results of the concurrent analysis of the bottom and topside electron content values derived using unique 11 years database of COSMIC GPS Radio Occultation ionospheric profiles of electron density (ionPrf) product available on http://cdaac-www.cosmic.ucar.edu/, topside GPS measurements onboard the GOCE and TerraSAR-X satellites in order to estimate the electron content representation performance of the IRI, NeQuick-2 and IRI-Plas empirical models. The representative periods of low, moderate and high solar activities of the 24th solar cycle were analyzed. All three models were found to demonstrate good results for the bottom-side ionosphere's specification. The IRI and IRI-Plas models overestimate the electron content within the 250-500 km altitude interval for low solar activity and the topside total electron content (TEC) for the 500-20,000 km altitude range during daytime local time at low and moderate solar activities. The NeQuick 2 model demonstrates very similar to the IRI results for the 250-500 km region and the opposite behavior for the region above 500 km with underestimated values for all considered seasons and local time. The most important region for the model/model differences was found to be within the altitude range of 500-2000 km. The observed understatement in the NeQuick 2 topside TEC results can be related to the simplified extension of the electron density profile toward the GPS orbit altitude without adjustment of the specific plasmasphere model. However, the plasmasphere model included into the IRI-Plas leads to the noticeable overestimation of the TEC values derived from the spaceborne GPS measurements.

We can conclude that both IRI and NeQuick models have a need to be essentially improved in order to be able to specify more correctly the ionosphere-plasmasphere density above the F2 layer peak. It is strongly important because the profile-based empirical ionospheric models like IRI and NeQuick are required for the trans-ionospheric radiowaves propagation tasks, both navigation and communication.

C4.1-0008-18 BASE LEVEL TEC DERIVED FROM A GRIDDED REAL-TIME MODEL OVER THE INDIAN REGION

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A real-time model has been developed to provide the Total Electron Content (TEC) maps over the Indian region at 1°x 1° resolution in latitude and longitude. The input data is made available from a network of ground based dual frequency GPS (Global Positioning System) receivers deployed in India under the GAGAN (GPS Aided Geo Augmented Navigation) project. The multi-station diurnal runs of the model programme enables results of time-averaged TEC values at chosen intervals and grid sizes with graphical displays along with tabulated output. Apart from its utility for the navigation purpose, this real-time model is also well suited for off- line scientific applications to study TEC variations at high temporal and spatial resolutions. In this paper an attempt is made to generate a base-level standard of TEC variations for the low solar activity period of May 2007 to April 2008 separately for equatorial (11-18 °N)

and anomaly (19-24°N) latitude zones over India. The results are compared with the diurnal

TEC variations derived from IRI (International Reference Ionosphere) model under similar geophysical conditions. While there is a reasonably good agreement in the overall magnitudes of vertical TEC (VTEC) during different seasons, there are differences in the shape of the mean diurnal curve with IRI showing relatively smooth patterns compared to the real-time model results. Further the outcome of IRI model runs for a high solar activity year is compared with published data/results of GPS observations for similar periods from individual stations in India to check the effect of enhanced solar activity on the peak values and shapes of the diurnal pattern of TEC. The matches between IRI produced and observed VTEC for individual Indian stations for a high solar activity period of 2012 are better than those during 2007-08. Possible causes related to force functions from lower atmosphere need to be examined apart from the solar activity governed variations, particularly when the solar activity is low.

C4.1-0009-18 GLOBAL IONOSPHERIC AND PLASMASPHERIC ELECTRON CONTENT DERIVED FROM JASON-2/JASON-3 SATELLITES: COMPARISON WITH CLIMATOLOGICAL IONOSPHERIC MODELS

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Total Electron Content (TEC) derived from ground-based GPS/ GNSS measurements is one of the key ionospheric parameters widely used for ionosphere's research and space weather monitoring. Assimilation and adjustment of GPS/GNSS TEC to operational and assimilative ionospheric models is one of the most actual challenging task. Another important modeling effort relates to the accuracy improvement of the TEC representation by major climatological ionospheric models, like IRI and NeQuick, caused by known modeling issues for the topside ionosphere and plasmasphere.

The height of the GPS orbits is 20000 km above the Earth's surface. The ionized atmosphere surrounding the Earth at altitudes' range of about 80-100 km up to 3-5 Re represents a dispersive medium for GPS signals on their way to the ground-based GPS receivers. TEC, contributed by both the ionosphere and overlying plasmasphere along the ray GPS satellite

GPS receiver, is an integral value of electron density distribution in the ionosphere, iTEC, and the plasmasphere, pTEC. One of the limitations of the GPS TEC technique is impossibility to separate the GPS TEC value into its ionospheric and plasmaspheric parts, based on the ground-based GPS measurements only. We can gain new knowledge about plasma density distribution within the ionosphere-plasmasphere system using advantages provided by the space-borne GPS measurements. The satellite-borne up-looking GPS observations allows us to estimate directly the ionospheric/plasmaspheric TEC above the satellite altitude. We have investigated simultaneous measurements onboard the Jason-2/Jason-3 missions (altitude 1330 km): (1) the up-looking GPS measurement to derive global distribution of pTEC for altitudinal range of 1330-20000 km; (2) altimeter measurements over oceans to derive the iTEC distribution for altitudinal range of 100-1330 km. The present study is focused on a comparison of the iTEC/pTEC predictions provided by the IRI model (upper boundary limit of 2000 km) and by the models with plasmaspheric extension (assigned upper boundary to 20000 km), NeQuick-2 and IRI-Plas, with a unique data base of iTEC/pTEC as deduced from the Jason-2/Jason-3 satellites during four seasons of the years

2015-2017, moderate solar activity. We present major features of model-data discrepancies in a climatological domain for different longitudinal regions, local time and seasons.

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C4.1-0010-18 AN INSIGHT ON THE PERFORMANCE OF IRI MODEL IN ESTIMATING THE BOTTOM-SIDE AND TOP-SIDE ELECTRON DENSITY PROFILES DURING LOW AND HIGH SOLAR ACTIVITY CONDITIONS

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The equatorial and low latitude ionospheric variability is manifested by the typical electrodynamic phenomena namely, the Equatorial Ionization Anomaly (EIA). In the presence of large spatio-temporal gradients over the low latitudes, accurate estimation of ionospheric vertical electron density profiles and Total Electron Content (TEC) has gained significant importance in view of the satellite based communication and navigation applications. The present study gives a comprehensive report on the performance of IRI model in estimating different parameters in the bottom-side as well as the top-side profiles including the F-layer peak parameters and the TEC. The ground based ionosonde data and FORMOSAT-1 (formerly called ROCSAT) measured in-situ electron density in the topside ionosphere over the Brazilian equatorial and low latitude sectors during different solar activity conditions are considered for this study. The ionosonde derived bottom-side electron density profiles are used to validate the performance of three different options 'Gul-1987', 'Bil-2000' and the 'ABT-2009' in the IRI model. It is seen that the Gul-1987 method shows better predictions of the observed B0 at the equatorial and low latitudes when compared with the other options. The latest option 'ABT-2009' has shown improved predictions in the estimation of B1 compared with those from the other methods particularly during the night-time hours. A comparison on the seasonal characteristics of the day maximum values of B0 between observations and the three different options in IRI reveals that the Gul-1987 method shows better predictions of the seasonal variations in B0 while ABT-2009 method shows better predictions of seasonal variations in B1. The ground based ionosonde data in conjunction with the FORMOSAT-1 electron density are used to construct the top-side electron density profiles. A comparative study has been made on the diurnal and seasonal variations of F-layer peak parameters, top-side effective scale height (HT) and TEC between observations and IRI model simulations. It is observed that the models perform better in the prediction of NmF2 and hmF2 than in the prediction of TEC during day-time hours.

Further, it is observed that both IRI and the NeQuick2 models show considerable deviations in the estimation of the bottom

side profile parameters while more discrepancies are observed in the prediction of topside effective scale height values particularly during day-time hours.

C4.1-0011-18 PERFORMANCE OF MODEL OPTIONS OF IRI AS COMPARED WITH IONOSONDE DATA

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International Reference Ionosphere (IRI) is one of the most acclaimed and widely used climatic models of ionosphere that is used to obtain various parameters of ionosphere and plasmasphere such as electron density distribution, critical layer plasma frequency, maximum ionization height and ion and electron temperatures between 60 km and 2.000 km in height. IRI uses CCIR or URSI background hourly-monthly median model coefficients in determination of F2 layer critical frequency, foF2. IRI offers different model options that incorporate the ongoing contributions of IRI task group for optimum representation of global ionosphere. In the online version of IRI-2016 available at www.irimodel.org, there are two sets of options for the F2 layer: 'Fpeak storm model' (on or off) and 'F-peak height' (BSE-1979, AMTB-2013, SHU-2015). The solar, ionospheric and geomagnetic indices that are used in the model can be listed as 12- month running mean of sunspot number (Rz12), Ionospheric Index (IG12), Daily Solar Radio Flux (F10.7D), 81-day Solar Radio Flux (F10.7 81D), 3 hourly Ap (3-h ap), daily Ap (daily ap) and 3 hourly Kp (3-h kp). In this study, foF2 and hmF2 options are compared with all available ionosonde values during the equinox months October for 2011 and March 2015, in Root Mean Square (RMS) and Normalized RMS (NRMS) sense. The ionosondes are grouped into global (all ionosondes available), midlatitude, high-latitude, equatorial, northern midlatitude, southern midlatitude, northern high-latitude and southern high-latitude regions. Daily and monthly averages of all RMS and NRMS values for foF2 and hmF2 are computed for all ionosonde stations as well as regions. It has been observed that URSI-88 and CCIR model options provide very similar differences for midlatitude and quiet days, whereas on disturbed days, CCIR model in midlatitude and URSI model in equatorial regions provide a better fit to ionosonde results for foF2. As for hmF2, AMTB-2013 height model gives a smaller RMS and NRMS value compared to SHU-2015 both in midlatitude and equatorial regions for disturbed days. This study is supported by TUBITAK 115E915.

C4.1-0012-18 PERFORMANCE OF INTERNATIONAL REFERENCE IONOSPHERE (IRI2016) AND INTERNATIONAL REFERENCE IONOSPHERE-PLASMASPHERE (IRI-PLAS) MODELS OVER LOW LATITUDE INDIAN REGION DURING 23RD TO 24TH SOLAR CYCLE

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The present study is about ionospheric total electron content (TEC) over the low latitude Indian region from global positioning system (GPS) observables and comparative analysis with present version of International Reference Ionosphere (IRI-2016) and International Reference Ionosphere-Plasmasphere (IRI-Plas) models. With the recent revision of the solar sunspot number (SSN) time series, it insists re-examination of predictive efficiency of the above models whose underlying database have been updated with the recalibrated SSN values. Moreover, substantial improvements have been done in the 'IRI-Plas' model incorporating various solar proxy parameters (SSN1, SSN2, F10.7, Global Electron Content (GEC), TEC, IG, Mg II, Lyman-α and GEC_RZ). Hence, in the present work ionospheric TEC extracted from GPS stations at different latitudes across the Indian region covering the 23rd and 24th solar cycles are considered whose corresponding values are compared with IRI-2016 and IRI-Plas estimations with various solar proxy options. Also, the effectiveness of IRI-Plas by injecting observed TEC values into the model are analyzed taking diurnal, seasonal and solar cycle variability in to consideration. The studies report interesting interpretations, particularly in the IRIPlas model, leading towards sensible ionospheric model improvements over equatorial and low latitude region.

C4.1-0013-18 ELECTRON DENSITY MODELS OF PLASMASPHERE

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Electron densities at altitudes below 10,000km were estimated from the upper-hybrid resonance (UHR) emission observed by the plasma wave and sounder experiments (PWS) on Akebono satellite from February 22, 1989 to April 23, 2015. The electron densities at more than 4 million locations in the plasmasphere have been obtained for 26 years. We have constructed two kinds of electron density model of plasmasphere from the Akebono/PWS data. One is the empirical model by use of simple base functions with the parameters of longitude, latitude, local time, season and solar/magnetic activities. The other model is made with deep learning method with the same parameters to the empirical model. Both models show very good correlations with the satellite data. Both electron density models of plasmasphere were compared with International Reference Ionosphere model below 2,000 km altitudes. There are good agreements between IRI model and the plasmasphere models. However, we found some differences in the polar cap region. The electron density enhancements seen in the models and satellite data may be due to plasma heating and/or polar winds in the polar region. The models indicates that the plasmaspheric electron density contributes to TEC with a few percent.

C4.1-0014-18 COMPARING ISS FPMU TOPSIDE ELECTRON DENSITIES WITH IRI-2016 MODEL AND COSMIC RADIO OCCULTATION MEASUREMENTS

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The Floating Potential Measurement Unit (FPMU) instrument suite on the International Space Station (ISS) provides redundant measurements of the electron density, electron temperature, and spacecraft potential along the ISS orbit. Deployed in August 2006, the FPMU includes a Wide Langmuir Probe, Narrow Langmuir Probe, Floating Potential Probe, and a Plasma Impedance Probe. The instruments are used for ISS engineering applications, ISS science payload support, and collaboration with the ionospheric science community. FPMU provides in-situ observations of plasma density and temperature at or above the peak plasma density in the F2-region ionosphere due to the typical 350 km to 400 km flight altitude of the ISS. This presentation will first compare the in-situ FPMU measurements of electron density and temperature with the IRI-2016 model and COSMIC radio occultation measurements of electron density. We then describe FPMU data that is now available to the space science community through NASA's Space Physics Data Facility, providing a new source of topside ionosphere plasma density and temperature values for use in working with the IRI model, other ionospheric physics models, and other satellite and ground based observations.

C4.1-0015-18 IMPROVING THE SOLAR ACTIVITY VARIATION OF THE IRI TOPSIDE ELECTRON DENSITY PROFILE

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In situ measurements by the Low Earth Orbital (LEO) satellites, such as CHAMP, GRACE, and C/NOFS satellites have shown that the International Reference Ionosphere (IRI) model has shortcomings in describing the solar activity variation of the topside electron density. In particular IRI overestimates the measured densities during the very low solar activity reached during the last solar minimum (2008-2009). IRI is an empirical model and so if discrepancies are found between IRI and a reliable data set the logical next step is to use this data to improve the model. We have undertaken a study to correct the IRI topside profile not only with the CHAMP, GRACE, and Swarm in situ measurements but also with the data from the Alouette and ISIS topside sounder satellites. These data are used to introduce a solar activity term to the IRI-2016-corr option model for the topside electron density profile. We will discuss the improvement achieved by using theses satellites observations within the new IRI model.

C4.1-0016-18 ASPECT OF TOPSIDE ELECTRON DENSITY MEASURED BY RADIO OCCULTATION OF FORMOSAT-3/COSMIC SATELLITES AND DIGISONDES ON A GLOBAL SCALE WITH IRI

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This study represents a comparison of the topside electron density of the F2-layer measured by FORMOSAT-3/COSMIC satellites in terms of GPS radio occultation technique and digisondes as manually scaled ionograms being provided by DIDBase (Digital Ionogram Database) with IRI. This study encompasses data from more than 40 locations for an extended period from January 2007 to December 2015. It utilises a subset of around 1000 very well matched (in terms of bottomside) FORMOSAT-3/COSMIC (Digisonde electron density profile pairs to compare the corresponding topside electron density profiles with IRI. The selection criteria for the electron density profile pairs, apart from coincidence of COSMIC and Digisonde electron density in the bottomside, is a collocation distance of less than 2.5o in terms of latitude and longtitude and 15 min maximum time difference in measuring NmF2 with the two techniques.

C4.1-0017-18 IMPROVING THE ELECTRON AND ION TEMPERATURE MODELS IN IRI

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The International Reference ionosphere (IRI) model includes models of the electron and ion temperatures. For the electron temperature two options (TBT-2012 and Bil-1985) are available based on spherical harmonics expansion up to 8th order. The ion temperature in IRI is derived from the energy balance equation among ions, electrons and neutrals. In this study we will discuss recently available data sets (Swarm LP, ISS-FPMU, and Champ LP) to assess their potential for improvement of the electron temperature model especially its spatial resolution. We will present the global distributions of the electron temperature modeled using higher order of spherical harmonics and we will discuss their inclusion in the TBT-2012 option. We have re-examined ion temperature data from older satellites and combined them with newly available data from DMSP, C/NOFS, and others (primarily from SPDF: https://spdf.gsfc.nasa.gov/pub/data/) into a unified data-base. This data-base has been used to establish global patterns of the ion temperature and to determine Ti variation with solar activity. To better understand the solar activity variations of the ion temperature at different latitudes and local times we have used simulations with the Field Line Interhemispheric Plasma flow (FLIP) model. We will also present ratio of the electron and ion temperatures dependence on geophysical parameters and a comparison with recent measurements from another sources (e.g. Kharkiv Incoherent Scatter Radar). Finally, we will discuss future improvements of the plasma temperature models through data assimilation.

C4.1-0018-18 A COMPLETED 3D IONOSPHERIC ELECTRON DENSITY MODEL FOR USE AT HIGH LATITUDES: E-CHAIM

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Following the development of the Empirical Canadian High Arctic Ionospheric Model (ECHAIM)'s F2-peak and topside components, we have now undertaken the challenge of creating a matching bottomside for E-CHAIM. For this bottomside, we have developed a variable semiEpstein layer parameterization, where the scale thicknesses of this layer are represented by a sum of layer functions associated with the E-region, F1-layer, and F2-layer. The coefficients of each of these layers are independently modeled using a spherical cap harmonic expansion in magnetic latitude and magnetic local time to represent horizontal and diurnal variability. A Fourier expansion in day of year is used to represent seasonal variations. By modeling our bottomside in the scale thickness domain of a single layer, we avoid the need for an F1-layer occurrence trigger, such as that used by the International Reference Ionosphere (IRI). This study details the E-CHAIM bottomside profiler, whose development was informed by challenges that have been reported in the use of the IRI and NeQuick at high latitudes.

With the bottomside online, the E-CHAIM set of models is now a complete 3D electron density representation for the high latitude ionosphere. In this talk we will further demonstrate some of the capacities of the model and discuss the next step in model development, namely the incorporation a data assimilation framework.

C4.1-0019-18 AN EMPIRICAL MODEL OF GLOBAL DAND E-REGION ELECTRON DENSITY FROM GPS-RO OBSERVATIONS

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A background electron density (Ne) model is developed from the Dand E-region (80-120 km) ionosphere using GPS radio occultation (GPS-RO) observations in 2006-2017. While the background Ne morphology (monthly maps, zonal means and diurnal variations) retrieved from GPS-RO is in overall agreement with the IRI (International Reference Ionosphere) model, differences remain and can be readily seen in the seasonal transition and in the D-region ionosphere. The daytime GPS-RO Ne profiles can be well characterized by the Chapman function of three parameters (NmE, hmE and H), showing that the bottom of E-region is deepening and sharpening towards the summer pole. The empirical model of the background E-region Ne developed here is based on the Chapman function (Chapman, 1931a,b) but generalized for the nighttime Ne. Chapman (1931b) extended the near-nadir formula (Chapman, 1931a) with the intent to better describe twilight Ne profiles. The generalized function (Chapman, 1931b) is used to fit the GPS-RO observations, and the fitted coefficients are functions of solar zenith angle and the Lyman-α index. The empirical Ne model is able to capture most of daytime and twilight Ne variabilities in the Dand E-region ionosphere at scales from diurnal to solar 11-year cycles.

C4.1-0020-18 NUMERICAL MODELING OF SEASONAL AND DIURNAL VARIATIONS OF LOWER IONOSPHERIC REFLECTION PARAMETERS BASED ON IRI MODEL

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Very Low Frequency (VLF) radio wave travels through the earth ionosphere waveguide and modulates according to the electron/ion density profile of the ionosphere. The Wait's two component model deals with ionospheric reflection parameters known as effective reflection height

(h1) and steepness parameter (β). Theoretically, β is the positive slope electron density profile curve as a function of height. We try to compute a range of values from the electron density profile of ionosphere. International Reference Ionospheric (IRI) model 2012 is an empirical standard model of the ionosphere, based on all available data sources. We compute the ionospheric reflection parameters (β and h1) from the true electron density profile as taken from

IRI model for the year 2016 from altitude range 65 km - 85 Km at IERCOO/ICSP, Sitapur (22.5°N, 87.48°E). We try to compute all sets of possible β and h1 for NWC-IERCOO path for different time of the day and for the entire 2016. By using β and h1 and LWPC code, a diurnal and seasonal trend of VLF signal amplitude profile is computed.

C4.1-0021-18 THE USE OF EFFECTIVE IONOSPHERIC AND SOLAR INDICES TO UPDATE THE IRI MODEL

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A method to real-time update the IRI model through data assimilated by a European ionosonde network is proposed, described and statistically evaluated under disturbed geomagnetic conditions. This method, called IRI UP (International Reference Ionosphere UPdate), relies on foF2 and M(3000)F2 ionospheric characteristics routinely recorded by a network of 12 European ionosonde stations. Assimilated data are used to calculate updated values of IRI indices IG12 and R12 (identified as IG12eff and R12eff) for every station's point; then, starting from this discrete dataset of values, two-dimensional maps of IG12eff and R12eff are generated through the universal Kriging. Five variogram models are used and statistically tested to verify which of these perform better for each effective index. Maps of IG12eff and R12eff are then used as input for the IRI model, which consequently gives as output updated values of foF2 and hmF2. In order to evaluate the ability of the proposed method to catch fast-time and smallscale changes that are usual under disturbed conditions, statistical quantities are calculated for two test stations (not considered in the assimilation process), Fairford (51.7 N, 1.5 W) and San Vito (40.6 N, 17.8 E), for the IRI model with the STORM option set to on, and for IRI UP and for IRTAM methods. The method here proposed turns out to be very effective, with significant improvements regarding foF2 and slight improvements for hmF2.

C4.1-0022-18 UNPHYSICAL BEHAVIOR IN IRI-2016 AND SUITABILITY FOR APPLICATIONS

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We describe a number of unphysical features, such as discontinuities, observed in the International Reference Ionosphere 2016 model, when fed with real solar data input parameters observed in 2016 and 2017. We also describe how these unphysical artifacts impact various applications of researchers and space weather users.

C4.1-0023-18 CORRELATION OF IRTAM AND FPMU DATA CONFIRMING THE APPLICATION OF IRTAM TO SUPPORT ISS PROGRAM SAFETY

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A "Real-Time" plasma hazard assessment process was developed to support International Space Station (ISS) Program real-time decision-making providing solar array constraint relief information for Extravehicular Activities (EVAs) planning and operations. This process incorporates real-time ionospheric conditions, ISS solar arrays' orientation, ISS flight attitude, and where the EVA will be performed on the ISS. This assessment requires real-time data that is presently provided by the Floating Potential Measurement Unit (FPMU) which measures the ISS floating potential (FP), along with ionospheric electron number density (Ne) and electron temperature (Te), in order to determine the present ISS environment. Once the present environment conditions are correlated with International Reference Ionosphere (IRI) values, IRI is used to forecast what the environment could become in the event of a severe geomagnetic storm. If the FPMU should fail, the Space Environments team needs another source of data which is utilized to support a short-term forecast for EVAs. The IRI Real-Time Assimilative Mapping (IRTAM) model is an ionospheric model that uses real-time measurements from a large network of digisondes to produce foF2 and hmF2 global maps in 15-minute cadence. The Boeing Space Environments team has used the IRI coefficients produced in IRTAM to calculate the Ne along the ISS orbital track. The results of the IRTAM model have been compared to FPMU measurements and show excellent agreement. IRTAM has been identified as the FPMU back-up system that will be used to support the ISS Program if the FPMU should fail.

C4.1-0024-18 VALIDATION OF THE IRI-2016 MODEL WITH GPS-BASED GROUND OBSERVATION OVER A LOW LATITUDE INDIAN REGION FOR THE YEARS (2009-2014)

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The present study reports the analysis of GPS derived TEC from three different stations in the low latitude Indian region. The data are obtained in RINEX format from IGS stations IISC (geographic latitude 13.02°N, geographic longitude 77.57°E; geomagnetic latitude 4.58°N), HYDE (geographic latitude 17.25°N, geographic longitude 78.30°E; geomagnetic latitude 8.65°N) and a standalone GISTM receiver in operation at SURAT (geographic latitude 21.16°N, geographic longitude 72.78°E; geomagnetic latitude 12.90°N), for six years (2009-2014) in a period of low to high solar activity. The seasonal variations of the obtained GPS-TEC are plotted for all the stations (situated at latitude interval of 4 degrees) and compared with those obtained by latest IRI2016 model https://omniweb.gsfc.nasa.gov/vitmo/iri2016vitmo.html). The analysis is done to check the IRIp Quick and IRI01–corr for the year 2010.However, there are deviation in 2011–2014. Overall as we go towards the higher latitude (i.e., Anomaly crest), with an increase in solar activity the deviation increases from overestimation and underestimation of the TEC for anomaly crest station Surat.

C4.1-0025-18 COMPARISON OF GLOBAL IONOSPHERE MAPS USING DIFFERENT BASIS FUNCTIONS

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Several IGS (International GNSS Service) associated analysis centers (AC) provide ionosphere information in terms of global ionosphere maps (GIM). In general, GIMs represent the vertical total electron content (VTEC) as a 3-D function depending on latitude, longitude and time. Usually function representations on sphere-like surfaces are based on appropriately defined basis functions, such as spherical harmonics (SH), voxels or B-splines. The choice for appropriate basis functions for ionosphere modelling is a trade-off between the distribution of available data and their possibility to represent high-frequency ionosphere signals. However, the IGS associated ACs generate GIMs by the usage of different basis functions and represent the VTEC with different spectral and spatial resolutions. Hence, a comparison of their products in terms of VTEC maps seems not to be advisable. Within this contribution we define a procedure to compare VTEC models on the basis of their spectral and spatial resolutions. We use this procedure to compare SH models with B-splines representations and derive relations in terms of given resolution levels.

C4.1-0026-18 SIMILARITIES AND DIFFERENCES OF IONOSPHERIC PLASMA GRADIENTS DERIVED FROM GROUND-BASED REGIONAL TEC MAPS AND IRI MODEL

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The ionosphere is a very important research area from the radio science and radio telecommunication based applications point of view, as it is a highly dispersive and refractive medium for radio waves. Moreover it is very unstable and multiple factors dependent. For decades the ionosphere has been widely monitored using various spaceand ground-based facilities and techniques. As result many empirical ionospheric models - such as International Reference Ionosphere (IRI) - were developed. The models quite well illustrate the general structure and variability of the ionosphere, but many impossible or difficult to predict fluctuations may interfere with the radio signal on the level that would seriously affect satellite or radio astronomical systems performance. The irregularities also have been extensively studied by different techniques, including ground-based GPS/GNSS observations. Ionospheric irregularities can be monitored with the maps, by studying horizontal gradients of the plasma density (total electron content, TEC) in time. We developed the TEC gradient maps based on the global UQRG product and high-resolution (0.5 degree in latitude and longitude) regional TEC maps covering Europe. GNSS-based ionospheric monitoring provides also instruments dedicated to plasma fluctuations detection. One of such well-know and widely used tools is the rate of TEC index (ROTI), which is currently available for whole community as an International GNNS Service (IGS) product (for the Northern hemisphere). Presented climatological characteristics of the spatial TEC gradients are superimposed and analyzed with the global and regional ROTI product and IRI in order to reveal development of highly intense plasma irregularities occurred at high and middle latitudes. During geomagnetic storm the complex of physical processes at auroal zone leads to development of intense ionospheric irregularities and traveling ionospheric disturbances (TIDs). We present results compared for the quiet time periods and geomagnetic storm events.

C4.1-0027-18 MORPHOLOGICAL STUDY ON THE SEASONAL VARIATIONS OF EQUATORIAL IONIZATION ANOMALY (EIA) OVER THE BRAZILIAN SECTOR USING GPS-TEC NETWORK AND IRI MODEL DATA DURING LOW SOLAR ACTIVITY

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The equatorial and Low-latitude ionospheric regions show solar cycle, seasonal and day-today space-time variations, due to strong electrodynamics and thermosphere-ionosphere coupling. Consequently, the Equatorial Ionospheric Anomaly (EIA) morphology and space-time evolution show a strong variability. In this study the EIA seasonal morphology and space-time variations are investigated using the observations from a network of 35 GPS-TEC receivers over the Brazilian sector during the low solar activity period from January 2016 to December 2016 (mean F10.7=89 10 -22 W/m2 Hz). Since the distances between the geographic and magnetic equators vary from 3 o to 10 o (350 to 1200 km) in the Brazilian sector, the EIA characteristics are investigated in 3 different longitudinal sectors. These longitudinal sectors are separated from each other by about 6 o longitude (700 km). It is noticed that the EIA is formed during daytime from 11:00 to 24:00 UT for the whole year. However, the EIA is much more intense from January to April and less intense from May to August. In addition, the pre-reversal electric field follows the similar behavior. In general the EIA in all 3 chosen sectors are quite similar. However, some differences are noted during the months of September and October. Also, a comparison between the GPS-TEC data and IRI model output is made and the results are discussed.

C4.1-0028-18 STATISTICAL PROPERTIES OF IONOSPHERIC EAND F1-LAYER MEASURED WITH THE CYPRUS DIGISONDE AND COMPARISONS WITH IRI PREDICTIONS

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Characteristics of ionospheric Eand F1-layer (critical frequency, peak height, and occurrence probability) derived from Digisonde measurements from 2009 to 2016 at the low-middle latitude European station of Nicosia, Cyprus (geographical coordinates: 35°N, 33°E, geomagnetic lat. 29.38°N, I = 51.7°) have been investigated. Manually scaled monthly median values of foE, hmE, foF1, and hmF1 are compared with IRI-2012 predictions with a view to assess the predictability of IRI.

SPACE STUDIES OF THE UPPER ATMOSPHERES OF THE EARTH AND PLANETS INCLUDING REFERENCE ATMOSPHERES (C)

DEVELOPMENT OF MODELS RELATED TO THE COSPAR INTERNATIONAL REFERENCE ATMOSPHERE (CIRA) AND TO ISO STANDARDS FOR THE ATMOSPHERE (C4.2)

C4.2-0001-18 THE ONGOING DEVELOPMENT OF THE COSPAR INTERNATIONAL REFERENCE ATMOSPHERE (CIRA) AND RELATED ISO STANDARDS FOR THE EARTH'S ATMOSPHERE.

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This presentation will review the significant upgrades of global models that have provided the basic structure of CIRA. In addition, the formal extension of CIRA downward from 100 km to ground level is proposed. This extension is provided by the GRAM and MSIS-E-00 models which are currently adopted formally above 100 km) only and by reference to the assimilative model provided by ECMWF. The later model provides corrected high-resolution data on the atmosphere on a day-by-day basis.

C4.2-0002-18 EARTH GLOBAL REFERENCE ATMOSPHERIC MODEL (GRAM) OVERVIEW AND FUTURE IMPROVEMENTS

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NASA Marshall Space Flight Center's (MSFC) Earth Global Reference Atmospheric Model (GRAM) is a reference or standard atmosphere used for design and mission planning of various aerospace systems. Earth-GRAM was developed in response to the need for a design reference atmosphere that provides complete global geographical variability, complete altitude coverage (surface to orbital altitudes), and complete seasonal and monthly variability of thermodynamic variables and wind components. A unique feature of GRAM is that, in addition to providing the geographical, height, and monthly variation of the mean atmospheric state, it includes the ability to simulate spatial and temporal perturbations in these atmospheric parameters. The NASA/MSFC Natural Environments Branch recently released Earth-GRAM 2016 to the user community. A main feature in Earth-GRAM 2016 was converting the code from Fortran90 to C++. The Natural Environments Branch intends to make future improvements to EarthGRAM as well as investigate the availability and improvements of model reanalysis for data input. The paper will describe an overview of Earth-GRAM, examine future updates, and identify areas of needed improvement.

C4.2-0003-18 NRLMSIS 2.0: NEW FORMULATION, NEW DATA

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A major upgrade to the NRLMSISE-00 (Naval Research Lab Mass Spectrometer and Incoherent Scatter Radar Extended) empirical atmosphere model is presented. This model describes the temperature and eight atmospheric species as a function of position, time, solar activity, and geomagnetic activity. The new MSIS2.0 formulation includes 1) an effective hydrostatic species mass parameterization to represent the transition from a fully mixed atmosphere to diffusive separation; 2) an atomic oxygen (O) profile extending down to 50 km altitude, with a robust representation of peak O density and a chemistry-dominated region decoupled from temperature below 85 km; and 3) a temperature profile with C2 continuity throughout the atmosphere. Major new assimilated data sets include 1) lower atmospheric meteorological reanalyses; 2) space-based and ground-based measurements of temperature in the mesosphere and lower thermosphere (MLT); 3) space-based measurements of O and H densities in the MLT; and 4) upper thermospheric mass density derived from satellite orbit data (covering 47 years) and from accelerometers. The presentation will show new model output against the assimilated data, and highlight important differences between the outputs of MSIS2.0 and NRLMSISE-00. Work sponsored by NASA and the Chief of Naval Research Naval Research Laboratory Base Program.

C4.2-0004-18 THE UPDATED JB2008 SOLAR INDICES AND WHAT THEY INFER ABOUT THE CHANGING THERMOSPHERE

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The JB2008 thermospheric density model uses solar and geomagnetic indices to calculate the temperatures and densities of the upper atmosphere. On a periodic basis we review the indices and update them by comparing the derived densities in JB2008 with densities required to produce well-known calibration satellite drag phenomena. We describe the most recent update to the JB2008 solar activity indices using this methodology. One interesting feature is during the solar minimum timeframes of every solar cycle, including solar cycle 24 whose minimum we are now entering. The reduction in thermospheric densities in JB2008 required to match the collapsed density of the thermosphere as seen by the satellites is significant. This has historically been referred to as thermospheric cooling due to excess carbon dioxide cooling in the lower thermosphere. Because JB2008 does not account for this secular density reduction, we empirically use the strongest solar index, S10, as the input we can most effectively change to affect thermospheric densities. While the Sun irradiances in the 28.4 and 30.4 nm bands, as represented by S10, do not change to the extent we require, as measured by the SDO EVE satellite, we report on changes we make to S10 on the order of -30% during solar cycle 24 minimum to achieve the same densities above 200 km in JB2008 as seen by LEO satellites. We discuss implications for improvements to future measurements and model requirements.

C4.2-0005-18 THE H2020 PROJECT SWAMI (SPACE WEATHER ATMOSPHERE MODEL AND INDICES)

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In the framework of the H2020 project SWAMI funded by the European Commission (EC), which started in January 2018, a new whole atmosphere model (0-1500 km) will be developed that can be used for: • launch operations, • re-entry computations, • orbit determination and prediction, • aeronomy and space weather studies. Such a model is currently not available in Europe, whereas models in the US and Japan have certain sometimes critical limitations and cannot be used in (operational) orbit computation.

The model will be constructed by blending two existing models, the Drag Temperature Model (DTM) and the Unified Model (UM). The CNES thermosphere specification model DTM2013, which was developed in a previous EC project (ATMOP), will first be improved by assimilating more density data to drive down remaining biases as a function of solar activity and seasons mainly. Secondly, a new high cadence Kp geomagnetic index, which will be developed as part of the project, will be used in order to improve storm-time performance. The whole atmosphere model will be made available in a user-friendly package in 2020.

In this presentation, the established benchmark (DTM2013-to-data comparisons and the adopted model performance metric) for the new thermosphere model as well as preliminary model results will be shown.

C4.2-0006-18 AN OPEN DISCUSSION OF CURRENT AND FUTURE DEVELOPMENT OF THE COSPAR INTERNATIONAL REFERENCE ATMOSPHERE AND RELATED ISO STANDARDS FOR THE EARTH'S ATMOSPHERE.

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This is intended to provide an opportunity for open discussion of the current and future development of the COSPAR International Reference Atmosphere (CIRA) and related ISO Standards for the Earth's Atmosphere. The discussion is intended to include the ongoing work of SC-6, which it is hoped can be presented and discussed during the C4.2 / C0.1 Meetings held during the COSPAR-2018 Assembly.

C4.3-0001-18 UPDATING THE VENUS ATMOSPHERIC STRUCTURE FOR VIRA

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Many atmospheric profiles of the temperature structure have been obtained since the adoption of the Venus International Reference Atmosphere (VIRA) model in 1985 (Seiff et al., 1985) from occultations (Venus Express, Magellan and Akatsuki orbiters), passive remote sensing (VIRTIS on Venus Express) as well as balloons (VeGa 1 and VeGa 2) and descending probes through the atmosphere (VeGa 1 and VeGa 2 landers). Interim updates to the VIRA model were proposed by Moroz and Zasova (1997) and Zasova et al. (1996). Limaye et al. (2017) presented a comparison of post VIRA results on the atmospheric structure which included results from different Venus Express investigations as well as those from ground based observations. Akatsuki orbiter is currently obtaining radio occultation profiles of temperature (Imamura et al., 2017). These post VIRA data have expanded the coverage in latitude, longitude and local time and altitude, and thus updates to the temperature structure on Venus with altitude (pressure) and latitude and local time are possible and needed.

It is worth re-visiting the thermal structure data in light of the apparent confirmation of a gradient in the nitrogen mixing ratio (Peplowski Lawrence, 2016) as high as 64 km altitude from MESSENGER neutron spectrometer observations and was previously detected by (Oyama et al., 1980) but not explained. It is possible that this gradient exists because both the major constituents (carbon dioxide and nitrogen) of the Venus atmosphere should exist near the surface under supercritical conditions and the supercritical nature was not considered in any of the profiles. This density gradient can affect all calculations of altitude that involve the hydrostatic balance assumption and affect the adiabatic lapse rate (Lebonnois Schubert, 2017).

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C4.3-0002-18 PROGRESS TOWARDS A POST-VENUS EXPRESS CLOUDS & HAZE REFERENCE MODEL FOR VENUS

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With the end of Venus Express in 2014, the focus of the scientific community has gradually moved from the study of Venus Express mono-instrumental data sets to cross-instrumental studies involving pure modeling as well. This is especially true for the clouds and hazes that surround most of the planet between 48 and 70 km. They play a major role at the crossroads of various atmospheric processes among which the radiative budget as well as the dynamical and chemical coupling between the lower and upper atmosphere. In order to support such efforts, ISSI has supported from 2013 to 2015 a "Clouds Hazes of Venus" scientific team involving Venus Express and ground-based observers as well as microphysical modelers. Together, they compared their results in order to achieve a more unified and consistent view of Venus' clouds and hazes, taking into account its spatial and temporal variability more in detail than previously available VIRA-1 and 2 cloud models. We will review the individual data sets and models that have been used, and then present our strategy towards a unified cloud model. We will first make available some observable parameters to the wider community through a web-based repository. Future steps may involve more advanced techniques (e.g. data assimilation) in order to achieve our objective of a unified Venus clouds haze model that encompasses its various variabilities as well as possible.

C4.3-0003-18 MODELING OF HIGH-PRESSURE MULTI-SPECIES TURBULENT MIXING APPLICABLE TO THE VENUS LOWER ATMOSPHERE

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The thermodynamic conditions in the Venus atmosphere, nominally at a pressure of 92 atm, a temperature of 750 K and having a global nominal composition of 96.5% CO2 and 3.5% N2 imply that heat and mass exchange processes in the atmosphere occur under supercritical conditions. In contrast to well-known heat and mass exchange processes at 1 bar, 298 K and Earth atmosphere composition, those on Venus must be described using real-gas thermodynamics, generalized species-mass and heat fluxes based on the formulation of dissipation-fluctuation theory and consistent high-pressure transport properties utilizing high-pressure valid mixing rules. The presence of minor (i.e. tracer) species in the Venus atmosphere - 150 ppm SO2, 70 ppm Ar, 20 ppm H2O and 17 ppm CO — may introduce some aspects, such as metastable states, that have not been considered so far. A comprehensive theory of high-pressure multispecies mixing is presented and salient results pertinent to the Venus atmosphere are discussed. Further, using this theory, simulations of CO2 and N2 mixing at high pressure and temperature are discussed and analyzed. To evaluate the model, spatial, rather than temporal simulations were performed of a N2 jet at 750 K injected into a chamber pressurized to 60 atm and containing CO2 at 450 K. The Direct Numerical Simulation computations reveal that the high density gradients observed in the five-species mixing are also present for CO2/N2 mixing and are of order 104 kg/m4. Time-averaged results exhibit a potential core near the inlet, downstream of which the density increases due to the mixing of N2 with the heavier CO2. The studies described above show the intricacies of multi-species turbulent mixing under Venus-like loweratmosphere pressure and temperature conditions. The model can be used to study the time evolution of a three-dimensional vertical slice of the Venus Planetary Boundary Layer with a domain having non-reflecting boundary conditions (i.e. domain size influence minimized). Since the near-ground Venus atmosphere composition is not known with certainty, additional to CO2/N2, other compositions, i.e. including minor species, can be simulated to determine whether the Venus atmosphere could be in a metastable state in which micro-drops are suspended into a fluid; then the interpretation of signals from probes moving vertically through the Venus atmosphere would require special interpretation, i.e. accounting from scattering from the micro-drops. The near-ground unstable temperature gradient may also be explained by such findings.

C4.3-0004-18 SOIR INFRARED SPECTRAL ATLASES OF THE VENUS' ATMOSPHERE

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Based on the entire set of SOIR spectra measured during the Venus Express mission (2006- 2014), spectral atlases have been produced. During its lifetime, SOIR measured 779 solar occultations, spanning the Venusian atmosphere with tangent heights from 65 to 180 km. The instrument combined an echelle spectrometer and an Acousto-Optical Tunable Filter (AOTF) for order selection. It measured spectra in the IR region (2.2 - 4.4 µm) at a resolution of 0.10 0.24 cm−1 [?]. This spectral range allows a detailed chemical inventory of the Venus atmosphere above the cloud layer with emphasis on the vertical distribution of gases (CO2, CO, H2O, HCl, HF.). Both the spectra and the derived profiles are accessible online through the ESA PSA archive1 and the VESPA interface2 [?], respectively.

To produce spectral atlases, the transmittances obtained in [?] have been averaged over latitudinal bins in different altitude ranges, for the morning and evening terminator respectively. A statistical analysis of the dataset has been performed leading to the creation of one atlas per bin of latitude/altitude/terminator. These atlases will be compared from different viewpoints in order to highlight molecular species variability.

In addition, the sensitivity of the SOIR instrument, coupled with the long absorption paths sounded during solar occultations, enable us to assign the ro-vibrational lines measured in the spectra. The assignment of the lines has been done using HITRAN2016 [?]. A tool of automatic 1https://archives.esac.esa.int/psa/ 2http://vespa.obspm.fr/planetary/data/epn/query/all/ assignment was developed and applied to each atlas leading to the creation of the wavenumber list of each absorption line.

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C4.3-0005-18 MARS AND VENUS GLOBAL REFERENCE ATMOSPHERIC MODEL (GRAM) UPDATES

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The Global Reference Atmospheric Models (GRAMs) are engineering-level atmospheric models applicable for engineering design analyses, mission planning, and operational decision making. GRAMs are currently available for Earth, Mars, Venus, Neptune, and Titan. Over the past decade GRAM upgrades and maintenance have depended on inconsistent and waning projectspecific support. The first GRAM Virtual Workshop was held on September 21, 2017 and was attended by GRAM developers, GRAM users, planetary atmospheric modelers, and other interested parties. This workshop served to identify and prioritize user needs along with facilitating communication between modelers and developers. Based on the current status of the GRAMs as well as the workshop findings, the NASA Science Mission Directorate (SMD) has agreed to provide funding support in Fiscal Year 18 and 19 to upgrade the GRAMs. This presentation will provide an overview of the current status of Mars and Venus-GRAM, the findings from the GRAM Virtual Workshop, as well as the objectives, tasks, and milestones related to the Mars and Venus-GRAM upgrades funded by NASA SMD.

C4.3-0006-18 EXPLORING THE INTERANNUAL VARIABLITITY OF THE MARTIAN ATMOSPHERE WITH THE MARS CLIMATE DATABASE V5.3

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The latest Mars Climate Database (version 5.3) includes synthetic scenarios (namely the “clim” climatology scenario, representative of a standard Mars year without any global dust storm) as well as specific scenarios corresponding to eight actual Mars years, from Mars Year 24 to Mars Year 32.

At the COSPAR 2018 scientific assembly, we will address the validation of MCDv5.3 scenarios with available observations from spacecrafts and landers, and discuss more specifically of the obtained multi-annual climatologies and how these deviate over the years.

C4.3-0007-18 REFERENCE DATASETS FOR THE MARTIAN ATMOSPHERE USING SATELLITE DATA GRIDDING, KRIGING, AND ASSIMILATION

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We provide a multiannual climatology of airborne dust from Martian year 24 to 33 using atmospheric observations from April 1999 to May 2017 made by the Thermal Emission Spectrometer (TES) aboard Mars Global Surveyor, the Thermal Emission Imaging System aboard Mars Odyssey, and the Mars Climate Sounder (MCS) aboard Mars Reconnaissance Orbiter.

Our methodology works by gridding the available retrievals of column dust optical depth (CDOD) from TES and THEMIS nadir observations, as well as the estimates of this quantity from MCS limb observations. The resulting (irregularly) gridded maps were validated with independent observations of CDOD by PanCam cameras and Mini-TES spectrometers aboard the Mars Exploration Rovers “Spirit” and “Opportunity”, by the Surface Stereo Imager aboard the Phoenix lander, and by the Compact Reconnaissance Imaging Spectrometer for Mars aboard MRO. Regular maps of CDOD are produced by spatially interpolating the irregularly gridded maps using a kriging method. These latter maps are used as dust scenarios in the Mars Climate Database (MCD) version 5, and are useful in many modelling applications. The two data sets (irregularly gridded maps and regularly kriged maps) for the ten available Martian years are publicly available and can be downloaded from the MCD website at http://www-mars.lmd.jussieu.fr/mars/dust_climatology/index.html .

We also use a much more sophisticated methodology to produce a reanalysis of fundamental atmospheric and surface variables for Mars, using data assimilation of TES retrievals of temperature profiles and CDODs, as well as MCS retrievals of temperature and dust opacity profiles. The Mars Analysis Correction Data Assimilation (MACDA) version 1.0 is a publicly available dataset that contains the atmospheric reanalysis covering a period of about four Martian years (MY 24 to 27) during the TES science mapping phase (February 1999 - August 2004). Data have been assimilated into a Mars global climate model (MGCM) using the Analysis Correction scheme developed at the UK Meteorological Office. The used MGCM is the UK (Oxford University and The Open

University) spectral version of the Laboratoire de Meteorologie Dynamique (LMD, Paris, France) MGCM. MACDA v1.0 is available from the UK Centre for Environmental Data Analysis (CEDA) at http://bit.ly/165Ulxd.

The MACDA reanalysis is currently being extended from MY 28 to MY 33. Improved dust assimilation, higher resolution, the use of the latest versions of TES and MCS retrievals, and improved validation are some of the key features of the new multiannual atmospheric reanalysis.

C4.3-0008-18 RADIO SOUNDING OF THE MARS IONOSPHERE OVER A FULL SOLAR CYCLE BY THE MARS EXPRESS RADIO SCIENCE EXPERIMENT (MARS)

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The Mars Express Radio Science experiment MaRS sounds the ionosphere of Mars since 2004. It started during the declining phase of the past solar cycle in 2004, went through a pronounced deep and long solar minimum in 2008 and 2009 and covers most of the current solar cycle through its solar maximum. The great advantage of the MaRS experiment compared to other radio sounding experiments at Mars performed at only a single frequency is the dual-frequency radio sounding at X-band simultaneously at S-band. This helps to identify the true electron density distribution and to separate true ionospheric features, in particular in the topside, from contributions caused by the spacecraft.

The large-scale daytime ionosphere shows a two-layer structure of a main layer M2 and a lower layer M1 formed by mostly solar EUV and solar X-ray and secondary ionization, respectively. The base is typically identified at 90 km. Sometimes additional electron density may be found below the M1 layer which is suspected to be caused by short solar X-rays interacting with the neutral atmosphere (see presentation by K. Peter et al.).

The topside is defined by a transport region with varying plasma scale heights. The ionopause is rarely seen, mostly when the general electron density noise background is low which coincides with observations during planetary opposition.

The M1 and M2 peak densities are clearly under solar control and follow the solar zenith angle and the solar cycle. The altitudes of both layers change also with the solar zenith angle. Variations in altitude for a given solar zenith angle may be caused by atmospheric waves propagating through ionospheric altitudes (see presentation by Tellmann et al.).

The vertical electron content follows also the solar zenith angle and is dominated by the M2 layer which contains at least 50% of the total.

This presentation reviews the MaRS ionospheric soundings over 13 years and a full solar cycle.

C4.3-0009-18 FLARE AND NON-FLARE ELECTRON DENSITY PROFILES IN THE D AND E REGIONS OF MARS' IONOSPHERE

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Solar X-ray flare responses in E region of Mars' ionosphere were observed from Mars Global Surveyor (MGS) on 6 April, 2001 and 17 March, 2003. We have developed a coupled model for the calculation of Ionospheric Electron Content (IEC), flare and non-flare electron density profiles due to impact of X-rays (0.5-90 Å) and Galactic Cosmic Rays (GCR) in the D and E regions of Mars' ionosphere simultaneously. In the non-flare profile D layer is produced at 25 km due to impact of GCR and hard X-rays (0.5-3 Å) with electron densities 1.0 x 102 cm-3 and 8 x 102 cm-3 respectively while E layer is produced at 110 km due to impact of soft X-rays (3-90 Å) with electron density 4 x 104 cm-3. The D peak density produced by hard X-rays is larger by about an order than that produced by GCR. The D and E flare peaks are produced for a short time at 30 km and 100 km with electron densities 2- 4 x 104 cm-3 and 1-2 x 105 cm-3 respectively. The predicted flare E-peak density is higher by factor of 2 than the measurements carried out by MGS. The D peak density of flare profile is larger by 1-2 orders of magnitude than that produced for non-flare profiles.

SPACE STUDIES OF THE UPPER ATMOSPHERES OF THE EARTH AND PLANETS INCLUDING REFERENCE ATMOSPHERES (C)

ACTIVE SPACE EXPERIMENTS (C5.1)

C5.1-0001-18 PLASMA DENSITIES AND WAVES STIMULATED BY HIGH POWER HF WAVES IN THE IONOSPHERE

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High Power HF Waves can be used to control both the electron density and electrostatic wave environment of the earth's ionosphere. Parametric decay of electromagnetic waves into other resident plasma wave modes requires satisfying the Manley-Rowe conditions for both frequency and wave number in the media. When these conditions are matched, high power electromagnetic waves launched from ground transmitters can efficiently disturb the Eand F-layers by heating, structuring, and ionizing processes depending on the transmission power and wave coupling process.

Breakdown of the neutral atmosphere at ionospheric altitudes can be achieved with high power HF waves that reflect on the bottomside of the ionosphere. For overdense heating (i.e., wave frequency < maximum plasma frequency in the F-layer), the largest electric fields in the plasma are found just below the reflection altitude. There, electromagnetic waves are converted into electron plasma (Langmuir) waves and ion acoustic waves. These waves are measured by scattering of the 430 MHz radar

at Arecibo to from an enhanced plasma line. The photo-electron excitation of Langmuir waves yields a weaker plasma-line profile that shows the complete electron profile with the radar.

Once HF enhanced Langmuir waves are formed, they can accelerate the photo-electron population to sufficient energies for neutral breakdown and enhanced ionization inside the HF Radio Beam. Plasma pancakes are produced because the breakdown process continues to build up plasma on bottom of the breakdown clouds and recombination occurs on the older breakdown plasma at the top of these clouds. Thus, the plasma pancake falls with altitude from the initial HF wave reflection altitude near 250 km to about 160 km where ion-electron recombination prevents the plasma cloud from being sustained by the high power HF. Experiments in March 2017 have produced plasma pancakes with about 100 Mega-Watts effective radiated power 5.1 MHz with the Arecibo HF Facility. Observations using the 430 MHz radar show falling plasma pancakes that disappear at low altitudes and reform at the F-layer critical reflection altitude. Sometimes the periodic and regular falling motion of the plasma pancakes is influenced by Acoustic Gravity Waves (AGW) propagating through the modified HF region. A rising AGW can cause the plasma pancake to reside at nearly constant altitude for 10 to 20 minutes. Dense cavities are also produced by high power radio waves interacting with the F-Layer. These structures are observed with the Arecibo 430 MHz radar as intense bight-outs in the plasma profile. Multiple cavities are seen simultaneously.

Using one-tenth the power of the HAARP HF Facility in Alaska, the Arecibo HF Facility in Puerto Rico has produced artificial plasma pancakes. The production at surprisingly low power is attributed to acceleration of natural photo electrons near 1 eV to suprathermal energies greater than 10 eV. The importance of this work is (1) less power than previously thought is required to produce artificial ionization in the upper atmosphere, and (2) the enhanced ionization regions can be examined with the high resolution Arecibo 430 MHz Incoherent Scatter Radar and HF sounders.

C5.1-0002-18 MAGNETIZED STIMULATED BRILLIOUN SCATTER EXCITED IN THE F REGION AND SPORADIC E AT ARECIBO OBSERVATORY

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With the previous Arecibo HF facility at Islote, Puerto Rico, Magnetized Stimulated Brillioun Scatter (MSBS) was strongly excited at an HF frequency, fHF, of 3.175 MHz under winter, nighttime, solar minimum conditions. The peak HF power of the Islote facility was only 80 MW ERP. When the HF beam was turned on in a cold unmodified F region plasma weak MSBS backscatter appeared within 10 s, but a large intensification occurred after 10 - 15 min. This coincided with the formation of strong spread F. Also the amplitude of detected lower hybrid waves increased as the MSBS intensified. In the F region the ion acoustic MSBS mode is dominant, and the electrostatic ion cyclotron mode is pumped but stable. At lower heights, strong excitation of MSBS in sporadic E occurs when vertical gradients are not too steep. The excitation of F region MSBS is feasible when FoF2 is between 3.5 and 4.5 MHz, and fHF is near 3.2 MHz. In this case, the electron-ion cooling rate is extremely low, and local losses near HF reflection are not large enough to constrain the HF-induced electron heating. As a result the electron temperature rises to measured values of 4000 K, which greatly decreases the MSBS threshold. Electron thermal conduction along geomagnetic field lines ultimately carries the locally deposited thermal energy to heat sinks above and below the deposition height. This limits the local electron temperature. To date, MSBS experiments performed with the new HF facility located at the Arecibo Observatory have yielded no new data. Despite the fact that the HF ERP increased to 100 MW ERP at fHF = 5.1 MHz and 200 MW ERP at fHF = 8.175 MHz the electron thermal loss rates due to electron-ion collisions disproportionally increase at these two higher frequencies. The older recovered Islote data are included in this presentation. However, the special circumstances under which MSBS may be generated with the new HF facility will be discussed.

C5.1-0003-18 RECENT OBSERVATIONS AND MODELING OF MID-LATITUDE IONOSPHERIC STIMULATED ELECTROMAGNETIC EMISSIONS

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High power electromagnetic (EM) waves transmitted from the ground interact with the lo- cal plasma in the ionosphere and can produce Stimulated Electromagnetic Emissions (SEEs) through the parametric decay instability (PDI). The classical SEE features known as wideband SEE (WSEE) with frequency offset of 1 kHz up to 100 kHz have been observed and studied in detail in the 1980s and 1990s. A new era of ionospheric remote sensing techniques was begun after the recent update of the HF transmitter at the High-Frequency Active Auroral Research Program (HAARP) in Alaska. Sideband emissions of unprecedented strength have been reported during recent campaigns at HAARP, reaching up to 10 dB relative to the reflected pump wave, which are by far the strongest spectral features of secondary radiation that have been reported. These emissions known as narrowband SEE (NSEE) are shifted by only up to a few tens of Hertz from radio-waves transmitted at several megahertz. One of these new NSEE features are emission lines within 100 Hz of the pump frequency and are produced through magnetized stimulated Brillouin scatter (MSBS) process.

Stimulated Brillouin Scatter (SBS) is a strong SEE mode involving a direct parametric decay of the pump wave into an electrostatic wave (ES) and a secondary EM wave that sometimes could be stronger than the HF pump. SBS has been studied in laboratory plasma experiments by the interaction of high power lasers with plasmas. The SBS instability in magnetized ionospheric plasma was observed for the first time at HAARP in 2010. Our recent work at HAARP has shown that MSBS emission lines can be used to asses electron temperature in the heated region, ion mass spectrometry, determine minor ion species and their densities in the ionosphere, study the physics associated with electron acceleration and artificial airglow.

Here, we present new observations of NSEE features at the new mid-latitude heating facility at Arecibo. This includes the direct mode conversion of pump wave through MSBS process. Collected data using ground-based SEE receiver, ISR, ionospgram, as well as satellite observations will be discussed. The different characteristics of parametric decay instabilities in the high and mid-latitude will be compared. Preliminary theoretical and computational modeling of mid-latitude NSEE will be presented.

C5.1-0004-18 EFFECTS ON GNSS AND HF FROM HEATING USING THE ARECIBO HF FACILITY

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Artificial Ionospheric Modification (AIM) attempts to temporarily alter a small region of the ionosphere in order to perturb the RF propagation environment. This can be achieved through injecting the ionosphere with aerosols, chemicals or radio signals. The effects of any such modification can be detected through the deployment of sensors, including ground based highfrequency (HF) sounders and dual-band Global Navigation Satellite System (GNSS) receivers. HF sounders allow measurements of the bottom-side of the ionosphere. GNSS receivers offer a convenient means of obtaining information about the ionosphere, including ionospheric disturbances through changes in the derived total electron content information.

The Heating EXperiment (HEX), which took place in March and May 2017, was designed to further our understanding of the phenomena caused by artificially heating a small region of the ionosphere, using the Arecibo facility in Puerto Rico. This was achieved by utilizing a HF measurement experiment spread between Texas and Trinidad and the deployment of a small scale travelling ionospheric disturbance (TID) detection network near the heater. The TID network comprised three GNSS receivers along baselines of approximately 4 km, located 20 km north of the heater. This paper presents HF and GNSS results from the HEX campaign, including evidence of heating-induced disturbances modifying HF propagation.

C5.1-0005-18 NEW OBSERVATIONS OF THE PLASMA LINE OVERSHOOT WITH THE ARECIBO OBSERVATORY HF FACILITY

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In the 1970's and 1980's, enhanced plasma waves were frequently detected with the 430 MHz radar at the Arecibo Observatory within 2 to 8 msec after the HF heater had been turned on (Showen, 1975). The enhanced plasma wave phenomenon is best described as a rapid increase in the return power level of the plasma line by one or two orders of magnitude, followed by a slow decay back to a lower "steady state" value associated with HF heating. The formation of short scale striations has frequently been cited as a plausible explanation of the plasma line overshoot. The idea is that as the striations form, they absorb or scatter energy from the HF heater wave. This diminishes the amount of power available to excite the plasma waves detected by the 430 MHz radar. Short scale striations are thought to form at the altitude where the frequency of the HF wave matches the upper hybrid resonance - below the altitude of HF reflection. In 1981, the decay of the plasma line overshoot was correlated with the rise of the short scale striations utilizing an HF pulse rate of 4 seconds on/off, with the HF transmitter tuned to 5.1 MHz, and an estimated E.R.P. of 38 MW (Coster et al., 1984). In July 2017, a series of HF heating experiments designed to examine the enhanced plasma line with the new Arecibo Observatory HF facility and the improved diagnostics of the modern system. These experiments were designed to study possible mechanisms responsible for the formation and decay of the plasma line overshoot. In the experiment, the HF heater was cycled on and off at various cycles:. 8 min on/off, 4 min on/off, and 2 min on/off, and enhanced plasma lines were detected throughout the experiment. We report on significant findings from this experiment

C5.1-0006-18 HF ACTIVE EXPERIMENTS AT ARECIBO TO TEST E - F REGION COUPLING THEORY

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Exceptional data has been collected where the E -region plays an important role in the generation of the artificial ionosphere in the F region, opening the door to test theories about the natural phenomena of E and F-region interaction. Although, the HF Facility works at frequencies that are a higher than the typical maximum E-region plasma frequency.

During HF experiments at Arecibo, modulation of artificial field-aligned irregularities (AFAIS) in the F region was observed in the presence of natural billowy E region. Tsunoda and Cosgrove, 2001, proposed that the E-F region is electro-dynamically coupled in the presence of billowy sporadic E (Es). Hysell et al., 2011, suggested that the strong currents in the Es layers and the large polarization electric fields that drive them can be maintained, for example, when the currents are allowed to close in the F layer. Observational evidence of these theories has been challenging to find. However, a possible demonstration of the closed loop is seen under the effect of the artificial irregularities observed on March 18, 2017, when the remarkable resolution of the ISR at Arecibo allows to see the natural E-region activity and the F-region AFIS modulation.

The link between the theory and the observations is one example of how the HF Facility and the full diagnostics can be used as a center of space plasma physics to test ionospheric coupling theories.

C5.1-0007-18 THE SPACE PLASMA PHYSICS OF THE GLOWING DUST BALL FROM THE CARE II ROCKET EXPERIMENT

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The CARE II mission was launched from Andoya, Norway, in September 2015. The primary objective of CARE II was to study hypersonic expansion of dust and molecular clouds in the presence of an ambient ionosphere. This flight had a full set of plasma diagnostics to measure the charged dust density, the electron and ion densities, and the electrical fields associated with plasma waves produced by the release. The chemical release payload were solid rocket motors that releases about aluminum oxide dust particulates. A charged dense dust cloud was formed for detection as enhanced radar scatter. The in situ electric field measurements

determine the sources of some of the observed plasma waves launched by rocket engines that fire in the ionosphere. The CARE II payload trajectory and velocity profiles were nominal with the released on target for radar and sensor viewing. The rocket motor payload on CARE II was a good representation of commonly used solid rocket motors that fire in the ionosphere.

The CARE II rocket fired 37 rocket motors simultaneously to inject 66 kg of dust particles in the upper atmosphere at an altitude of 266 km (approximately 165 miles above Earth). The dust, composed of aluminum oxide particulates, was accompanied by 130 kg of molecules such as carbon dioxide, water vapor, and hydrogen. The large concentration of dust and exhaust material interacted with the ionosphere to produce dusty plasma with high-speed "pickup ions," a technical term for ionized or electrically charged (positive or negative) particles. The launch occurred just after sunset to place the dust particles in sunlight for easy viewing by cameras in darkness on the ground. Digital cameras were used onboard a Beechcraft B200 airplane to photograph sunlight scattered from the expanding dust cloud, and the captured images show a dispersal of the dust that appears almost spherical.

The electric field instrument on the CARE II rocket functioned as both a plasma wave sensor and fluctuation monitor. The instrument sensitivity was better than 100 μmicroVolt/m and with a frequency range extending above 10 kHz. These parameters were chosen to cover both low frequency waves from the dust and magnetohydrodynamic (MHD) components and higher frequency waves associated with ion acoustic fluctuations. The instrument used a 32 ks/s sampling rate with a 12-bit analog-to-digital converter. The individual samples from eight separate probes in double-double configurations provided multiple baselines for measuring electric fields between sensor pairs. Both low-frequency MHD waves and higher frequency ion waves have been identified in the data.

The plasma densities at CARE II instrument payload were measured with electron satura- tion current fixed-bias Langmuir probes (FLP), a sweeping Langmuir probe (SLP), and an impedance (or resonance) probe (IP). These probes yielded the background plasma before the CARE II release and the density reductions and plasma irregularities excited by the dust and molecule debris injection. The plasma density instruments used electron saturation currents or the frequency spectrum of the plasma probe impedance to measure the electron densities. The sensitivity of the plasma probes were chosen for electron density ranges between 2.0 103 and 1.6 106 cm−3. The range for the ions is 2.4 104 to 9.4 106 cm−3. The electron temperature is also measured between 0.02 and 1.0 eV. The plasma resonance probe covers the 1.2 104 to 1.2 106 cm−3 density range with increased accuracy. The sample rate on the Langmuir probes was 43 kHz for electrons and 10 Hz for electron temperature. The resonance probe was swept with a 10 Hz rate.

Our two-fold goal for ongoing theoretical study of CARE II data is to (1) explain the disturbance observations recorded by the CARE II sensors and (2) predict the magnitude of the plasma turbulence stimulated by the dust injection. The theoretical effort is supported by particle-incell and fluid models developed at Virginia Tech. The generation of MHD and Whistler wave modes by localized dust and molecule expansion in the ionosphere uses several wave excitation mechanisms. The MHD model for payload impulse response uses both fluid theory for the MHD shock-wave generation and anisotropic media ray tracing to predict the path of the disturbance wave. Irregularity generation and sensing involves dust and molecule streaming instabilities described by both fluid and kinetic theory. The physics of field aligned irregularities uses both fluid and kinetic descriptions.

C5.1-0008-18 ACTIVE SPACE EXPERIMENTS POSTER REVIEW I

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This talk will highlight the Active Space Experiments poster contributions

C5.1-0009-18 HAARP, A POWERFUL ACTIVE IONOSPHERIC LABORATORY OPEN FOR INTERNATIONAL RESEARCH

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The High-frequency Active Auroral Research Program (HAARP) is the most powerful and capable ionospheric heater in the world. High-power, high-frequency (HF) transmitters provide a means to study the ionosphere, upper atmosphere, and magnetosphere in ways not possible with traditional insitu or remote sensing observations. With an HF "heater" an overhead region of the ionosphere can be modified briefly to create a desired effect and then observe the ionosphere as it relaxes to its original state. By varying the frequency, amplitude, or on/off transmit time, the ionosphere can be used as an antenna to generate low frequency waves (ULF, ELF, VLF, Whistler, etc.) which propagate along magnetic field lines into the magnetosphere or are injected into the earth-atmosphere waveguide. High power HF energy can be used to create artificial airglow, perform radio science experiments and drive a variety of plasma instabilities, irregularities and turbulence. HAARP is powered by four 3600 HP diesel engines and can transmit 3.6 MW at multiple frequencies and multiple beams anywhere in the interval 2.8 - 10 MHz. HAARP has been used to create artificial airglow, long-lived artificial ionospheric layers, instabilities, irregularities and turbulence; and various forms of low frequency waves. The Geophysical Institute of the University of Alaska Fairbanks (UAF/GI) recently took ownership of HAARP from the Air Force Research Laboratory, restored the facility to operational status and has been conducting scientific campaigns for outside investigators. The HAARP facility is open to international researchers. The status and future plans for HAARP and a summary of recent experiments will be presented.

C5.1-0010-18 IONOSPHERIC TURBULENCE GENERATED BY HIGH POWER HF TRANSMITTERS

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Active experiments in the ionosphere performed using high power ground-based HF transmitters may allow for the controlled generation and study of turbulence and density irregularities and their impacts on wave propagation through the ionosphere, (e.g. GPS scintillation). The largest HF transmitter built to date is the HAARP phased-array HF transmitter near Gakona, Alaska which can deliver up to 3.6 Gigawatts (ERP) of CW RF power in the range of 2.8 - 10 MHz to the ionosphere with millisecond pointing, power modulation, and frequency agility. With an ionospheric background thermal energy in the range of only 0.1 eV, this amount of power gives access to the highest regimes of the nonlinearity (RF intensity to thermal pressure) ratio. HAARP's unique features have enabled the conduct of a number of nonlinear plasma experiments in the interaction region of overdense ionospheric plasma including generation of artificial aurorae, artificial ionization layers, VLF wave-particle interactions in the magnetosphere, parametric instabilities, stimulated electromagnetic emissions (SEE), strong Langmuir turbulence (SLT) and suprathermal electron acceleration. Diagnostics include the Modular UHF Ionospheric Radar (MUIR) sited at HAARP, the SuperDARN-Kodiak HF radar, spacecraft radio beacons, HF receivers to record stimulated electromagnetic emissions (SEE) and optics for stimulated optical emissions. Recently, a new HF transmitter has begun operations at Arecibo Observatory. The new Arecibo heater is comprised of two arrays of three crosseddipoles each, at 5.1 MHz and 8.175 MHz located at the bottom of the 305 m dish feeding a subreflector suspended from the Arecibo platform. The vertical HF beam generated is rated at 100 MW ERP at 5.1 MHz and 200 MW at 8.175 MHz, making it comparable to the previous Arecibo heating facility at those frequencies. The most prominent diagnostic at Arecibo is the 430 MHz dual beam ISR with an ERP of 2 TW. Other diagnostics include HF receiver ar- rays to record SEE and HF scatter, spacecraft radio beacons, and optics for stimulated optical emissions. We report on short timescale ponderomotive overshoot effects, onset and growth of artificial field-aligned irregularities (AFAI), the aspect angle dependence of the intensity of AFAI, large-scale density cavities of depths exceeding 50% over tens of kilometers, the production of suprathermal electrons and related artificial ionization layers. Applications are made to the ionospheric turbulence and irregularities affecting spacecraft communication and navigation systems, as well as the controlled study of fundamental nonlinear plasma processes of relevance to laboratory plasmas.

C5.1-0011-18 HF POWER-RAMP EXPERIMENTS AT HAARP: EXPERIMENTAL DETERMINATION OF THRESHOLD POWER REQUIRED FOR THE ONSET OF HFENHANCED PLASMA LINES, AND ONSET OF ARTIFICIAL IONIZATION IN THE LOWER F-REGION IONOSPHERE.

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High-power HF radio waves transmitted from the HAARP facility produce HF-enhanced ionacoustic and Langmuir waves, and other effects such as artificial optical emissions and ionization. We present data from experiments where the HF power was slowly increased to determine the transmitted power levels for the onset of plasma waves and the onset of artificial ionization. The MUIR UHF radar (446MHz) was used as a diagnostic to detect plasma waves produced by HAARP. Past experiments have shown that power levels as low as 1% of full power can produce enhanced plasma waves. We have therefore used the unique capability of the HAARP phased array to extend the transmitted power to extremely low initial levels. This was accomplished by initially transmitting from only four dipoles from zero power upward in small power increments, and progressively adding more dipole transmitting elements. In this way it was possible to provide upward (or down-ward) power ramps from very low power (with no production of plasma waves) to full power. The HAARP antenna phasing was chosen for transmission in the direction of the earth's magnetic field and the transmitted power was determined at the center of the antenna beam in the direction of the magnetic field. Power densities and electric field values were calculated at 200km altitude, near the altitude of the observed plasma waves. The threshold electric field for the onset of plasma waves is about 50mV/m. However, the HF electric field near the HF reflection height is enhanced by the swelling effect of a factor about 4, thus the actual threshold electric field is about 200mV/m, which is consistent with theory.

Because the upper hybrid resonance layer is located below the HF reflection layer, upper hybrid waves may also be excited parametrically by the HF heating wave. Due to the field-aligned nature of the upper hybrid waves, these waves could not be detected directly by the UHF radar. On the other hand, the excitation of these waves may be manifested by the appearance of artificial ionization in the lower region. Short wavelength upper hybrid waves, which have high parametric excitation threshold, effectively energize electrons via finite Larmour radius effect implemented as a Doppler shifted harmonic cyclotron resonance interaction. The onset time of significant artificial ionization was

determined from the start of a sharp downward trend in the altitude of the plasma wave production; a threshold electric field value of about 700mV/m was calculated.

In addition, spectral analysis of the plasma-line cascade was performed to determine the progressive heating effect on the ion-acoustic wave frequency. The plasma-line cascade results from the parametric decay instability followed by successive Langmuir decay instability events. These spectral lines are separated in the frequency domain by intervals corresponding to the Doppler shifted ion-acoustic frequency appropriate for the wavelength of the diagnostic radar.

C5.1-0012-18 THE PRODUCTION OF ARTIFICIAL IONIZATION FROM HAARP: RESULTS AND EXPERIMENTAL APPROACHES FOR HF FREQUENCIES NEAR ELECTRON GYRO-HARMONICS

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We present observational results for high-power HF modification of the F-region ionosphere at the HAARP facility. There is a distinct difference between use of HF frequencies close, but higher than, gyro-harmonic values, compared with frequencies close, but below gyro-harmonic values. Experimental evidence demonstrates the production of artificial ionization is a minimum (or zero) for frequencies close to a gyro-harmonic. The altitude of the HF interaction region was determined from the production of HF-enhanced ion-acoustic and Langmuir waves as observed by a UHF diagnostic radar. Experiments were all conducted by directing the HAARP HF antenna and the UHF radar antenna along the direction of the earth's magnetic field. For experimental cases where the HF frequency is chosen above the gyro-harmonic value the HF interaction altitude initially decreases due to production of artificial ionization, but this production stops when the HF interaction altitude approaches the height of the local gyro-harmonic value. Subsequently, following chemical recombination, the HF interaction height rises and artificial ionization resumes. In this way, a continuous ionization production is maintained. As this generally occurs for heights about 200-300km, the continuous upward heat flux results in continuous upward plasma outflow from the ionosphere with corresponding enhanced plasma densities in the top-side ionosphere (and presumably far into the magnetosphere). Experimental satellite data at about 1000km altitude has verified this effect. These enhanced densities and plasma fluxes may be maintained for extended periods and could serve as waveguides for VLF waves produced by HAARP. The primary source of the ionization in the topside ionosphere is daytime photo-ionization. For experimental cases where the HF frequency is chosen to be less than the gyro-harmonic the production of artificial ionization results in decreasing altitude of the HF interaction. When the interaction altitude drops to about 150km or less, the HF interaction stops due to collisional effects, chemical recombination takes place and the cycle resumes. We show that using an FM sweep of the HAARP transmission produces a controlled slow descent of the artificial ionization production in the lower F-region ionosphere. Future development of this technique may permit us to maintain long-lived ionization structures in the lower F-region (about 180-200

km). The mechanism for the production of ionization in the lower F-region ionosphere is primarily due to electron acceleration from the action of upper hybrid and electron Bernstein waves; this has been extensively discussed in the literature. The selection of HF frequencies is critical for the success of the above experimental approaches. The HF frequency must be chosen to suit the local foF2 value and also the proximity to a gyro-harmonic. Other ionospheric modification facilities with limited choices of available HF frequencies will not in general be able to duplicate these results. Appropriate choice of HF frequencies with spacing as small as 10-50 kHz can be significant.

C5.1-0013-18 NEW PERSPECTIVE OF STIMULATED ELECTROMAGNETIC EMISSIONS AND FIELD ALIGNED IRREGULARITIES PRODUCED DURING IONOSPHERIC HEATING: TOWARDS MAXIMUM RESONANCE

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This talk will report on new observations of the complex dynamics of wideband stimulated electromagnetic emission (SEE) generation with simultaneous measurement of field aligned irregularities (FAIs) near the third electron gyroharmonic frequency by high power high frequency HF radio waves from High Frequency Active Auroral Research Program (HAARP) facility. The time evolution of the wideband SEE spectral component is more clearly investigated with the benefit of tilted beam angle heating experiments. It is observed for the first time that HF radar echoes intensify for pump frequencies above electron gyroharmonic frequencies at HAARP, which indicates correlation between enhanced FAIs and the formation of the so-called Broad Upshifted Maximum BUM spectral line. The polarimetry of SEE spectral lines are also analyzed to reveal that the downshifted maximum DM spectral line has a higher degree of circular polarization for heating above gyroharmonic frequencies.

To explain the asymmetric enhanced FAIs and correlated BUM emissions, a four-wave parametric process is investigated by using two-dimensional electrostatic particle-in-cell simulations for the first time. The variation of the four-wave decay instability is investigated for a range of plasma and pump wave frequency parameters. The numerical simulation results show the dependence of the maximum parametric decay process on the wave propagation angle with respect to the magnetic field, which agrees with theoretical analysis. The threshold of the BUM and 2BUM is also investigated for different electron oscillating velocity and pump wave frequency near electron gyroharmonics. The temporal-spatial characteristics for small scale plasma irregularities is also obtained. The comparison of the BUM observations with theoretical models provides a powerful tool for specifying nonlinear processes for plasma irregularity excitation.

C5.1-0014-18 PROPOSED ELF/VLF WAVE INJECTION EXPERIMENTS FROM AN HF HEATING FACILITY: GENERATION OF ELF/VLF WAVES AND ARTIFICIAL DUCTS

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Using an ionospheric HF heater to simultaneously generate ducts and ELF/VLF waves, we propose a new generation of wave injection experiments. Highly successful whistler mode wave injection experiments from SIPLE station, Antarctica, have established the importance of such experiments to study magnetospheric wave-particle interactions, and for cold and hot plasma diagnostics [Helliwell and Katsufrakis, 1974; Sonwalkar et al., 1997]. Modulated heating experiments from HAARP have shown that it is possible to launch ELF/VLF waves into the magnetosphere that can be observed on the ground after one-, two-, and multi-hop ducted propagation [Inan et al., 2004]. Past research has also shown that ionospheric heating experiments using an HF heater can lead to the formation of magnetospheric ducts [e.g. Milikh et al., 2010]. Recently it was shown that modulated HF heating from HAARP at frequencies about 50-100 kHz greater than gyro frequency harmonic just below F2 peak can generate and sustain ducts during day time [Watkins et al., 2013]. Collectively, these results indicate that an ionospheric heater can be used to form ducts on nearby L shells as well as to inject and trap heater generated ELF/VLF waves in those ducts. The ELF/VLF source region of heater generated waves is in the F-region ionosphere [Moore et al., 2012] permitting injection of waves at a greater range of wave normal angles not possible with ground-based wave injection experiments. These new generation experiments also provide control over duct generation and sustenance. Using raytracing studies, we demonstrate, as an example, the feasibility of a new generation of wave injection experiments from the HAARP transmitter (L 4.9). Ray tracing calculations using a model magnetosphere show that ducts of width dL 0.1-0.3 and enhancement factor dNe/Ne 10-20% or more can trap ELF/VLF waves in ducts with L shells near the HAARP heater. The plasmapause location with respect to transmitter plays a role in the nature of trapping. The duct locations and parameters required for trapping ELF/VLF waves inside the ducts are consistent with past observations of ducts generated by the HAARP transmitter. Trapped wave normal angles obtained from ray tracing calculations combined with estimated ELF source power can be used to estimate wave intensity inside the duct, on the ground, and on satellites such as Van Allen probe, and planned DSX, and to calculate resonant energetic electron energy. This new generation of wave injection experiments from an ionospheric heater will provide new understandings of ducts, ELF/VLF wave propagation, wave-particle interactions, and radiation belt physics.

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C5.1-0015-18 INVESTIGATION OF THE ARTIFICIAL IONOSPHERIC TURBULENCE AT THE HAARP FACILITY USING MULTI-FREQUENCY DOPPLER SOUNDING

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The dependence of the electron concentration profile modification was analyzed, in the ionosphere at various pump-wave frequencies at the fourth electron cyclotron frequency harmonic (fc), below and near it, and the preliminary results are presented. They were obtained from the data of the 2014 experiments on phase sounding of the perturbed ionosphere at the HAARP facility (Alaska, USA). The position of the pump wave frequency with respect to 4fc was determined by the spectrograms of stimulated electromagnetic emission. The inverse problem of reconstructing the electron concentration profile from the phase variations of broadband probe signals in the 450 kHz - band, including the pump wave plasma resonances, is solved for the six frequencies of the action of 5540, 5570, 5600, 5630, 5660 and 5730 kHz (fc 5690-5700 kHz); the Doppler frequency variations maps of the of radio signals, variations in the altitudes of their reflection, and virtual vertical velocities of the displacement of equal-concentration lines are plotted. In [1] the data obtained under the action at a frequency of 5500 kHz are analyzed in detail. The results are as follows:

All artificial perturbations of these quantities were observed on the background of natural changes in the plasma's electron density.

For all cases of plasma pumping, the effects of plasma expulsion from the plasma resonance region near the pump wave reflection level were observed already on the first second of pumping and, on the contrary, the concentration increase (lowering of the plasma layer) below the pump wave upper-hybrid resonance level.

The effect of plasma expulsion was characterized by an increase in the reflection height of the diagnostic pulse by $\sim$ 250 m at the velocity of $\sim$ 75 m/s.

Regarding the upper hybrid resonance level during pumping at the frequencies below the 4th gyroharmonic plasma expulsion (more significant than in the plasma resonance level) on the 2-3th second of pumping and the profile restoration after pumping were observed.

At the frequency of 5730 kHz (above the 4th gyroharmonic), the plasma expulsion effect at the upper hybrid resonance level was not present, on the other hand, the effect of increasing the electron concentration on the entire probe wave's network was mainly observed (and the most significant for lower values of the frequencies).

The results 1-3 correspond to the results obtained at the Sura facility (Nizhni Novgorod region, Russia) [2], although the HAARP facility used effective radiated power (400 MW) is approximately eight times higher than that of the Sura heating facility. In order to make definite conclusions on the effect of pump wave frequency offset with respect to 4fc on the plasma expulsion effect additional experiments are required. This work was supported by the RSF grant 17-72-10181, by RFBR grants 16-02-00798 and 18-02-00622.

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C5.1-0016-18 SIMULTANEOUS OBSERVATIONS OF THE HIGH FREQUENCY PLASMA LINE AND STIMULATED ELECTROMAGNETIC EMISSIONS DURING GENERATION OF THE ARTIFICIAL IONIZATION LAYERS AR HAARP.

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We present results of concurrent observations of stimulated (secondary) electromagnetic emissions (SEE) and incoherent high frequency plasma line (HFPL) backscatter from the MUIR radar during HF pumping of the ionosphere by the HAARP heating facility (62.4° N, 145.15° W, magnetic inclination 75.8°) with the pump wave (PW) slow (by 30 kHz once in a 5 min, by 20

kHz once in 2 min) and fast (once in 0.2 s by 1 kHz) frequency stepping about the fourth electron gyroharmonic (4fc). Result were obtained in 2011 and 2013. Relations between dynamic Broad Upshifted Maximum SEE spectral feature, descending and ascending HFPL generation regions, altitudes of the 4th electron gyroresonance of the pump wave and artificial ionization layers in the ionosphere are discussed.

C5.1-0017-18 ELF/VLF PLASMA ANTENNA BASED ON SUPER-PARAMAGNETIC NANOPARTICLES (SPN): RADIATION BELT REMEDIATION (RBR) REVISITED

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Earth's Radiation Belts (RB) were the first major discovery of the Space Age. Following the 1957 prediction of Nick Christofilos the presence of the RBs was confirmed in 1958 by Jim Van Allen. Interestingly their prediction and discovery was related to what is known as the grandest scientific experiment ever, the Argus series of High Altitude Nuclear Detonations (HAND), that resulted in injection of beta decay MeV electrons in the inner RB, increasing the natural MeV flux by several orders of magnitude. The artificial RBs, whose formation is also known as the "Christofilos Effect", deliver a lethal dose to Low Earth Orbit (LEO) satellites destroying their electronic capability within weeks with great economic and military consequences. The need for a Radiation Belt Remediation (RBR) system was recognized long ago and systems were explored following a Defense Threat Reduction Agency (DTRA) briefing in 2001 that concluded that one 10 kT HAND above 150 Km altitude will incapacitate 90% of LEO satellites in less than a few months and the Rumsfeld II report that called such an event a "Pearl Harbor in Space". Given the recent N. Korea capability to conduct high altitude nuclear tests and the possibility of a HAND caused by the salvage fusing of a US ballistic missile intercept, lack of credible RBR system limits the range of available responses. For example, does a HAND causing material damage justify a nuclear attack? A deterrent based on an RBR system is urgently needed. From the physics point of view the solution is evident, since experiments reinforced by recent results from the NASA Van Allen mission, indicate that whistler waves in the 2-3 kHz range and EMIC waves in the 100 Hz range interact strongly with MeV electrons causing pitch angle scattering into a cone (loss cone) that leads to precipitation into the atmosphere and out of the RBs. This process operating at the average whistler amplitude of 10 pT will bring back the MeV electron flux to the natural level in several years. However, if this amplitude is artificially enhanced by a factor of 3-5 the time to return to equilibrium becomes a couple of weeks clearly before significant damage to the fleet of satellites. RBR schemes based on injection of ELF/VLF waves by space based transmitters have been proposed, but was determined that the power required and the associated number of radiating satellites to achieve precipitation before significant spacecraft loss was unacceptably high. Experiments and theory indicated that the power and satellite number would be significantly lower if the wave-particle interaction amplified the injected waves by 10-20 dB

i, a process that has been observed experimentally but is difficult to predict and control. The objective of this presentation is to show that use of novel metamaterials in the form of SuperParamagnetic Nanoparticles (SPN) as ELF/ VLF transmitters in the RB plasma can increase the efficiency of generation of ELF/VLF by more than 10-20 dB, reduce the compactness of the system so that it can be placed on CubeSat's and provide propagation ducts that act as fibers to guide the injected power to the desired location. SPNs can be described as ensembles of non-interacting magnetic moments with m=104 105μB each and when driven by a magnetic field B energyE=-mB. Matrices containing SPNs behave like ordinary paramagnets, but with ferromagnetic susceptibility. An ensemble of SPNs embedded in a liquid or solid non-conducting matrix is driven to rotation or oscillation at the desired ELF/VLF frequency by RF coils surrounding the matrix. The near field electric field associated drives field aligned plasma currents such as were observed in Rotating Magnetic Field (RMF) experiments at the UCLA/LAPD chamber [Gigliotti et al., Phys. of Plasmas 16:092106, 2009; Karavaev et al., Phys. of Plasmas 17(1):012102,2010]. The magnetic moment of the AC coil is amplified by the SPN ensemble that depending on the grain size, material and volume can reach relative permeability μ=100-500. Preliminary estimates indicate that less than 1 kg of SPN grains driven by RF power of the order of 10 W can inject in the radiation belts EMIC and whistler waves with amplitude more than 100 pT and controlled chirp.

C5.1-0018-18 THE MAGNETOSPHERE-IONOSPHERE CONNECTIONS EXPLORER (CONEX): A MISSION TO CONNECT THE DYNAMIC MAGNETOSPHERE AND AURORAL IONOSPHERE

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On the nightside of the Earth the magnetic connections between the dynamic ionosphere and magnetosphere have a great deal of uncertainty. Since the 1990s, the space plasma physics group at Los Alamos National Laboratory (LANL) has been working on a mission concept to connect magnetospheric physical processes to auroral phenomena in the ionosphere by firing an electron beam from a magnetospheric spacecraft along magnetic field lines and optically imaging the beam spot in the ionosphere [1,2]. This concept can address some central outstanding scientific questions in our field:

1. Why do the aurora occur when and where they do 2. How do magnetospheric processes produce the conditions where auroras can occur? 3. How accurately can ionospheric and auroral observations specify the state of the magnetosphere?

The magnetospheric spacecraft will carry a steerable electron accelerator, a power-storage system, a plasma contactor, and instruments to measure magnetic and electric fields, plasma, and energetic particles. The spacecraft orbit will be coordinated with a ground-based network of cameras to (a) locate the electron beam spot in the upper atmosphere via its optical airglow

emission and (b) monitor the aurora. Recently, a LANL-led multi-institution team has made rapid advancements in this mission concept. The advancements are based on (1) a new understanding of the dynamic spacecraft charging of the accelerator and plasma-contactor system in the tenuous magnetosphere based on ion emission rather than electron collection [3], (2) a new understanding of the propagation properties of pulsed MeV-class beams in the magnetosphere, and (3) the design of a compact high-power 1-MeV electron accelerator and power-storage system. An overview is presented of the mission concept, the spacecraft-charging problems, the accelerator, the ground-based ground network, and the magnetospheric measurement instrumentation. The overview will include a discussion of the accelerator-energy tradeoffs between reducing spacecraft charging, avoiding loss-cone-drift issues [4] and improving beam detectability, and will include a discussion of a strategy to reduce of spacecraft charging when the accelerator is fired. This strategy to (a) determine the magnetosphere-to-ionosphere magnetic connections and (b) reduce accelerator-platform charging responds to one of the six emerging-technology needs called out in the most-recent National Academies Decadal Survey for Solar and Space Physics: "Magnetosphere-to-Ionosphere Field-Line Tracing Technology". Our overview will also address a range of outstanding auroral physics questions that can be addressed with this mission concept.

C5.1-0019-18 IN-SITU OBSERVATIONS OF IONOSPHERIC HEATERS BY THE E-POP RADIO RECEIVER INSTRUMENT

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Since its launch on 29 September 2013, the e-POP Radio Receiver Instrument (RRI) on the Canadian small satellite CASSIOPE has been commanded to operate in the vicinity of ionospheric heaters on a number of occasions. RRI has been turned on to observe heater RF fields on over 145 passes near the following facilities: SPEAR, HAARP, Sura, EISCAT Heating and Arecibo Observatory. At mission outset, it was anticipated that the 81° inclination and the 325-km perigee of the CASSIOPE orbit would present ongoing opportunities for close measurements of heating physics in the F region. The RRI observations have established the tendency of ionospheric density structure to complicate propagation in the F region and thereby affect conditions whereby nonlinear processes leading to ionospheric modification can be achieved. Density irregularities, either spontaneous in the background plasma or enhanced by heating effects, play major roles in the intensities and the directions of propagation of pump radiation in the F layer. D/E region absorption may mitigate against pump-field intensities needed to destabilize nonlinear processes in the F-layer, since RRI spectra are found to contain few indications of Raman or Brillouin scattering. As the CASSIOPE future orbital altitudes diminish with time, perigee altitude may offer unusual experimental opportunities. These might include new observations of wave physics in collisional plasmas, in particular where the (de)focusing effects of horizontal gradients are less important than in the dense F-layer peak in the measurement of heater radiation patterns.

C5.1-0020-18 NRL SPACE CHAMBER INVESTIGATIONS OF LINEAR AND NONLINEAR SPACE PLASMA DYNAMICS

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The geospace environment harbors a wide variety of linear and nonlinear phenomena. Knowledge of the various signatures and driving mechanisms gives insight into the local conditions not only at the instant that the observations are made, but also into how the conditions may evolve in time. Comprehensive, controlled investigations of the underlying physics associated with space plasma phenomena are difficult to accomplish through in situ methods alone. Consequently, properly scaled laboratory experiments can offer a complementary approach to investigating the space plasma dynamics. Laboratory devices have been utilized to investigate space plasma phenomena including instability mechanisms, wave generation, growth, and propagation characteristics, wave-particle interactions, and nonlinear effects to name a few. In this talk, we review examples of scaled laboratory investigations of space phenomena conducted in the Naval Research Laboratory's Space Physics Simulation Chamber, the associated space observations, and comparisons to theory.

C5.1-0021-18 EXCITATION OF PLASMA IRREGULARITIES IN THE F-REGION

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Excitation of articial plasma irregularities in the auroral ionosphere by high frequency X-mode radio wave will be presented. This is done by introducing a new theory based on two step process. As a rst step the thermal self-focusing instability excited in the F-region of the ionosphere under the action of a strong high-frequency (HF) radio wave is adopted. This instability causes the formation of perturbations of the electron temperature and plasma concentration across the magnetic eld. In addition, the plasma becomes depleted in the regions of the electron temperature enhancements and vice versa, since the gradients of plasma concentration and the electron temperature have opposite signs. In such conditions the temperature gradient instability comes into play. As a second step we consider this instability to be responsible for the generation of irregularities with transverse sizes smaller than the typical scales of the self-focusing instability. Alternative mechanisms such as excitation of drift instabilities (the gradient-drift and the current-convective in-stabilities) which are often attributed to the generation of plasma irregularities in the F-region and can contribute to the formation of articial irregularities in the case of X-mode heating are also discussed.

C5.1-0022-18 OBSERVATIONS OF SYSTEMATICALLY RECURRING TOPSIDE IONLINE ENHANCEMENTS DURING HF MODIFICATION EXPERIMENTS NEAR ELECTRON GYROHARMONIC FREQUENCIES

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Observations of electron gyro harmonic effects in the polar ionosphere were made during experiments in March 2016 and October 2017, with the European Incoherent SCATer (EISCAT) UHF radar and Heating facilities near Tromso, Norway. During transmission of a high power, high frequency radio wave, the HF-pump frequency was slowly stepped around the double resonance of the 3rd and 4th multiple of the electron gyro frequency and the local plasma frequency in the F-region ionosphere. Simultaneous to the previously well-documented enhancements on the bottom side of the F-layer at the HF reflection height, a smaller, but clear, ion-line enhancement was observed above the F-region peak. Topside enhancements occurred systematically when the pump frequency was close to multiples of the electron gyro harmonic frequency for numerous heating ON cycles during both experiments. We present ISR observations of these topside enhancements and the results are discussed in terms of possible L-mode propagation through the F-region peak.

C5.1-0023-18 OBSERVATION AND SIMULATION STUDY OF PARAMETRIC INSTABILITY AND LANGMUIR TURBULENCE

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Parametric decay instability (PDI) is an important process in ionospheric heating. HFPLs and HFILs in spectra of ISR are the direct observational evidence of PDI excitation. Stimulated electromagnetic emissions (SEE), enhanced airglow and artificial ionized layer are also closely related to PDI. The focus of this talk will be on the generation of PDI and Langmuir turbulence based recent observational and simulational study. This presentation includes a few topics: (1) Recent heating experiments presented excitation of PDI during the X-mode heating period by EISCAT. We suggest that the full dispersion relationship of the Langmuir wave can be employed to analyze the X-mode parametric instability excitation. A modified kinetic electron distribution is proposed to satisfy the matching condition of parametric instability excitation. (2)The simulation results of 1D and 2D Zakharov model show that caviton collapse dominates in higher altitude area and cascade dominate in lower altitude, which is consistent with strong Langmuir theory (SLT). Based on the spectrum analysis, the development of PDI to Langmuir turbulence is investigated in details. (3) Langmuir turbulence leads to strong electron acceleration. Generation mechanism of Langmuir turbulence and electron acceleration are also discussed with the help of numerical simulations.

C5.1-0025-18 SPATIAL VARIATION OF ELECTRON HEATING DURING IONOSPHERIC HF-RADIO-WAVE PUMPING

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The question of how much energy is dissipated has long been a central question in the field of high-power HF radio-wave ionospheric modification experiments. This report presents EISCAT incoherent scatter radar observations of electron temperature variations during daytime experiments with EISCAT Heating. Observations were made with rapid scanning of the radar making it possible to determine the three-dimensional variation of the enhanced electron temperature. By combining the radar observations with modelling of the electron temperature we determine the spatio-temporal variation of electron heating, with respect to time, altitude and direction. The results will be compared and contrasted with previous estimates of efficiency of producing artificial aurora at 6300 Å (Pedersen et al. 2008) and of electron heating in magnetic zenith (Senior et al. 2012).

C5.1-0026-18 THE 3D DISTRIBUTION OF ARTIFICIAL AURORA INDUCED BY HF RADIO WAVES IN THE IONOSPHERE

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We present 3D volume emission rate estimates of artificial aurora in the ionospheric F-layer, induced by high frequency (HF) radio waves from the EISCAT heating facility. Simultaneous imaging of the artificial aurora was done at four separate ALIS stations, permitting tomographylike 3D auroral reconstruction in the enhanced atomic oxygen emissions at 5577 Å (green), 6300 Å (red) and 8446 Å (infra-red). Inspection of the aurora models suggest that the distribution of energized electrons are less extended in altitude than predicted by transport simulations of energized electrons. We propose that an anisortopic electron acceleration, with an extended electron acceleration distribution perpendicular to the magnetic field, can explain the resulting 3D volume emission rates.

C5.1-0027-18 RECENT (2010-2017) STUDYING OF ARTIFICIAL AIRGLOW AT THE SURA FACILITY (SHORT REVIEW)

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A short review of the investigations of the artificial airglow in the red (630 nm) and green (557.7 nm) lines of atomic oxigen obtained at the SURA facility in 2010-2017 is presented. The attention is payed to the following.

Excitation of magneic field aligned bands (strata) in the red line emmission registered by CCD camera.

Excitation of the redline artificial emission in the magnetic zenith independently on the pump wave incident angle.

Dependence of the arthificial airglow brightness on the ratio between the pump wave frequency anf the 4th electron gyrohamonic.

Studying spatial characteristics of the red line (630 nm) artificial airglow generations region By be-static registrations with CCD cameras.

Suppression and following recovery of the red line airglow background during ionospheric plasme heating.

Correlation ot the total electron content of the ionosphere spatial behavior on the GPS signal path and artificial airglow brightness at 630 nm.

C5.1-0028-18 CORRELATION OF TOTAL ELECTRON CONTENT OF THE IONOSPHERE SPATIAL BEHAVIOR ON THE GPS SIGNAL PATH AND ARTIFICIAL OPTICAL EMISSION IN THE RED LINE (630 NM) OF THE ATOMIC OXYGEN AT THE "SURA" FACILITY.

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Results of simultaneous measurements of the ionosphere total electronic content (TEC) on the GPS signal path and artificial airglow of the ionosphere in the red line of atomic oxygen ($\Lambda = 630$ nm) during HF pumping of the ionosphere by the "Sura" heating facility radiation are presented.

Totally during 5 years we had only 5 nights of lucky experimental conditions: the satellite passed over the "Sura" facility antenna pattern when the sky were clear and ionosphere critical frequency exceeded the pump wave frequency. The latter condition is needed for effective excitation of plasma waves, providing the electron acceleration until the excitation levels of the ionosphere neutral atoms (the O1D for the red line of the oxygen). The former conditions is necessary for the airglow registration.

GPS receiver and optical device (CCD camera S1C/079-FP(FU)) were situated close (<500 m) to each other and to "Sura" facility. It was established that when the signal propagation path 'navigation satellite - GPS receiver' intersected a spot of the artificial airglow, maximum brightness of the latter on the line of optical device sight on the navigation satellite was observed in the region of the TEC minimum.

C5.1-0029-18 OBSERVATION OF THE LOWER IONOSPHERE C-REGION USING ARTIFICIAL PERIODIC IRREGULARITIES CREATED BY THE SURA HEATING FACILITY

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We present some results of the observation of the ionospheric C-region which is developing at altitudes below the normal D-region height. In other words, we observed the stratification of the D-region. Our observations are based on measurements of the amplitude and the decay time of the signal scattered by artificial periodic irregularities that were created by the power transmitters of the SURA heating facility (56,1 N; 46,1 E). APIs are formed by the powerful standing radio wave produced by interference of the incident wave and reflected one from the ionosphere. In the F-region the ponderomotive force causes the API formation and relaxation processes near the altitude of the power wave reflection. In the E-region they are caused by the ambipolar diffusion. In the D-region APIs are caused by the temperature dependences of the attachment rate of electrons with oxygen molecules during three-body collisions (V.V.Belikovich, E.A.Benediktov, A.V.Tolmacheva, N.V.Bakhmet'eva. Ionospheric Research by Means of Artificial Periodic Irregularities – Katlenburg-Lindau, Germany. 2002. Copernicus GmbH. ISBN 3-936586-03-9). Irregularities disappear after the heating turn off. Ionosphere diagnostics bases on the API relaxation (or decay) stage by their pulse sounding. Amplitudes and phases of the API back scattered signals are measured. For the first time we observed the D-region stratification in April, 2004 and in September, 2005. It turned out that the dependence of the amplitude of the scattered signal vs. altitude had two maxima. One of them was located in altitudes of 62-64 km. The altitude of the second maximum was in the region of 72-76 km while the API relaxation time changed with altitude in the usual way. We assume that the lower maximum of the amplitude is associated with the appearance of the C-layer at these heights. Our long-term API observations showed that in summer the amplitude of the scattered signal had one maximum at altitudes of the D-region about 74-78 km. Since the amplitude of the signal is proportional to the electron concentration, this allows us to assume that its minimum is due to a minimum in the electron density profile. At first, we believed that the C-region exists only at certain times of the year, for example, in the spring and in the autumn possibly. However, our recent observations in 2014-2017 have shown the C-region exists in the summer, too. We observed the stratification of the D-region before the sunset and the sunrise. Our observations demonstrate that APIs are a good tool for the observation and the investigation of the D-region stratification.

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C5.1-0030-18 ARTIFICIAL IONOSPHERIC IRREGULARITIES INVESTIGATIONS WITH RAPID RUN IONOSONDE

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Powerful HF radio emission to the Earth's ionosphere can be a reason of complex phenomena, which leads to the generation of artificial ionospheric turbulence. One of the most important components of turbulence is artificial ionospheric irregularities with a transverse dimension from a fraction of a meter to ten or more kilometers. The investigations of their spectral and dynamic characteristics makes possible to study the instabilities properties caused by the powerful radio wave and to study the features of dynamic processes in the ionosphere, and also to determine the possible influence of artificial irregularities to the different ranges radio waves propagation. Therefore, in May 2010, a few heating experiments were carried out at the SURA heating stand. The experiments were carried out during several days at the day and evening hours. The ionosphere disturbance was performed by transmitters with power of 150/180/160 kW. The radio waves had next properties - frequency of 4.7 MHz, repetition rate - 15/3/12 seconds, pulse durations - 20/30/16 ms and extraordinary polarization. Observation of generated irregularities occurred at a distance 170 km from the SURA stand at the observatory of Kazan Federal University (near Kazan) with ionosonde Cyclone. The control system of the ionosonde was set to the fast mode of ionograms recording (1 ionogram per minute), which allowed observing the temporal and height dynamics of excited artificial ionospheric irregularities. A possible mechanism of the observed effect is discussed.

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C5.1-0031-18 ACTIVE SPACE EXPERIMENTS POSTER REVIEW II

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Review of Active Space Experiments posters

C5.1-0032-18 MODIFIED MSTIDS BY SURA POWERFUL RADIO WAVE EMITTING

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The first results of two-dimensional TEC perturbation mapping to investigate the artificial plasma perturbations caused by powerful HF radiowave emitting of the ionosphere are presented. We analyze the results of measurements while SURA heating in the daytime between 14:45 and 17:30 UT on October 1, 2016 with a 15-minute emitting interval and 15-minute pause interval. To observe the ionosphere modification the dense GPS/GLONASS receiver's network was used. It was found that heating of the ionospheric plasma by powerful radio waves is able to effect on characteristics of natural TIDs, e.g. increasing their amplitude and wavelength.

C5.1-0033-18 THE E-REGION DISTURBANCES UNDER THE INFLUENCE OF THE POWERFUL HF RADIO EMISSION

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We present results of new experimental researches of artificial disturbances of the E-region of the ionosphere and its irregular structure during the HF heating period. Experiments have been carried out on base of the SURA heating facility (56.1 N; 46.1 E) in 2014-2017. Experiments were carried in the morning, afternoon and evening hours LT. The probing of the artificial disturbed E-region were carried out at two observation sites. One of them was located near Vasil'sursk 1 km from the SURA facility and the other site was located at the observation point of Kazan State University (55.85 N; 48.8 E) from 170 km to the East. Pumping time was varied from 5 s to 15 min. Antenna of the SURA heating facility was pointed at zenith, or was inclined at 12º to the south in the magnetic zenith direction. The disturbed region of the ionosphere in Vasil'sursk was probed by the vertical sounding technique using the partial reflexions radar at the frequency of 2.95 usually. Sometimes ionospheric sounding was conducted alternately at two frequencies 2.95 and 4.7 MHz. For the oblique sounding of the disturbed region the modied ionosond Cyclon-M operated at ten frequencies from 2.01 to 6.51 MHz was used at the Kazan site. Under modification of the ionosphere by O-mode and sometimes by X-mode of the pumping wave of the SURA facility at frequencies range of 4.3, 4.7 and 5.6 MHz with EPR of 50-120 MW artificial disturbances of the probe signal were obtained. On many heating sessions simultaneous variations of the probing partial reflection signals in Vasil'sursk and backscattered signals in Kazan site were observed at the height at 40-120 km below the reflection height of the pumping wave. These observations were correlated with the pumping periods of the SURA facility. Observation results showed that perturbations of the E-layer of the ionosphere and the lower part of the layer F1 influenced on probe wave at the frequency of 2.95 MHz the most likely. The growth of the electron density in the lower ionosphere during the heating period and an evolution of its irregular structure could provide the emergence of additional signals during pumping period. Estimates made on the base of the electron density profile recovered from the ionograms of the vertical sounding showed that these signals could appear due to an increase of the electron density of 5-10% in the pumping session. Such an increase of the electron density corresponds to theoretical estimations of the heating of the E-region by passing radio waves with EPR about 80-100 MW. Additional (in Vasil'sursk) and backscattered (in Kazan) signals were often received in two point located in the distance of 170 km simultaneously. The artificial disturbances propagated at altitudes of 40-120 km downward from the height of the reflection of the powerful waves that is significantly below the height of the resonant interaction of highpower radio waves with ionospheric plasma. They are probably related to the development of irregularities and the perturbation of the electron density in the E-region.

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C5.1-0034-18 FEATURES OF AII GENERATION UNDER X-MODE HEATING.

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The absence of resonant interaction between the ionospheric plasma and the powerful HF radio wave of extraordinary (X) polarization, should limit the excitation of artificial ionospheric irregularities (AII). In the report we present new experimental results on the effects observed under X-mode heating of the mid-latitude ionosphere. During the X-mode heating at the SURA heating facility the AII in a wide range of their scales were investigated. The decameter AII (with l = 10 - 50 m), which are well excited during O-mode heating near a pump wave reflection level in the ionosphere disturbed volume (IDV), were never detected during X-mode heating. This can be explained by the fact that the generation of decameter AII is determined by the thermal (resonance) parametric instability. The middle-scale AII (l = 50 - 200 m), which were detected in the IDV, demonstrated 6 dB lower intensity comparing to the O-mode heating. This can be explained by the fact that the generation of such AII depends on both resonant and self-focusing effects [1]. The large-scale AII (l > 200 m), which were detected in the IDV by its sounding by means of GPS satellite signals, also demonstrated 10 dB lower intensity comparing to the O-mode heating [1].

The work was supported by the Russian Education Ministry grant 3.1844.2017. REFERENCES

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C5.1-0035-18 INFLUENCE OF THE MAGNETIC ZENITH EFFECT ON THE GENERATION OF THE SUPER-SMALL-SCALE ARTIFICIAL IONOSPHERIC IRREGULARITIES

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HF heating at frequencies slightly higher than multiples of the electron gyrofrequency leads to generation of the super-small-scale (l=10-20 cm) artificial ionospheric irregularities (SSSI) in the plasma density [1]. In the report we present new experimental results on their features. During the first group of experiments for SSSI detection the method of ionosphere disturbed volume (IDV) sounding by the signals from GPS satellites was used. During the gyroharmonic ionosphere pumping with the schedule [10s - on, 10s - off] the appearance of TEC variations with the period consistent with the heating facility operation schedule was observed. The strongest variations were registered near the area of the magnetic zenith for the pump wave. The obtained results allow concluding that the generation of SSSI is more efficient in the magnetic zenith area. Another group of experiments was based on the fact that the value of spectrum widening of the signals scattered from the decameter irregularities depends heavily on the location of the scattering surface in the IDV and on the fact whether it passes through the magnetic zenith [2]. The widening itself, according to [1], is connected with generation of SSSI inside the decameter irregularities. The results of processing of scattered signals received in the observation point for eight measurement series demonstrated that together with the increase of the scattered signal power, more spectrum widening was detected. Taking into account that the increase of scattered signal intensity indicates the approaching of the scattering surface to the magnetic zenith, we can conclude that both widening of the scattered signal spectrum and efficiency of SSSI generation have their maximum in the magnetic zenith area.

The work was supported by the Russian Education Ministry grant 3.1844.2017. REFERENCES

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C5.1-0036-18 ENERGETIC ELECTRON PRECIPITATION INDUCED BY THE SURA FACILITY

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In the report experimental results regarding to features of energetic electron precipitation HFinduced by means of O-mode powerful radio waves emitted in the ionosphere by the SURA heating facility are presented. Registration of energetic electrons in the energy range from 70 keV to about 0.8 MeV were made in 2005 - 2010 using the IDP spectrometer placed on the French micro satellite DEMETER [1]. The obtained results have been allowed to determine the following features of such precipitation. 1) The precipitation was observed only when a pump wave frequency was below the F2 region critical frequency, f0F2, and ionosphere modification was conducted under evening or nigh conditions with the effective radiation power higher than 40 MW. 2) The precipitation was registered along a satellite orbit from 300 km to the south to 700 km to the north from the center of the HF-disturbed magnetic flux tube resting on the ionosphere disturbed volume, in which strong plasma perturbations are excited due to developing parametric instabilities. The maximal flux of the energetic electrons is observed in the HF-disturbed magnetic flux tube, sometimes the presence of a plasma density duct was the cause of increasing the value of the electron flux. 3) In most cases the precipitation of energetic electrons with E 125 keV and the flux value of about 90 (part/seccm2srkeV)were registered. The work of V.L. Frolov was supported by the RFBR grant 17-05-00475. The work of A.O. Ryabov was supported by the Russian Education Ministry grant 3.1844.2017.

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C5.1-0037-18 EXCITATION OF ARTIFICIAL PLASMA TURBULENCE IN THE OUTER IONOSPHERE

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In the paper experimental results regarding to features of plasma perturbations HF-induced in the outer ionosphere are presented. For ionosphere modifications O-mode HF radio waves radiated by the SURA facility were used. Testing of plasma disturbances were made using the onboard equipment of three European SWARM satellites flying at heights of 450 - 500 km. Experiments were conducted in 2016 - 2017 [1]. The obtained results allowed formulating necessary conditions for the excitation of the plasma density and temperature perturbations. They are: a) pumping has to be carried out under evening and nigh conditions; b) a pump wave (PW) frequency (f0) has to be lower than the F2 region critical frequency, f0F2; c) the effective radiation power has to be higher than 40 MW; d) PW reflection height has to be higher than 200 km. It has been found that strong plasma density and temperature variations (up to 10%) were observed at altitudes of 450 - 500 km. It was registered the enhancement of plasma temperature on the average but was not observed plasma density structures like the ducts, which were revealed at altitudes of 660 km in SURA-DEMETER and HAARP-DEMETER experiments. The work of A.O. Ryabov was supported by the Russian Education Ministry grant 3.1844.2017. The work of V.L. Frolov was supported by the RFBR grant 17-05-00475.

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C5.1-0038-18 SEE PROPERTIES DURING INCLINED HF IONOSPHERIC PUMPING AT THE HAARP FACILITY

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In March 2011 a set of experiments at the HAARP facility were performed aimed to study of artificial ionospheric turbulence using stimulated electromagnetic emission (SEE) measurements at different incident angles of the pump wave on the ionosphere. The main attention was paid to zenith (vertical) and magnetic zenith (MZ, along the magnetic field, the inclination of 14.2° to the South in the magnetic meridian plane) directions of the pump beam radiation. In addition, the experiment with a change of the pump beam incident angle from α = 28° (north) to α = +28° (south) in the magnetic meridian plane with a step of 7° was performed. For each angle, the pump wave frequency f0 was swept in the range 5930 5730 5930 kHz (near the 4th harmonic of the electron cyclotron frequency 4fc) during 80 s. SEE receiving was carried out at three sites situated along the magnetic meridian at 113 km (A), 82 km (B) and 11 km to the south from the HAARP facility. The results are as follows:

Under low duty cycle of pumping (pulse duration ≤ 50 ms) it was established that during vertical impact, the SEE spectrum has a "continuum" type in the range 80 < Δf = f0 fSEE < 0 kHz without the any prominent special features. During MZ pumping, after 20 ms a number of narrow equidistant peaks appear in the SEE spectra at frequency shifts

Δf = 8, 16 kHz more pronounced for more remote receiving sites. These offsets are close to the first and second harmonics of the lower hybrid frequency in the region of the pump wave interaction with the ionospheric plasma. At the site C (near the facility), the SEE intensity during vertical pumping exceeded the intensity during the MZ pumping by 3-4 dB, while in the site A, mostly remote from the facility, there is an reverse picture:

the SEE intensity during the MZ pumping is larger by ~ 10 dB.

During pump frequency sweeps the intensity of the upper-hybrid related downshifted maximum (DM) SEE feature increased monotonically from the minimum at fDM = 4fc which varied from 5.73 till 5.74 MHz at different incident angles till maximum at f0 > 5.9 MHz. The DM intensity at the gyroharmonic was maximum at the MZ pumping. The broad upshifted maximum (BUM) intensity peak occurred at the ΔfBUMpeak 60 kHz for the incident angle α = 28° and then approached to the pump wave frequency with motion of the incident angle to the South. Its frequency shift achieved ΔfBUMpeak 5–

25 kHz at α = +(14°–28°). With an increase of the pump beam inclination to the north, the SEE intensity decreased at all receiving sites, especially noticeable in the site A. At the maximum inclination to the south, the SEE intensity at the site A increased.

During the MZ pumping, when the additional ionization layer appeared and manifested in SEE spectra as an additional "dynamic" BUMD feature [1], some weakening of the other upper hybrid related SEE features was observed.

This work was supported by the RSF grant 17-72-10181 and by RFBR grant 16-02-00798.

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C5.1-0039-18 MODELING OF THE DYNAMICS OF RADIO WAVES ABSORPTION DUE TO ELECTROMAGNETIC DRIVE OF STRONG LANGMUIR TURBULENCE IN SMOOTHLY INHOMOGENEOUS PLASMA

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Experiments on the investigation of self-action of radio wave incident on the ionosphere from ground base transmitter at the so-called Langmuir effect stage initiate this study. Emphasis is placed on the influence of "self-sustained" turbulent plasma radio wave absorption excited in the smoothly inhomogeneous plasma layer with unperturbed linear density profile under the wave amplification in resonance region. Absorption and reflection indexes dynamics is obtained numerically depending on the intensity of the pumping wave and dumping peculiarities. Calculations of "soft" and "hard" regimes of anomalous absorption development and hysteretic modes with the differing several times "on" and "off" thresholds are carried out. The study and the obtained results could served as the basis of more adequate and thorough simulation for the interpretation of experimental Langmuir stage observations.

C5.1-0040-18 DUAL ION-LINE STRUCTURES OBSERVED AT THE HAARP IONOSPHERIC MODIFICATION FACILITY.

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We present results for experiments using high-power O-mode HF waves generated by the HAARP ionospheric modification facility. The data pertain to ion-line data resulting from the parametric decay instability (PDI). The HF interaction with the F-region ionosphere occurs near, but below, the HF reflection height. For the upgoing HF electromagnetic wave the PDI results in a forward scattered Langmuir wave and a backscattered ion-acoustic wave. After the subsequent reflection the down-going HF wave again participates in the PDI resulting in a down-going Langmuir wave and upgoing ion-acoustic wave. A UHF diagnostic radar was used to detect the HF-enhanced ion-acoustic waves. Since the diagnostic radar has only one receiver it was not possible to additionally detect Langmuir waves. In most cases the up and down-going plasma waves occur at approximately the same altitude. However we show that in many cases the up and down-going ion-acoustic waves occur at two separate heights separated by as much as 5-7 km. We suggest this height difference results from wave propagation effects near the reflection height. Doppler spectral analysis of the scattered radar signals indicate that the plasma wave intensity is greater for the height layer with downward ion-acoustic waves, corresponding to the upgoing HF electromagnetic wave. This altitude layer with stronger wave scattering may occur above or below another layer with weaker wave activity that corresponds to the downward HF electromagnetic wave after reflection. These observations are consistent with many past ion-line observations at HAARP and other facilities that show the downward travelling HF-enhanced ion-acoustic waves generally show greater scattered power than upward waves. The new aspect of these observations is the frequently observed separation in altitude of the two layers, and we have found that this behavior depends on the particular HF frequency used. For example we show from an experiment that stepped in 10kHz increments of the HF frequency 4.10, 4.20,4.30,4.40,4.50 MHz that the ion-lines separated into two distinct height layers only for the 4.20 and 4.50 MHz cases. In some examples the height layer with upgoing ion-acoustic waves is extremely weak or non-existent. We suggest that the weaker or non-existent PDI wave structures that correspond to the downward electromagnetic wave after reflection likely results when the power of the HF wave falls below the threshold for the PDI.

C5.1-0041-18 ELECTRON ACCELERATION BY PARAMETRIC DECAY INSTABILITY AND LANGMUIR TURBULENCE IN IONOSPHERIC HEATING

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Ionosphere modified by powerful radio transmitters from ground has been observed in the 1970s. Since then many phenomena had been observed and many physical mechanisms are proposed. Parametric decay instability (PDI) is an important process in ionospheric heating, which are proved to be excited by HFPLs and HFILs observed in spectra of ISR. Langmuir waves and ion-acoustics waves are excited in PDI process and Langmuir turbulence (LT) could be generated. The electrons acceleration, which could lead to enhanced airglow and artificial ionized layer in ionospheric heating, is also related to PDI process and LT. Electron acceleration in ionospheric heating has been an active topic for many years. In this study, we investigate electron acceleration due to Langmuir turbulence in two different approaches. In the first approach, excitation of parametric instability (PDI) and subsequent Langmuir turbulence (LT) is investigated by a two-fluid Zakharov model. Electron acceleration is described by a FokkerPlanck model with an effective diffusion coefficient calculated from Langmuir wave spectrum. The results demonstrate that both PDI process and LT could accelerate plasma electrons but the diffusion coefficient in LT is larger than PDI process, which lead to the electrons acceleration more effectively in LT than in PDI process. The electron temperature increase from 0.2 eV to 5 eV according to the simulation results. In another approach, we investigate the electron acceleration process by using a direct kinetic Vlasov-Poisson system. Simulation results present the evidence of generation of Langmuir cavitons and corresponding electric field maxima at the initial stage. Collapse of the cavitons and cascade of spectra are then found in the simulation results. At this stage, the electrons were generally accelerated form 0.2 eV to 2.7 eV. The nonlinear saturation of temperature is presented in the last stage. Last but not least, we will briefly discuss the consistency and difference between these two approaches.

C5.1-0042-18 BRAZILIAN SUBORBITAL LAUNCH OPPORTUNITIES FOR SCIENTIFIC EXPERIMENTS AND RESEARCH

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The Brazilian Space Program has, for a long time, been supporting scientific research developed by research centers, students and universities interested in suborbital rocket launches experiments. The record shows that, the first space activities held in Brazil about Ionospheric research with sounding rockets are dated from as far as 1960. Those activities were initiated and carried out at Centro de Lançamento da Barreira do Inferno (CLBI) almost sixty years ago. Scientific probes were used to collect data from space with dedicated instrumentation and experiments set perform specific scientific experiments. The first Brazilian probe, developed by the Instituto Nacional de Pesquisas Espaciais (INPE), was launched in 1965. To realize these launches, the Instituto de Aeronáutica e Espaço (IAE) first developed a family of four sounding rockets - SONDA I, SONDA II, SONDA III, SONDA IV. More advanced space vehicles have been under planning and development such as, the VS-30, the VSB-30, the VS-40, and the VS-43 vehicles, thus building and increasing the capacity to take more heavy and complex space probes to orbit. Two major solid propellant rocket engines, the S30 and the S31, can be assembled together to be used to perform suborbital flights to study the Earths high altitude atmosphere. Those motors can also be combined with the American artifact the Orion vehicle to assemble a vehicle suitable to a required mission and performance. By 2020 there will be a VSB-30 launch opportunity which could carry a scientific probe and experiments from interested researches. In this work, the author reports achievements obtained so far and the future vehicles and platforms that will be available for suborbital launches. Also, it is presented the planning for future high atmospheric sounding rocket launches and directions on how to join these initiatives.

C5.1-0043-18 SPECTRAL SIGNATURES RECORDED BY WHISPER SOUNDER MODE ON BOARD CLUSTER2 MISSION INSIDE DIFFERENT MAGNETOSPHERE REGIONS: PLASMA FREQUENCY DETERMINATION

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The Wave of High frequency and Sounder for Probing of Electron density by Relaxation (WHISPER) performs the measurement of the electron density on the four satellites of the CLUSTER2 mission. The two main purposes of the WHISPER experiment are to record the natural waves and to make a diagnostic of the electron density using the sounding technique, the various working modes and the fourier transforms calculated on board provide a good frequency resolution obtained in the bandwidth 2-80 kHz and a well instrumental adaptability to determine the electron density in various plasma. In this presentation, we focus our attention to the active mode when WHISPER is working as a sounder. Cluster2 orbits cross various plasmas around the earth with a weak or a strong magnetic field (solar wind, magnetosheat, cusp, aurora zones, magnetotail etc). Plasma response is strongly different following region. Spectra exhibit numerous resonances where it is difficult to recognize the plasma frequency .We shall show the characteristics features in each region and we shall describe the methods to identify observed resonances as electron gyro frequency and harmonics, plasma frequency, upper-hybrid frequency and Bernstein modes.

C5.1-0044-18 ACTIVE EXPERIMENTS WITH THE DSX MISSION

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This year, the Air Force Research Laboratory will launch its Demonstration and Science Experiments (DSX) mission to investigate wave-particle interactions, to characterize the distribution of natural and man-made VLF waves, and to map the radiation and plasma environment in medium Earth orbit (MEO). Active experiments will be carried out with onboard VLF transmitters and receivers, the Loss Cone Imager (LCI) particle detector, and the Low-Energy Electro-Static Analyzer (LEESA) to investigate VLF transmission, propagation, and interaction with charged particles. DSX will also observe the natural wave population and explore the basic physics of an antenna in a plasma. We will describe the capabilities of these instruments, science plans, and opportunities for collaboration.

C5.1-0045-18 PARAMETRIC EXPERIMENTS IN MITIGATING SPACECRAFT CHARGING VIA PLASMA CONTACTOR

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Spacecraft charge mitigation in tenuous space plasmas can be a difficult problem. It is especially difficult and essential during active experiments that feature ion or electron beams, as collection from the ambient plasma is often insufficient to balance the beam emission current. For electron emission, the use of a plasma contactor that emits an ionized gas is the only practical option. A series of parametric chamber experiments were completed to address how spacecraft charge mitigation using a plasma contactor may scale in tenuous space plasmas. Experiments focus on how spacecraft potential scales with beam emission current, contactor current (the rate at which the contactor generates quasi-neutral plasma), and contactor propellant mass (ion mass). These experimental results are compared to scaling laws derived via Curvilinear Particle-In-Cell (CPIC) simulations for further validation and physical insight. Implications for enabling future active experiments such as the Connections Explorer mission are discussed.

C5.1-0046-18 EXPERIMENTAL INVESTIGATION OF COLLIDING PLASMA FLOWS USING PULSED POWER DEVICE

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We are investigating colliding plasma flows in which the opposing magnetic fields are frozen in the flows. The magnetized plasma expands radially away from a dual-wire explosion until collision in the stagnation region, between the wires. This region exhibits characteristics that are highly suggestive of magnetic reconnection. To better understand this process and its relation to astrophysical events such as CME's from our sun and colliding winds in binary star systems, the Plasma Physics and Sensors Laboratory, located at Wright-Patterson AFB, developed an experimental setup to study the colliding flows using wire explosion techniques in a controlled setting. Fine metallic wires are placed in a parallel configuration inside our vacuum chamber, and a pulsed power source is used to deliver enough energy to the wires to expel their material in an ionized and gaseous state. We have verified through light emission experiments that there are two distinct time phases that represent this process. The first time phase is characterized by interpenetration and mixing of the leading parts of the flows comprising of hot and fully ionized coronas. This initial corona is primarily composed of light ions and electrons of which had naturally formed on the porous surface of each wire. The colliding coronas produce a collisionless shock in the stagnation region generating weak light emission. We believe these observations of the initial time phase, lasting about 250 ns, are due to wave turbulence in the stagnation region. In the second time phase, the much cooler and denser gas emanating from the wire core provide the separate regime. During this second phase, from 250 750 ns, the weakly ionized gas is driven towards the stagnation region resulting in a collisional shock. Here, intense light emission is observed due to the collisions and deceleration of the gaseous particles. We will present experimental results and analysis of the colliding flows from Al wire explosions. Spatial and temporal observations of light emissions are recorded with an ICCD and simultaneously encompass an end-on and perpendicular view of the stagnation region. Spatial and temporal observations of the electron density will be presented through interferometry. Thermal fluctuations in the stagnation region are obtained with spectroscopy and line ratio analysis.

C5.1-0047-18 BEAM-PLASMA COUPLING PHYSICS IN SUPPORT OF ACTIVE EXPERIMENTS

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The recent development of compact relativistic accelerators might open up a new era of active experiments in space, driven by important scientific and national security applications. Examples include using electron beams to trace magnetic field lines and establish causality between physical processes occurring in the magnetosphere and those in the ionosphere. Another example is the use of electron beams to trigger waves in the near-Earth environment. Waves could induce pitch-angle scattering and precipitation of energetic electrons, acting as an effective radiation belt remediation scheme.

In this work, we revisit the coupling between an electron beam and a magnetized plasma in the framework of cold-plasma theory. We show that coupling can occur through two different regimes. In the first, a non-relativistic beam radiates through whistler waves. This is well known, and was in fact the focus of many rockets and space-shuttle campaigns aimed at demonstrating whistler emissions in the eighties. In the second regime, the beam radiates through extraordinary (R-X) modes. Nonlinear simulations with a highly-accurate Vlasov code support the theoretical results qualitatively and demonstrate that the radiated power through R-X modes can be much larger than in the whistler regime. Test-particle simulations in the wave electromagnetic field will also be presented to assess the efficiency of these waves in inducing pitch-angle scattering via wave-particle interactions. Finally, the implications of these results for a rocket active experiment in the ionosphere and for a radiation belt remediation scheme will be discussed.

C5.1-0048-18 A COMPARISON OF PARAMETRIC INTERACTIONS FOR THE NON-LINEAR GENERATION OF WHISTLER WAVES

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We report on experiments utilizing the simultaneous generation of varying plasma waves in the afterglow of a cold-magnetized helium plasma for the purpose of the non-linear excitation of whistler waves. Two cases which non-linearly excite whistler waves are compared. The first scenario employs electrostatic lower-oblique-resonance waves (LOR) with slightly offset frequencies. The second scenario applies an electrostatic ion-acoustic wave (IAW) with a LOR wave. Plasma is generated using a high-density helicon plasma source in a one meter long, half meter diameter, cylindrical chamber. The spatial and temporal data of the electromagnetic and electrostatic components of the plasma waves are then captured with in-house developed diagnostics such as Langmuir probes, B-dot probes, and dipole probes. Obtained wave spectra and observed time domain data will be analyzed and reported.

C5.1-0049-18 HARMONICS OF ELECTROSTATIC ION CYCLOTRON WAVES IN THREE COMPONENT MAGNETISED PLASMA

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Electrostatic ion cyclotron (EIC) waves and their instability (electrostatic ion cyclotron instabilityEICI) have been observed in various regions of magnetosphere, by various satellites, e.g., Cluster, FAST and THEMIS, as well as in laboratory plasmas. EIC waves propagate nearly perpendicular to ambient magnetic field, with a small finite wave number along ambient magnetic field. EIC waves have gained importance as they provide perpendicular heating of the ions in the magnetosphere. EICI pertaining to the higher harmonics of proton and Helium cyclotron modes is investigated in a three-component magnetized plasma consisting of beam electrons, protons and doubly charged Helium ions. Fewer harmonics of proton cyclotron waves with decreased growth rates and higher number of Helium harmonics with decreased growth rates can be seen with increase in the angle of propagation. Except for one particular case where second harmonic also become unstable, in most of the scenario only odd Helium harmonics are excited. The growth rate of the instabilities enhances with the increase in number density of ions, however, temperature of ions has adverse effect on the growth rate. In addition to this, as the electron beam speed is increased, the number of harmonics as well as peak growth rate increases. Our results are relevant to laboratory and space plasmas where field-aligned currents exist.

C5.1-0050-18 KINETIC ALFVEN WAVES DRIVEN BY ION BEAM AND VELOCITY SHEAR

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A plasma model for the excitation of the Kinetic Alfvén Wave (KAW) by the ion beam and velocity shear will be discussed. The three components model comprising of the cold stationary background ions, hot electrons and hot ion beams will be presented. A general dispersion relation is derived where all the three components are assumed to have drifting Maxwellian distributions and velocity shear. As a special case, the results with ion beam and ion velocity shear will be presented and applied to Earth's auroral regions where the kinetic Alfvén have been observed. It is found that in the presence both velocity shear ion beam are, they have to be opposite to each other in order to have a reasonable growth rate. The effect of other parameters such as ion beam density temperature is also discussed.

C5.1-0051-18 IONOSPHERE AS ASTROPHYSICAL DETECTOR: EXTRACTING SPECTRAL AND TIMING INFORMATION OF CELESTIAL TRANSIENTS USING VLF STUDIES

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The increased electron and ion densities at lower part of earth's ionosphere during astrophysical transient events, like solar flares are the combined effect of ionization by the soft X-rays and the recombination of the electrons and ions with neutrals. The rate of ionization and it's variation with altitude depend on the incident spectra. Hence the altitude variation of electron density values in lower ionosphere modulated by such sources should bear information on soft X-ray spectra of those events. We found that by analyzing the Very Low Frequency (VLF) amplitude modulation during different classes of solar flares we can uniquely determine the approximate soft X-ray spectra during the evolution of those flares. In addition, careful investigation of the peak time delay between the VLF signal amplitude and the transient lightcurve provides us important hints on the intensity and time evolution during the peaks of those events. Specifically, for solar flares uninterrupted monitoring of X-ray spectra is necessary to derive the information on time evolution of non-thermal electron acceleration, transport and interaction during flares in the solar atmosphere. Considering the limitations with space based satellite observations due to restricted window of the instruments to avoid saturation, our method of reconstruction of flare spectra from VLF data may provide us a continuous and uninterrupted mean of monitoring those events. Higher energy photons from flares (in hard X-rays) produce most of the ionization at much lower heights. The hard X-ray and gamma ray from extra-galactic transients like, SGR, GRB etc. penetrate even deeper in the atmosphere ionizing the molecules present there. With suitable means of observation of electron densities and proper extension of our deconvolution method for those heights, we should be able to extract information of hard X-ray spectra of solar flares and those of extra-galactic transients also. The outline is that the earth's atmosphere may be an excellent and ever-present gigantic detector of ionizing extra-terrestrial events with VLF and any other suitable means of detection of it's modulation in plasma properties in different parts of the atmosphere.

C5.1-0052-18 A NEW INTERPRETATION OF THE UPPERAND LOWER-FREQUENCY CUTOFFS OF LIGHTNING GENERATED NONDUCTED MAGNETOSPHERICALLY REFLECTED (MR) WHISTLERS: REMOTE SENSING OF MAGNETOSPHERIC PLASMA DENSITY AND COMPOSITION

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Nonducted whistlers resulting from lightning and observed on a magnetospheric satellite appear on a spectrogram as a series of magnetospherically reflected (MR) traces with characteristic dispersion (time delay versus frequency) and upperand lower-frequency cutoffs. We explain the upperand lowerfrequency cutoffs of MR whistlers in terms of interior and exterior caustics associated with ELF/VLF waves injected from lighting into the magnetosphere [Dantas, 1972; Sonwalkar et al., 1994]. Caustics are the boundaries that define a region of space that is accessible to waves arriving from a certain source. In a smooth magnetosphere, the locations of the caustics depend on frequency, range of injection latitude, magnetospheric plasma density and composition, and any irregularities present in the magnetosphere (e.g. plasmapause or cross-L density drop-offs). At a given frequency, the accessibility of waves injected from lighting to a certain location in the magnetosphere is determined by the locations of interior and exterior caustics. This in turn determines the upperand lower-frequency cutoffs of MR whistlers observed in the magnetosphere. We demonstrate our new interpretation of MR whistler frequency cutoffs with the help of ray tracing calculations in a smooth magnetosphere. The previous works explained MR whistlers cutoffs in terms of Landau damping that requires the presence of hot electrons at specific energies [Thorne 1968, Bortnik et all., 2003] or propagation effects that require cross-L shell plasma density drop offs [Edgar, 1976]. Our explanation of MR whistler frequency cutoffs does not require the presence of hot electrons or density drop-offs, though either of these, if present, may play a role in the determination of frequency cutoffs. Ray tracing calculations show that caustics as well as MR whistler frequency cutoffs are strong functions of plasma composition (or $O^+/(H^+ + He^+)$ transition height) but are weak functions of plasma density. On the other hand, the dispersion of MR whistler traces is a strong function of the plasma density but is a weak function of plasma composition. This leads to a simple and efficient ray tracing inversion method to determine magnetospheric plasma density and composition from observed MR whistler dispersion and frequency cutoffs. This ray tracing inversion method has been demonstrated on case studies of whistlers observed on the

OGO 1 and Van Allen Probe (RBSP-B) satellites [Sonwalkar et al., 2017]. The results imply an important role that caustics may play in magnetospheric nonducted wave-particle interactions, and they highlight the possible role that ions may play in the physics of wave-particle interactions.

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C5.1-0053-18 STUDY OF THE EFFECTS OF VARYING LOCATION OF LIGHTNING-INDUCED ELECTRON PRECIPITATION (LEP) EVENTS OVER A CHOSEN VERY LOW FREQUENCY (VLF) RADIO WAVE PROPAGATION PATH ON THE SIGNAL AMPLITUDE

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The lower layer of the Earth's ionosphere and the ground forms a waveguide that guides Very Low Frequency (VLF) radio waves over long distances without much attenuation. There may be various sources of such waves, both natural and man-made. When a lightning discharge occurs, it emits electromagnetic waves in all directions, the majority of which gets trapped within the earth-ionosphere waveguide. But a small portion of it enters the magnetosphere where it moves along the magnetic field lines in a whistler mode wave and interacts with the radiation belt electrons. As a result of such wave-particle interaction, some of the electrons get trapped within the ionosphere and they precipitate resulting in localized enhanced ionization. In the present study, our aim is to determine the effects of such lightning-induced electron precipitation (LEP) events on Very Low Frequency (VLF) signal amplitude. We analyzed the VLF data collected by Indian Centre for Space Physics (ICSP) for paths VTX-IERCOO and NWC-IERCOO. Both positive and negative shifts in amplitude are observed which are characterized by fast rise and exponential decay. For this, we calculated the ionization rate per ion pairs formed with altitude and then by using the D region ion chemistry model, we determined the electron density variation over ionospheric heights. We then used these electron density profiles in the well-known Long Wavelength Propagation Capability (LWPC) Programme to obtain the signal amplitude. Finally, we varied the location of such disturbance region over a chosen VLF path (transmitter-receiver) so that we can understand its effect on the signal amplitude. From our study, we found profound influence of the variation of the location of the disturbance region on the signal amplitude. We found that the maximum effect on the signal amplitude is obtained when the disturbance region is near the transmitter end while if it's near the receiver end, very little or no influence is imposed on the signal amplitude. Also, the location of the disturbance region is the key factor in determining the nature of shift, i.e., positive or negative of the signal amplitude and the spatial extent influences the degree of signal modulation.

C5.1-0054-18 QUANTITATIVE MODELING OF LOWER IONOSPHERIC RESPONSE DURING SOLAR X-RAY EVENTS: A PROPAGATING RADIO WAVE SIMULATION APPROACH

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The surplus solar X-ray radiation during solar flares causes an enhancement of ionization in the lower ionospheric D-region and hence affects sub-ionospherically propagating Very Low Frequency (VLF) radio wave signal amplitude and phase. VLF signal amplitude and dynamic phase perturbation (ΔA) and amplitude time delay (Δt) (vis-á-vis the corresponding solar Xray as measured by GOES-15) of several VLF transmitters such as NWC/19.8 kHz, VTX/18.2 kHz etc. signals have been computed for solar flares. In the first part of the work, using the well-known Long Wave Propagation Capability (LWPC) technique, we simulated the flare induced excess amount of lower ionospheric electron density profile by amplitude perturbation method. Unperturbed D-region electron density is also obtained from simulation with the help of the 2-component exponential D-region model and compared with International Reference Ionosphere (IRI) model results. Further, in the second part, we compute the corresponding 'sluggishness' through Δt and effective electron recombination coefficient (αeff) analysis. We find that while Δt is anti-correlated with the flare peak energy flux (ϕmax) and the correlation factor is dependent on solar zenith angle values.

C5.1-0055-18 NUMERICAL MODELING OF LONG-PATH PROPAGATION CHARACTERISTICS OF VLF RADIO WAVES AS OBSERVED FROM INDIAN ANTARCTIC STATION MAITRI AND BHARATI

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Long path VLF radio wave propagation has a distinctive feature that during its propagation it experiences large variations of solar irradiation and degree of ionization. The propagating waveguide modes and modal conversion is completely different that for shorter path (<3000 km). Study of radio signal characteristics in Antarctic region during summer period in the Southern Hemisphere gives us a unique opportunity to explore such interesting phenomena. In addition, there is an extra feature in this path during summer which is whole day presence of solar radiation and hence the D region in at least some sections of the propagation path. We present long-distance propagation characteristics of VLF signals transmitted from VTX (18.2 kHz) and NWC (19.8 kHz) from India and Australia respectively recorded simultaneously at Indian permanent stations Maitri (Lat. 70°45'S, Long. 11°40E) and Bharati (Lat. 69°24'S, Long. 76°10'E). A very stable diurnal variation of the signal (both amplitude and phase) has been obtained with no signature of nighttime fluctuation due the presence of 24 hours of sunlight for both the stations. We reproduce the spatial signal amplitude variation by using advanced GPI ion chemistry model by calculating the ionization rate. We compute D-layer electron density profile over the entire path using the model. Using solar zenith angle profile and the Wait's two component model we reproduce the temporal signal amplitude variation for all possible VLF baselines. We present the attenuation rate of the dominant waveguide modes and the effects of Antarctic polar ice on the attenuation of propagated VLF signal. We observed strong attenuation in signal amplitude during propagating over Antarctic ice mass and we corroborate this by numerical simulation.

C5.1-0056-18 UNUSUAL SHIFTS OF THE TERMINATOR TIMES OF THE VLF SIGNALS FOR VTX-SALTLAKE (KOLKATA) PROPAGATION PATH BEFORE TWO MAJOR EARTHQUAKES, OCCURRED IN JUNE, 2010.

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We have presented the results of the analysis of the VLF signals transmitted from NWC (latitude 21.8°S, longitude 114.15°E) at 19.8 KHz and received at Salt Lake, Kolkata (latitude 22.56°N, longitude 88.4° E). We have analyzed the amplitude of the VLF signals for the period of 5th June, 2010 to 25th June, 2010. During this time period two major earthquakes of lowdepth (10 Km) and high magnitude (M>5), occurred near the propagation path of the VLF signals. The first one occurred on 13th June, 2010 at Nicobar Islands, India (latitude 7.8°N, longitude 92.0° E). The magnitude of it was 5.1 (in Richter scale). The second one of magnitude 6.0 (in Richter scale), occurred on 19th June, 2010 at Andaman Islands, India (latitude 13.4°

N, longitude 93.0° E). For both of these two earthquakes, we found that the terminator times of the VLF signals (mainly sun set terminator time), are shifted towards night time just one day before the event and hence the VLF-day-length (defined as the time difference between the sun set terminator and sun rise terminator time) became anomalously high one day before the earthquakes. To explain this effect we are trying to make a model using ion-chemistry and LWPC code.

C5.1-0057-18 THE SOLAR ENERGETIC PARTICLE BACKGROUND ESTIMATION IN THE SOLAR ORBITER/STIX MEASUREMENTS

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Spectrometer/Telescope for Imaging X-rays is one of ten instruments on board the Solar Orbiter (SO) mission. It will be launched in 2020 into heliocentric orbit. After three years of cruise phase and series of gravitational assist SO will reach first scientific orbit with perihelion distance equal to 0.3 AU. The STIX is Fourier X-ray imager which will provide spectra and images of solar sources within a range of 4-150 keV. On the heliocentric orbit with short perihelion distance the spacecraft will be highly affected by streams of energetic particle from the Sun. On the perihelion distance we expect fluxes of the SEP to be almost 10 times higher than at 1 A.U. Therefore we performed Geant4 simulation of particles interaction with instrument for different distances from the Sun and corresponding intensities of SEP events. We calculated detectors direct hits as well as secondary radiation from instrumental parts. We have found that the latter may influence measured X-ray spectra and reconstructed images.

C5.1-0058-18 SIMULATIONS OF CALISTE-SO DETECTORS

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The Caliste-SO is CdTe pixelized X-ray detector designed for STIX instrument. Our aim was to simulate a response of the detector to X-ray flux using Geant4 and compare it to laboratory measurements. The detectors were illuminated with X-ray sources Am241 and Co57 in several configurations (various temeperatures, voltages etc.). Moreover, Monte Carlo simulations of the detector response have been performed for each laboratory configuration. Obtained results allowed us to calculate Detector Response Matrices for each pixel with Fano noise, hole tailing, charge sharing, and other detector effects included. Final set of DRMs will greatly improve actual solar X-ray spectra analysis after Solar Orbiter launch in 2020.

C5.1-0059-18 SOLACES - A NOVEL APPROACH IN ABSOLUTE CALIBRATION FOR SOLAR EUV RADIOMETRY

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SolACES monitored the solar EUV radiation from 17 nm to 134 nm during a nine year mission period (ISS-SOLAR, 2008 to 2017). Severe degradation effects as caused by ageing effects and hydrocarbons from ISS supply vehicles required reliable in-orbit re-calibration capability of the EUV spectrometer system. For this task, SolACES was equipped with a gas-refillable double ionization chamber, operated as a primary detector standard, to serve as tool for absolutely calibrating the obtained spectral data. In this context, the SolACES team will present requirements and constraints for using ionization chambers as primary detector standard, as well as the principles of operation of such a device in space. A further improvement of the calibration procedure (and thus of the calibrated data) depends on the better understanding of the secondary ionization effects. For this reason, a mock-up of the SolACES ionization chamber was investigated at the MLS synchrotron of the PTB in Berlin enabling to derive data sets of even higher accuracy.

C5.2-0001-18 DUST ASTRONOMY WITH THE MISSION DESTINY+

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The interplanetary probe Destiny+ of the Japanese space agency JAXA/ISAS is a mission to the inner solar system and the active asteroid 3200 Phaethon. The launch of the mission is planned for 2022 and the flyby of the asteroid Phaethon is scheduled for 2026. The mission uses a solarelectric propulsion system and a dust telescope is used as a scientific payload. The telescope is a further development of the Cassini dust spectrometer and it is optimized for new in-situ observations in the field of Dust Astronomy. High resolution measurements to determine the elemental composition of individual micrometeoroids are combined with trajectory information. Main scientific questions are: What is the origin and nature of the dust particles that constantly fall onto the earth? What is the fraction and composition of organic material in interplanetary and interstellar matter? How do active asteroids work?

The discovery of interstellar dust in the outer and inner solar system in recent decades has enabled a new innovative approach to the characterization of galactic cosmic dust. The in-situ methods of Dust Astronomy complement and extend the results achieved so far. Destiny+ is the next logical step after the successful missions of Stardust, Rosetta and Cassini. In particular, the following questions are addressed: - In-situ analysis of the elementary and isotopic composition of individual cosmic dust particles including their organic constituents - Characterization of dust emission of the active asteroid 3200 Phaethon - Determination of the size distribution of interstellar dust - Characterization of the interaction of interstellar matter with the heliosphere - Determination and criteria for cometary and asteroidal interplanetary dust particles - Improvement of meteoroid models for the inner solar system

The Destiny+ Dust Analyzer (DDA) determines the particle density, composition, charge and mass of the smallest dust particles. It consists of two sensor heads, a 2-axis gimbal mechanism and an electronics box. The measuring principle is based on impact ionization, time-of-flight mass spectrometry and charge influence. The sensitivity (particle size, trace elements) and mass resolution has been improved up to a factor of 10 compared to the Cassini dust instrument.

C5.2-0002-18 INTERPLANETARY DUST: THE VIEW FROM NEAR AND FAR

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Interplanetary dust is present throughout the solar system and provides a key connection to fundamental planetary building blocks. IDP grains are produced via several processes, including asteroidal disruption, cometary outgassing, and grain-grain mutual collisions, from several parent sources, such as the asteroid belt, Jupiter-family, Halley-type, and Oort Cloud comets, and Edgeworth-Kuiper Belt objects. The relative density and flux of IDPs from any individual source at a given location in the solar system is a complex function of both dust production rates and subsequent gravitational and non-gravitational interactions. We describe recent modeling and observational efforts directed at understanding and constraining both the individual components and overall morphology of the interplanetary dust cloud throughout the solar system.

We also briefly discuss two new mission concepts regarding interplanetary dust. The first, i2DUNE, would measure interplanetary and interstellar dust from an Earth-orbiting (or nearEarth) spacecraft making use of next-generation trajectory and mass composition dust detectors. The second, Interstellar Probe, is a mission to leave the Solar System in order to gain a unique vantage point for look-back imaging of the interplanetary dust complex. IP would provide global imaging of our solar system's debris disk in analogy with the plethora of observations of exozodiacal disks around other stars. Both of these missions present exciting opportunities to revolutionize our view and understanding of dust both near and far.

C5.2-0003-18 STUDENT DUST COUNTER: STATUS REPORT AT 40 AU

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Information on the distribution of interplanetary dust particles (IDPs) provides constraints to the origin and evolution of planetary bodies. IDPs are subject to gravity, radiation pressure, EM forces, and Poynting-Robertson drag and will migrate throughout the solar system, often getting trapped in resonances with or scattered by the giant planets. Being able to accurately map the distribution of IDPs will provide insight into the sources, sinks, and dynamics of dust grains as well as the overall evolution of the solar system. The Student Dust Counter (SDC) is an in-situ dust detector aboard the New Horizons spacecraft observing the distribution of IDPs in the mass range of 10−12 < m < 10−9 g or approximately 0.5 - 5 μm in radius. New Horizons was launched on January 19th, 2006 and performed a fly-by of the Pluto system on July 14th,

2015. SDC has nearly continuously mapped the dust density distribution along the trajectory of New Horizons from Earth to 40 AU. We present results of the dust density distribution and compare these measurements to existing theoretical models.

C5.2-0004-18 DUSTY SPACE PLASMA DIAGNOSIS USING TEMPORAL BEHAVIOR OF POLAR MESOSPHERIC SUMMER ECHOES DURING SOLAR PROTON EVENT

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Natural dusty plasma formed by disintegration of meteors appears in the atmosphere's mesosphere region between 50 and 80 km altitude. Climate change and human activity have caused decreasing mesospheric temperatures and increasing water vapor content via increased methane concentration. Noctilucent clouds (NLC) occur in cold polar summer mesopause and are the direct visual manifestation of freezing of water vapor on the dust particles and formation of ice-coated meteoric dust particles. In-situ measurements using sounding rockets have shown deep depletion of electron density due to charging on mesospheric dust particles (Rapp, 2009; Robertson et al., 2009). Accumulation of free electrons on the ice particles produces electron density structures, which cause the reflection of radar waves. Polar Mesospheric Summer Echoes PMSE are strong coherent radar echoes produced by electron density fluctuations in the vicinity of polar mesopause and at the half the radar wavelength (Rapp and Lubken, 2004). The first VHF radar echoes from the high-latitude mesosphere were observed using the Poker Flat radar in Alaska (location 65.120 N, 147.430 W) (Ecklund and Balsley, 1981; Balsley et al., 1983).

We have investigated the behavior of polar Mesospheric summer echoes (PMSE) during solar proton event (SPE) including dusty plasma effects for the first time. The observational data recorded using the VHF (224 MHz) radar at the European Incoherent SCATter Scientific Association (EISCAT) on July 10 and 11, 2012 will be presented. The observed radar echoes show correlation and anti-correlation with the elevated background electron density variation. The experimental observations are compared with the numerical simulations of the temporal evolution of PMSE with different background dusty plasma parameters during SPE. Specifically, the effect of dust radius, dust density, and electron density on the behavior of PMSE layer and the associated dust charging process in the course of electron precipitation events is studied. It has been indicated that the ratio of electron density fluctuation amplitude ne to the plasma density (ne), dust density

and dust radius, recombination/photoionization rates play a critical role in appearance (and disappearance) of the layer. Possibilities of ice particles charging by mesospheric electrons will be discussed. The condensation of nuclei of the ice particles such as proton hydrate clusters (H+(H2O)n) or meteoric smoke particles (MSP) can be determined by employing microphysical simulations. This can resolve the discrepancy in the description of the observed phenomena. The possibilities of combining the Virginia Tech dusty plasma model with NCAR WACCM/CARMA (Whole Atmosphere Community Climate Model/ Community Aerosol and Radiation Model) to develop a large aperture radar simulator for the dusty space plasma in the near-Earth space environment will be discussed.

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C5.2-0005-18 METEORIC DUST, ICE NUCLEATION AND NOCTILUCENT CLOUD GROWTH

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Meteoroids entering the atmosphere ablate, whereupon the resulting material is believed to re-condense as smoke particles. These particles are thought to play a major role in mesospheric processes, effecting charge and radiation balance, ice nucleation and chemistry. In particular, they have long been considered the favorite candidate as a condensation nucleus for noctilucent clouds (NLC). There was, however, a puzzle; the atmospheric circulation efficiently transports the meteoric smoke away from the summer mesopause where NLC form, and ice growth models showed that the particles were transported away before they grow large enough to efficiently act as ice condensation nuclei. The ice growth models at that were used, were based on stationary conditions and thus drastically different from the vivid conditions that lidars and radars observe; temperature changes around 20 K per hour and winds of close to one meter per second that reverse direction sometimes several times per hour are not unusual. Here, the consequences of the choice of atmospheric conditions for ice growth and cloud characteristics are investigated. The results are compared to tomography observations from the OSIRIS instrument and it is found that inclusion of these rapid fluctuations is crucial to simulate clouds characteristics that correspond to observations. Moreover, the reduced number of meteoric ice condensation nuclei that is left in the summer mesopause is not a problem for ice formation once you include the rapid mesospheric fluctuations - in fact it leads to clouds that are better in agreement with observations.

C5.2-0006-18 METEORIC DUST EFFECTS ON THE ELECTRODYNAMICS OF LOW LATITUDE E-REGION PLASMA

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Electrodynamic processes occurring in the E-region of the equatorial ionosphere can be affected by dust particles of meteoric origin. The dust particles can capture the ambient electrons and cause considerable increase in the loss rate of electrons thus affecting the growth rates and amplitudes of the plasma irregularities. The attachment of electrons on dust particles can increase the threshold velocities needed for the onset of two stream and gradient drift instability mechanisms responsible for the generation of Type I and Type II plasma irregularities respectively, observed in the equatorial E-region plasma. In situ rocket observations also indicate that, under similar ambient conditions, the amplitudes of Type II irregularities observed in the lower E-region are considerably smaller than those observed at higher altitudes. This probably is a direct evidence for the effect of dust particles that dominate the lower E-region altitudes practically all the time. Electric field changes in the low latitude E-Region are attributed to changing neutral winds and to remote causes like the mapping of storm time electric field changes or changes in the neutral winds caused by Sudden Stratospheric Warming (SSW). Variation of electrojet currents is a manifestation of changing electric fields and/or electrical conductivities. Changes in the conductivity parameters, especially in the lower E-region can also be caused by the ambient dust particles of meteoric origin. Statistical studies have shown that the monthly occurrence rate of reversals in the electrojet currents is highly correlated to the monthly mean of meteor showers. This high correlation is seen even during geomagnetically disturbed periods. The meteoric dust particles thus play a very important role in altering the local electrical conductivities in the lower E-region and in controlling the electrodynamic processes in this region.

C5.2-0007-18 LABORATORY OBSERVATIONS OF METEOROID DIFFERENTIAL ABLATION

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Experiments at the University of Colorado's 3 MV dust accelerator facility have simulated the ablation of micrometeoroids entering planetary atmospheres by shooting submicron-sized particles into an air chamber at high velocities. These experiments allow direct observation of the fundamental physical processes that govern meteoric ablation, which is relevant to the study of meteoric entry in planetary atmospheres and the study of meteoroids in the Solar System. Current models of meteor ablation depend on an accurate specification of the drag and heating that meteors undergo when they enter a gaseous medium. In one set of experiments, aluminum particles were shot into a variety of gases at speeds of 1-10 km/s and their slowdown was measured using precise timing measurements at the beginning and end of the air chamber. The drag coefficient of the particles was calculated from the slowdown measurements and found to be around 1.3 regardless of gas type, which is somewhat higher than expected. In another set of experiments, magnesite and olivine particles were shot into an air chamber at speeds of 10-30 km/s. The charge production by the particles was spatially resolved inside the chamber, and multiple peaks were observed in the charge production profiles. The multi-peak observations are believed to correspond to the differential ablation of different constituents of the particle as the particle heats up during its passage through the chamber. The differential ablation charge production profiles enable the heating coefficient to be estimated. In this presentation, these experimental results are summarized and used to give us a more complete understanding of the ablation process through a better understanding of meteoric drag and heating.

C5.2-0008-18 RECENT ROCKET MEASUREMENTS AND SMOKE PARTICLE SIZE DISTRIBUTIONS

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We present results of in situ measurements of the MLT-dusty plasma conducted during the WADIS-2 sounding rocket campaign. These measurements included densities of electrons, positive ions, charged aerosols and neutrals. For the first time all plasma and neutral densities were measured with high spatial resolution in a true common volume. A new approach combining all measurements allows for a reliable derivation of mean sizes and a size distribution function for the charged meteor smoke particles (MSPs).

In addition a simple charging model is adapted to reproduce the in situ measured densities. We discuss the size distributions from the model and the in situ measurements.

C5.2-0009-18 THE FIRST DIRECT DETECTION OF SATURN'S MAIN RING MATERIAL - CASSINI COSMIC DUST ANALYSER GRAND FINALE RESULTS

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The Cosmic Dust Analyzer observations during the Cassini Grand Finale Orbits were designed for the in situ characterization of Saturn's rings' composition and to study their interactions with the host planet. It is found that the 2,000 km wide corridor between the inner most D ring and Saturn's cloud tops is lacking of larger, micron-sized dust grains but rich in nanodust particles (radius smaller than 50 nm) that only become detectable by CDA because of the high spacecraft speed of 30 km/s.

Regarding the grain composition, while the majority of CDA mass spectra recorded during this phase are too faint to be individually calibrated, two types of mass spectra has been identified - water ice and silicate types. While water ice type dominates, the observed silicateto-ice grain ratio is much higher than that of Saturn's main rings, implying a differential erosion that preferably removes the more refractory constituents from the rings in the form of nanograins. As for the dynamics, the observation confirms the electromagnetic transport of charged nanodust from the main rings along magnetic field lines to the planet, previously proposed to be responsible for the observed "Ring Rain" effect. The estimated ring mass loss rate is sufficient to support the required H3+ chemistry of the ring rain effect. The derived erosion rate also indicates a relatively young ring age, consistent with results from ring-moon system dynamics and other recent observational constraints.

C5.2-0010-18 ASTEROIDS AND DUST: RECENT FINDINGS AND FUTURE DIRECTIONS

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Classically, the discriminator between asteroids and comets is that the latter group is surrounded by a dust coma while the former group is not. Observations over the last decade or so, however, have found a class of “active asteroids” that have a comet-like coma but are otherwise like typical asteroids in physical and orbital properties. These observations have been accompanied by identification of processes that liberate dust from asteroidal surfaces, from the constant stream of ejecta from micrometeorite impacts to sudden, large-scale events that can lead to satellite formation. The presence of asteroidal dust leads to new opportunities for in situ compositional measurements that do not require surface descents or sample handling. We will discuss these topics, including how modern, capable dust analysis instruments could answer important questions in asteroid science.

C5.2-0011-18 DUST DETECTION IN SPACE BY WAVE INSTRUMENTS: CASSINI AND JUNO OBSERVATIONS

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Wave instruments onboard spacecraft are designed to detect radio and plasma waves in space. However, when spacecraft encounter dust at tens of kilometers per second, the plasma clouds released by energetic dust impacts can couple to the antennas of wave instruments and cause either voltage pulses in waveforms or broadband noise in the spectra recorded by the receivers. The impact signals have been simulated in the lab by shooting dust particles onto a spacecraft model with electric field antennas. During the Cassini and Juno mission, such signals have been detected by the onboard wave instruments in the solar wind and different regions of planetary magnetospheres. Given the particle velocity and impact charge yield function, the size and density of the particles can be estimated from the measured signals. We will compare the dust observations made by the two spacecraft and discuss the possible effects of background plasma density and magnetic field on the waveforms of the dust impact signals.

C5.2-0012-18 ELECTRIC FIELD INSTRUMENTS AS DUST DETECTORS, SIGNAL INTERPRETATION

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Electric field instruments are able to detect hypervelocity dust impacts on the spacecraft body as transient pulses in the measured electric field. This method is frequently used for dust detection in various parts of our solar system. In spite of intensive ongoing studies, signatures generated by dust impacts are not completely understood and explained. A very important issue is a reliable identification of dust impacts in obtained waveforms. Solitary waves and pulses generated by instrumental effects can be similar to pulses triggered by dust impacts. This fact can result in false dust detection. We present a study of a possible source of signal misinterpretation based on Cluster and MMS data. We show that the identification of dust impacts especially by a single electric field antenna is a very challenging issue and that it is necessary to be aware of that not all pulses in the electric field data are triggered by dust impacts.

C5.2-0013-18 LASER ORBITAL DEBRIS REMOVAL

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Laser orbital debris removal

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The efficiency with which a laser pulse energy couples into a target object and can generate momentum [1] is of critical importance for applications such as orbital debris removal. The selection of a suitable laser for deorbiting debris will strongly depend on the wavelength, pulse length, duty cycle and average power which can be delivered, with currrent estimates indicating that a 20-100 KW average power class laser driver is required. Over the last 30 years there has been a significant reduction in the pulse lengths from ns to fs's which can be routinely delivered. Although shorter pulses can more readily ionise a material for a given pulse energy, the absortpion efficiency can play a dominent role in the interaction. Recent studies have shown absorptions ranging from 4 - 97%, for ps pulses[3]. The absorption is strongly dependent on the plasma scale length and studies will be presented and reviewed considering the implications for the choice of ideal pulse length and energy density to optimise laser plasma coupling for orbital debris removal. The potential to now build such a system will be examined and studies looking at the atomic and particle debris will also be presented.

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C5.2-0014-18 EXPERIMENTAL SET-UP FOR LUNAR DUSTY PLASMA INVESTIGATION AND INSTRUMENT CALIBRATIONS

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Keywords: Lunar Dust, Lunar exosphere, Moon, Plasma, Dust

Introduction:

The scientific payload of the "Luna-Glob" lander includes PmL instrument. This instrument is designed to study the dust component, its dynamics in the near-surface exosphere of the Moon, the registration of micro-meteorites and secondary particles of the lunar regolith, impact by micrometeorites and the measurement of their physical characteristics. The device directly measures momentum, velocity, mass and charge of the particles. For the purpose of conducting physical experiments on modeling of the dusty environment conditions in the surface layer was created an experimental setup. This experimental set-up had been designed for carrying out functional tests, adjustments and calibrations of the instrument. The installation is carried out testing of the methodology of space experiment. It is planned to hold correction of the coefficients of relative sensitivity and verification of the scientific data obtained during the mission.

Experimental set-up: The experimental set-up is realized on the base of the vacuum chamber and includes a system of supply and control of vacuum, the injector (generator) of charged particles. The setup includes the control system for measuring the speed of the charge of particles and the system to measuring and control electrical signals and instrument parameters. Vacuum system provides vacuum with a residual pressure sufficient to operate the injector of the dust particles and simulate the conditions of the dust of the atmosphere. Injector (generator) of dust, charged particles produces a stream of metallic, charged particles with dimensions from units to hundreds of microns with flow rates from units to tens of meters per second with a charge of not less than 1000 electrons per the particle. The measuring system for the control of the speed and charge of particles consists of the induction sensor and charge sensitive amplifiers that allow to display and measure the signal. Method of measuring charge is based on the measurement of the induced mirror charge from the moving particles in the metallic electrode of the induction sensor. The geometry data of the placement of the induction sensors is used to measure the speed of particles by time delays of signals. The voltage applied to the injector governs the speed and charge of the injected particles. In the experiments are used different in size and mass of particles loaded into the injector. Since the process of injection and the detection of particles are random, the statistical methods to handle the large volume of accumulated data are used. Another source of charged dust particles possibly can be created from the UV-irradiation system inside experimental set-up which leads us to dust particles levitation inside the chamber.

Results:

The set-up made it possible to realize the streams of charged particles with velocities in the range of 2 to 60 m/s for the metalized particles with sizes from 10 μm to 200 μm. On the installation was carried out calibration of the engineering sample PML device, had allowed to determine the sensitivity of the sensors of the device. Threshold sensitivity for the charge is amounted to 2 000 the charge of the electron. The threshold sensitivity of the momentum is amounted to the value of 3*10−12 N*s.

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C5.2-0015-18 CREATING ASTROPHYSICALLY RELEVANT WATER-ICE DUSTY PLASMA IN THE LABORATORY

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Water-ice dusty plasmas occur terrestrially in polar mesospheric clouds, extraterrestrially in Saturn's E, F, and G rings, and throughout the universe in protoplanetary disks and molecular clouds [1-3]. The Caltech Water-Ice Dusty Plasma Experiment creates similar plasma in the laboratory. Background gas on the order of 100s of mTorr enters into a small vacuum chamber where it is ionized into plasma by 1-3 W of 13.56MHz RF across two parallel circular electrodes. These electrodes are cryogenically cooled with liquid nitrogen to 150K which causes water vapor to spontaneously freeze into ice grains in the plasma. The length and aspect ratio of the grains depend on the background plasma gas, the background gas pressure, and the applied magnetic field. Large grains (500 microns in length) are created in hydrogen plasma with low gas pressure (200 mTorr) and no external magnetic field. Increasing the background gas pressure, increasing the atomic mass of the plasma species, or introducing external magnetic field all make the ice grains smaller [4]. The growth of the water-ice grains in helium plasma was studied using a long distance microscope lens and an ultra-high speed video camera. Accretion likely dominates the growth because the grains have a large negative charge resulting in strong mutual repulsion to prevent agglomeration, even in the presence of observed waves (believed to be Dust Acoustic Waves) [5]. A Laser Induced Fluorescence diagnostic is under development for the Caltech Water-Ice Dusty Plasma Experiment. This diagnostic uses a diode laser, a photomultiplier tube, and a lock-in amplifier. Preliminary measurements without cryogenic cooling show that the temperature of the neutrals is close to room temperature. Indication of a flow velocity is also observed. When completed at Caltech, this project will be transported to Germany to measure temperatures and flow velocities on the ground-based PK4 replica.

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C5.2-0016-18 ION-ACOUSTIC SHOCK WAVES IN A SIX COMPONENT COMETARY PLASMA

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We investigate the propagation characteristics of Ion-Acoustic Shock waves in a six component cometary plasma composed of two hot and one colder electron component, hot lighter ions, and pair ions. The colder and one hotter component of electrons together with the lighter hydrogen ions are modelled by kappa distribution. The other hotter electron is described by q-nonextensive distribution. The KdVB equation is derived for the system and its solution plotted for different kappa values, oxygen ion densities, kinematic viscosities as well as the temperature ratios of ions. It is found that, in afore said composition shock wave shows a transition to soliton. The basic features of the Ion-Acoustic Shock waves such as amplitude, width, and phase speed have been extensively studied by a numerical analysis of the KdVB equation. The amplitudes of the Shock waves seem to be well correlated to the presence of water molecules in a cometary plasma and the associated photo-ionisation processes.

C5.2-0017-18 CYLINDRICAL SHOCK WAVE IN A SELF-GRAVITATING ROTATIONAL AXISYMMETRIC DUSTY GAS WITH DENSITY VARYING EXPONENTIALLY

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The propagation of a strong cylindrical shock wave in a self-gravitating and rotational axisymmetric dusty gas, having variable azimuthal and axial fluid velocities is work out in the case of isothermal and adiabatic flows. The dusty gas is assumed to be a mixture of small solid particles and perfect gas. The equilibrium flow conditions are assumed to be maintained, and the density of the mixture and the fluid velocities in the ambient medium are assumed to be varying and obeying an exponential law. The shock wave moves with variable velocity and the total energy of the wave is non-constant. Non-similarity solutions are obtained and the effects of variations of the mass concentration of solid particles in the mixture and the ratio of the density of solid particles to the initial density of the gas, and the presence of self-gravitational field and rotating medium on the flow variables are investigated at given times. The shock waves in self-gravitating rotational dusty gas can be important for description of star formation and shocks in stellar explosion, shocks in supernova explosions, in the study of central part of star burst galaxies, nuclear explosion, in industry, rupture of a pressurized vessel and explosion in the ionosphere. Other potential applications of this study include analysis of data from exploding wire experiments and cylindrically symmetric hypersonic flow problems associated with meteors or re-entry of vehicles and the measurements carried out by spacecraft in the solar wind and in neighborhood of the Earth's surface etc. A comparison is made between the solutions obtained in the case of rotating gravitating and the non-rotating gravitating or non-gravitating rotating or non-rotating non-gravitating. The obtained solutions are applicable for arbitrary values of time.

C5.2-0018-18 EFFECT OF DISCRETE CHARGE FLUCTUATIONS ON AGGREGATE GRAIN GROWTH

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The earliest stages of protoplanetary development are characterized by the coagulation of micron-sized dust grains. Aggregate growth due to collisions between grains is highly dependent on the local environment, including the dust and gas densities, turbulence, and grain charging mechanisms, as well as the physical characteristics of the aggregates themselves. In many regions of a protoplanetary disk, the gas is weakly ionized. Dust particles immersed in a plasma environment become charged through the collection of electrons and ions at random times, causing the dust charge to fluctuate about an equilibrium value. Sub-micron sized grains or grains in a tenuous plasma environment are sensitive to single additions of electrons or ions. These charge fluctuations occur on timescales which are relevant for dynamics of aggregate growth. Here we present a numerical model that allows examination of discrete stochastic charge fluctuations on the surface of aggregate grains and determine the effect of these fluctuations on the dynamics of grain aggregation. Coupled dynamics and charging models show that charge fluctuations tend to produce aggregates which are much more linear or filamentary than aggregates formed in an environment where the charge is stationary.

C5.2-0019-18 NEW INSIGHT INTO EM RADIATION FROM SPINNING DUST AND ITS INFLUENCE ON THE COSMIC MICROWAVE BACKGROUND

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Dust is ubiquitous in the Universe and its influence on the observed Electromagnetic (EM) radiation needs to be correctly addressed. In recent years it became clear that scattering of EM radiation from interstellar dust grains could change the local properties of the observed Cosmic Microwave Background (CMB) radiation. Here we summarize some new results concerning the relevant processes of emission and scattering of EM radiation from spinning dust particles, and discuss their possible influence on the CMB. In particular, we show that scattered radiation can establish a correlation between different spectral components of galactic dipolar emission. This could explain the observed correlation between the CMB and the 100-micron thermal emission form interstellar dust. Another important property of CMB is related with its polarization anisotropies, and the observation of a cosmological B-mode. We show that scattering of CMB radiation from dust grains in the presence of a static magnetic field could indeed create a Bmode spectral component, which is very similar to that due to primordial gravitational waves. This can be described by a kind of Cotton-Mutton effect on the CMB radiation. Finally, we review the low frequency spectrum of dusty plasma instabilities and their possible signature on the polarization and spectral correlations of the observed microwave radiation.

C5.2-0020-18 EVOLUTION OF TWISTED WAVES CARRYING ORBITAL ANGULAR MOMENTUM: APPLICATION TO THE LORENTZIAN (KAPPA) DISTRIBUTED NON-GYROTROPIC PLASMAS.

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Twisted waves are usually characterized as waves carrying orbital angular momentum (OAM), related to the helicity of the wave front, i.e. vortices. It is demonstrated experimentally with laser beams having OAM, that light and matter can interact and exchange angular momentum. About 10-15 years ago, the OAM (a macroscopic property of light) was rediscovered that can be also transferred from the light to a gas or plasma, which opens the door to new experiments and theoretical studies. The appearance of an azimuthal component is the new parameter, as compared to non-twisted plasmas, due to the presence of helical electric field perturbation in the plasma. The propagation of twisted waves in plasmas is predominantly prescribed by the longitudinal and azimuthal wave numbers. The longitudinal wave number reflects the variation in the spatial symmetry while the varying phase of nonplanar helical wave fronts is described by the azimuthal wave number.

The study of twisted waves is influenced by the many recent investigations of orbital angular momentum and its relevance for the Alfvénic and magnetic tornadoes, the High Frequency Active Auroral Research Program (HAARP) ionospheric radar facility and program to study plasma turbulence in the ionosphere of the Earth, twisted gravitational waves, ultra intense twisted laser beams, and quantum entanglement of twisted photons, neutrino physics, and astrophysics in the radio frequency range. In the optical frequency range, the variety of potential applications such as ultra-fast optical communication, quantum computing, microscopy and imaging are already well known. The observed morphologies of twisted modes are spiral, ringlike or helical, and may describe many phenomena in astrophysical and terrestrial environments like spiral galaxies, gravitational waves around rotating black holes, tornados in the solar corona, cometary tails, etc.

The first kinetic studies of twisted waves were performed for Maxwellian distributed (thermal) plasmas. It is, however, evident that most of the space plasmas are not in (local) thermal equilibrium, especially due to presence of superthermal particles in the tails of the distribution. The velocity (or energy) distributions of these plasmas are well reproduced by the generalized Lorentzian or Kappa distribution function. At present, we have investigated properties of the twisted waves in unmagnetized plasmas. Therefore, twisted Langmuir and ion acoustic waves are studied for plasma of Kappa distributed electrons and Maxwellian distributed protons (ions), as reported by the observations in various space plasma environments (e.g., the solar corona, planetary magnetospheres, etc.). The study of twisted waves is then further extended for the dusty plasmas, as dust is ubiquitous in astrophysical environment, planetary rings and interplanetary media, comets, interstellar medium, the Eagle nebula, supernova remnants, Jupiter's dusty rings and Earths mesosphere. These studies lead to the prediction of instabilities (growth rates and instability windows) for twisted waves of different types, e.g. the dust ion acoustic (DIA), and dust acoustic (DA) twisted waves.

Mathematically, twisted modes are well described by the Laguerre-Gaussian (LG) mode function in cylindrical coordinates, which decomposes the helical electric field and the perturbed distribution function into planar and non-planar components described by the longitudinal and azimuthal wave numbers. The characteristic system of Vlasov-Poisson equations is derived and solved to obtain the dielectric function for the twisted waves in the presence of a helical electric field. The approximative analytical and 'exact' numerical solutions are derived and analyzed to study the dependence of Landau damping or growth rates on various parameters like the wave numbers, drift velocities, temperature ratios, dust charging parameters, spectral indices, etc. The results are physically interpreted and their relevance for various applications is discussed.

C5.2-0021-18 ANISOTROPIC DUST COULOMB STRUCTURES IN CRYOGENIC AND MICROGRAVITY ENVIRONMENT: THE BRIDGE FROM CHAOS TO THE SELFORGANIZED MATTER

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The dust Coulomb systems are the ensembles of macroparticles carrying a charge and experiencing the mutual Coulomb interaction. Here we present the results of our studies the evolution of strongly coupled Coulomb systems of charged dust particles at cryogenic temperatures (temperatures of liquid helium and nitrogen) and microgravity conditions. The dust particles were trapped in dc glow discharge. In this case the active dust particles of micron-sized polydisperse CeO2 particles in He dc glow discharge at temperatures 5-10 K and 77 K were obtained. We present experimental evidence that cryogenic temperatures result in a non-equilibrium phase transition from random motion (chaos) of dust particles to formation of flow-aligned strings, due to the attractive downstream wake field, and then to collective rotational motions with non-zero mean velocities. The transition is continuous during discharge parameters change tending to align the direction of motion of particles. In our observations the dust particles in active motion state exist as one of two components in binary-like dust structure where other component consists of the same particles ordered in dust chains. The effect of a dc electric field on strongly non-ideal Coulomb systems consisting of a large number (104) of charged diamagnetic dust particles in a cusp magnetic trap are carried out aboard the Russian segment of the International Space Station (ISS) within the Coulomb Crystal experiment. Graphite particles of 100-400 mum in size are used in the experiments. The formation of threadlike chains of particles from graphite particles with diameter of 300 mum in a magnetic trap are observed experimentally under the illumination by the electroluminescent panel in the lower part of the experimental cell. The processes are simulated by the molecular dynamics (MD) method.

C5.2-0022-18 COMPLEX PLASMA EXPERIMENTS WITH PK-4 ON PARABOLIC FLIGHT CAMPAIGN DLR #31

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The Plasmakristall-4 (PK-4) plasma facility employs a dc discharge in a low-pressure noble gas inside a glass tube to study complex (dusty) plasmas under various gravity conditions. Micron-sized spherical particles injected into the plasma collect several thousands of electrons and interact with each other by a screened Debye-Hueckel (Yukawa) potential, forming a multiparticle system drifting along the tube towards the anode. The flowing particle cloud – illuminated by an expanded laser beam – resembles a fluid wherein the individual particles can by observed with a video camera. The particles in the videos are tracked providing full dynamic information.

A flight model of PK-4 is installed inside the Columbus module of the International Space Station ISS since November 2014. Another model is situated at the University of Giessen, Germany, which is used for experiments on ground and on parabolic flights to compare with and extend the experiments performed in space.

The results of a recent parabolic flight campaign are presented: Investigation of electrorheological effects in complex plasmas and a laser-induced shearflow to gain some material properties of the complex plasma fluid.

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C5.2-0023-18 PK-4 - COMPLEX PLASMA RESEARCH ON THE INTERNATIONAL SPACE STATION

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The PK-4 facility in the Columbus module of the International Space Station ISS allows longterm investigations of complex plasmas under microgravity conditions. “Complex plasmas” are dusty plasmas specially “designed” for the study of classical condensed matter physics. Due to the heavy component in the complex plasma - the microparticles - research under microgravity conditions is necessary to complement the knowledge gained from 2-dimensional and stressed 3- dimensional systems on the ground. Although phenomena in classical condensed matter physics are at the forefront of complex plasma research the basic know-how gained from experiments, theory and numerical simulations can be of importance for the understanding of naturally occurring dusty plasmas in space. In this presentation we will present recent work on complex plasmas from the PK-4 facility onboard the International Space Station ISS. This includes basic topics like charge and ion drag force on the microparticles, but also more dedicated research on shear induced melting, wave propagation, and electrorheology.

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C5.2-0024-18 FIELD ALIGNED STRINGY PLASMAS IN THE PK-4

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Complex plasmas are a versatile analog for studying systems where global behavior is determined by the combined effect of the particles' low temperature / kinetic energy, interparticle interactions, and global and local confinement. In general, the dust particles are small enough to act as probes of the local plasma conditions since their perturbations to the background plasma are small. However, when embedded in a plasma with directed ion flow the dust grains affect the ion trajectories, creating a focused ion region downstream. To date, most systems of charged dust particles and streaming ions have been examined under the presence of gravity, making the fundamental physics behind such correlation driven effects difficult to determine. Data from a recently funded (NASA / NSF) project proposing examination of field-aligned dust chains formed in the Plasma Kristall-4 (PK-4) onboard the International Space Station (ISS) will be discussed. The possibility that thermally excited waves propagating along and perpendicular to such chains can provide details of the resulting interparticle / interchain potential allowing study of the relationship between this potential, the ion wakefield and the controlling DC bias will be presented and the robustness of this conjecture discussed.

C5.2-0025-18 EKOPLASMA - THE FUTURE OF COMPLEX PLASMA RESEARCH ABOARD THE INTERNATIONAL SPACE STATION

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Ekoplasma is a joint German-Russian project, developing the future multi-purpose laboratory for the investigation of complex plasmas under microgravity conditions on the International Space Station (ISS). Complex plasmas are low-temperature plasmas, consisting of neutral gas atoms, ions, electrons and micro-meter sized particles as an additional component. The particles become charged in the plasma and as a result of their mutual repulsion form an optically thin cloud that can be studied in its full spatial and dynamical complexity on the granularity scale of each individual particle by optical cameras. Therefore, complex plasma allow fundamental investigations down to the kinetic level of individual particles also for a wide field of interdisciplinary topics in classical condensed matter physics.

The experimental apparatus of Ekoplasma features a newly developed large, cylindrical plasma chamber (the Zyflex chamber) with an adaptive internal geometry and 4 rf-driven electrodes for plasma generation. With the implemented technology, the accessible experimental parameter range will be extended by magnitudes (e.g. particle charge, neutral gas pressure range) and it will allow an independent control of plasma parameters. Further, particle dynamics will be investigated by a 3D optical diagnostic system, giving new insights into physical phenomena by adding the information of the 3rd dimension, which is usually lost when observing a 2D cross-section of the observation volume.

Ekoplasma will launch to the ISS after 2022, covering a wide range of research topics such as solidification and melting, phase separation in binary systems, the transition to turbulence, active matter or electrorheology. The experimental setup of Ekoplasma will be presented, as well as recent results of experiments performed on parabolic flights and in the ground laboratory, demonstrating the scientific possibilities of this new laboratory.

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C5.2-0026-18 NUMERICAL SPIS-DUST MODELLING OF PLASMA - LUNAR LANDER INTERACTIONS

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Introduction: One of the complicating factors of the future robotic and human lunar land- ing missions is the influence of the dust. Meteorites bombardment has accompanied by shockexplosive phenomena, disintegration and mix of the lunar soil in depth and on area simultaneously. As a consequence, the lunar soil has undergone melting, physical and chemical transformations. Recently we have the some reemergence for interest of Moon investigation. The prospects in current century declare USA, China, India, and European Union. In Russia also prepare two missions: Luna-Glob and Luna-Resource. Not last part of investigation of Moon surface is reviewing the dust condition near the ground of landers. Studying the properties of lunar dust is important both for scientific purposes to investigation the lunar exosphere component and for the technical safety of lunar robotic and manned missions. The absence of an atmosphere on the Moon's surface is leading to greater compaction and sintering. Proper-ties of regolith and dust particles (density, temperature, composition, etc.) as well as near-surface lunar exo-sphere depend on solar activity, lunar local time and position of the Moon relative to the Earth's magneto tail. Upper layers of regolith are an insulator, which is charging as a result of solar UV radiation and the constant bombardment of charged particles, creates a charge distribution on the surface of the moon: positive on the illuminated side and negative on the night side. Charge distribution depends on the local lunar time, latitude and the electrical properties of the regolith (the presence of water in the regolith can influence the local distribution of charge). On the day side of Moon near surface layer there exists possibility formation dusty plasma system. Altitude of levitation is depending from size of dust particle and Moon latitude. The distribution dust particle by size and altitude has estimated with taking into account photoelectrons, electrons and ions of solar wind, solar emission. Dust analyzer instrument PmL for future Russian lender missions intends for investigation the dynamics of dusty plasma near lunar surface. PmL consists of three parts: Impact Sensor and two Electric Field Sensors. One of the tools, which allows to simulate the dust emission from the Moon and asteroids, its transport, deposition and its interaction with a lander, is the SPISDUST (Spacecraft Plasma Interaction Software) code which based on Particle-in-Cell (PiC) method. This paper presents results of SPIS-DUST modelling of the interaction between the lunar plasma environment, regolith and a lander. The model takes into account the geometry of the Luna-Glob lander, the electric properties of materials used on the lander surface, as well as Luna-Glob landing place. Initial conditions were chosen based on the current theoretical models of formation of dusty plasma exosphere and levitating charged dust particles.

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C5.2-0027-18 EFFECTS OF ELECTROSTATIC ENVIRONMENT ON CHARGED DUST DYNAMICS NEAR LUNAR HOLES

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The Moon has neither dense atmosphere nor intrinsic magnetic field, and solar wind interactions with lunar surfaces are one of major plasma processes. The near-surface, dayside electrostatic environment is governed mainly by volume charges of solar wind plasma and photoelectrons as well as charged lunar surfaces. In fact, the electric environment strongly depends on surface topologies, as it will produce a shaded region, the electric environment of which can be very different from that in a sunlit condition. As one of high-profile terrains on the Moon, we have been focusing on the lunar vertical holes (or lunar pits), identified by the KAGUYA satellite and the Lunar Reconnaissance Orbiter. In order to model the distinctive electric and dust environments near the holes, we have started three-dimensional particle simulation analysis [1].

The particle-in-cell simulations address the plasma environment of a lunar hole that is accompanied with a subsurface cavern, and provide electric and plasma current fields in 3- dimensional space. We subsequently applied the obtained data to the study on the dynamics of submicron-sized charged dust grains around the distinctive landscape. We particularly focus on an effect of dynamic and stochastic charging processes of such small dust grains. Because of their small surface areas, the dusts will get/ lose one elementary charge infrequently, and thus charge amount owned by each dust should be a stochastic variable unlike a typical spacecraft charging. We develop a numerical model of such a charging process, which will be embedded into the test particle analysis of the dust dynamics. We report some results from our simulations on the dust charging process and dynamics around the lunar hole.

[1] Miyake, Y., Y. Funaki, M.N. Nishino, and H. Usui, Particle Simulations of Electric and Dust Environment near the Lunar Vertical Hole, Proc. 8th ICPDP, 020001, doi:10.1063/1.5020389, 2018.

C5.2-0028-18 CHAOTIC MOTIONS OF PLASMA AND DUST PARTICLES IN MAGNETIC RECONNECTION REGIMES IN EARTH'S MAGNETOTAIL

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We investigate the role of regular and chaotic motions of plasma and dust particles in the regime of magnetic reconnection of the Earth magnetotail on plasma processes. Our study is based on numerical simulations of particle orbits in plasma simulations. We analyze the variational system of equations together with the evolution and characteristics of the short time Local Lyapunov Indicators. We find regular and chaotic motions of (dust) particle orbits in phase space and link our results to open problems of plasma physics.

C5.2-0029-18 DUST IMPACT DETECTION BY ANTENNA AND FARADAY CUP INSTRUMENTS IN SPACE

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Electric field sensors or solar wind detectors based on Faraday cups are sensitive to impacts of high velocity dust particles. Despite a number of missions/instruments capable to detect dust particles, details of the detection mechanisms remain not fully understood. In order to study the properties of dust impacts, we conducted laboratory investigations of two principally different instruments: (1) antennas and (2) Faraday cups. Submicron-size iron dust particles within a velocity range of 1-40 km/s were generated by the dust accelerator facility operated at the University of Colorado. A scaled-down model of the Cassini spacecraft and three antennas of the RPWS (Radio Plasma Wave Science) instrument in dipole and monopole configurations have been used to study the response of antennas to dust impacts. Faraday cups were represented by an engineering prototype of the BMSW (Bright Monitor of the Solar Wind) instrument, operating onboard Spektr-R. Both instruments registered dust impact events with the recorded signals that resembling those detected in the space. We discuss the similarities and differences in physical processes leading to observed responses of detectors and corresponding electronics.

C5.2-0030-18 CURRENT-MODULATION-INDUCED VERTICAL DUST OSCILLATION IN A STRATIFIED GLOW DISCHARGE.

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The dust particle forced oscillation excited by square wave low-frequency current modulation are investigated. Amplitude-frequency response (AFR) of the single dust particle oscillation is obtained in the range of pressures p=0.06-0.66 torr. Resonance peaks at frequency, which is close to the eigenfrequency of the dusty plasma system, are observed at lowest pressures. Max-ima at multiple of the resonant frequencies are also observed. The eigenfrequency is determined by two independent methods. AFR for the different shapes of modulating signal is measured. The calculation of the phase-frequency characteristic is made. The resonance curves are used to obtain the vibrational characteristics of the dusty plasma system such as resonance amplitude, damping coefficient, eigenfrequency, Q-factor. The calculation of the single dust particle with help of the measured eigenfrequency is made.

C5.2-0031-18 TRANSPARENT DUST UNDER ELECTRON BOMBARDMENT: SURFACE ALTERATION AND HEATING

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Different kinds of transparent dust are widely spread across the solar system, besides silica or glass-like dust there exists a number of ices. Since the grains are exposed to space plasma and radiation environments, charging properties of such materials appear important. On the other hand, transparent grains can be easily overheated by particle impacts, since they cannot radiate in certain wavelength range. We have observed that electron bombardment could significantly alter the surface properties and also lead to the intense mass reduction. Further impacts include (a) intense sputtering when complemented with the electron bombardment and thus destruction of the grain, (b) fast production of neutrals and pick-up ions, (c) changes in grains albedo and its surface conductivity, etc. This paper presents a series of laboratory observations on spherical glass grains that are levitated in the quadrupole trap and exposed to the particle beam. An evolution of the grain is recorded and changes in grain mass and emission properties are estimated. Particular characteristics are compared with theoretical and numerical models. Suggestions are made towards ices in the solar system.

C5.2-0032-18 INTERACTION OF TWO DUST ION ACOUSTIC SHOCK WAVES IN A WEAKLY RELATIVISTIC MULTICOMPONENT NONEXTENSIVE PLASMA

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Complex dusty plasmas have been under intense scrutiny by plasma physicists for understanding various nonlinear phenomena in space and astrophysical environments. Dust is witnessed as an ubiquitous component in many environments such as magnetosphere of Earth, planetary rings, comets, ionosphere, interstellar molecular clouds and circumstellar disks. Shocks waves are characterized as an abrupt change in properties of the medium such as density, pressure etc. that propagate with supersonic speed. High-speed and energetic streaming ions with energies of 0.1-100 MeV are frequently observed in astrophysical and space environments. The relativistic effects cannot be ignored when particles have the streaming velocity in the order of the velocity of light. Tsallis statistics have been based on the usual Boltzmann-Gibbs statistics by introducing an additional parameter q measuring the strength of nonextensivity which has been successfully applied to a number of plasma systems such as Earth's magnetosphere, Mercury, Saturn and Solar wind. One of the interesting and important nonlinear phenomenon in the modern plasmas researches is interaction or collision between two waves. Keeping in view, the importance of dust, relativistic particles and nonextensivity, interaction of dust ion acoustic shock waves containing nonextensive electrons and positrons in a weakly relativistic plasma is studied. Employing extended Poincare-Lighthill-Kuo method with suitable asymptotic expansion, two Korteweg-deVries Burgers equations in a weakly relativistic plasma are derived for the study of phase shifts and time evolution of two shock waves after a head-on collision while travelling in opposite directions. Various physical parameters such as relativistic factor, nonextensivity, viscosity and dust etc. have paramount influence on the phase shifts and potential pulse profile of dust ion acoustic shock waves. The results may be helpful in understanding the head on collision between two dust ion acoustic shock waves in astrophysical and laboratory plasmas.

C5.2-0033-18 DUST MAGNETOSONIC BREATHERS AND FREAK WAVES IN A MAGNETIZED PLASMA

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Dust particles in motion generate new wave modes for shear Alfven, magnetosonic and whistler waves. During the last one decade, magnetosonic waves in dusty plasma have received an increased attention in major areas of basic research due to their important role in scattering energetic electrons in the magnetosphere through Landau resonance interaction. In the present study, a theoretical investigation of dust magnetosonic breathers and freak waves is presented in an electron-ion-dust magnetized plasma composed of cold dust fluid with inertialess electrons and ions. Nonlinear Schrödinger equation (NLSE) has been derived under the low frequency limit and admits spatially and/or temporally localized structures often called as breather solutions. Recently, there has been a great interest in these localized structures in many diverse fields, e.g., fiber optics, hydrodynamics, plasmas, etc. Kuznetsov-Ma breathers/solitons (spatially localized patterns oscillating in time) and Akhmediev breathers (spatially periodic structures localized in time) are two important classes of breather solutions. In present investigation, the exact analytical solutions of the NLSE for breather waves in the form of Akhmediev breathers, Kuznetsov-Ma (KM) solitons and freak waves (first and second order) are obtained. The results are also examined numerically using the observed data in space/astrophysical environments particularly in Earth's inner magnetosphere. The characteristics of different breather structures are significantly influenced by the relevant physical parameters of the observed data. The results obtained in the present investigation may be helpful in explaining the formation and dynamics of nonlinear excitations in different regions of space/astrophysical environments viz., Earth's magnetosphere, solar wind, Saturn's magnetosphere etc., where the existence of energetic electrons, ions and dust have been confirmed by various satellite observations. The present investigation can also be extended to investigate the characteristics of nonlinear excitations in super dense astrophysical regimes.

C5.2-0034-18 EFFECT OF POLARIZATION FORCE ON DUST ACOUSTIC ROGUE WAVES IN SUPERTHERMAL DUSTY PLASMA

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Dust is an ubiquitous component of space and astrophysical environments and has a wide ranging applications in the different fields as well as in the study of astrophysical and space environments. Most of the space and astrophysical observations revealed the presence of superthermal particles in different plasmas. The deformation in the Debye sheath formed by ions around the negatively charged dust grains is termed as polarization force, which is an important frontline area of research in dusty plasma from last few decades. The polarization force is eloquently modified due to the presence of superthermal ions and thus produces the drastic changes in dust-acoustic waves (DAWs). In this investigation, the modulational instability (MI) of dust acoustic waves under the influence of polarization force, which is induced by superthermal ions, are examined. Using the reductive perturbation method, the nonlinear Schrödinger equation that governs the MI of the DAWs is obtained. It is found that the effect of the polarization term R is to narrow the wave number domain for the onset of instability. The amplitude of the wave envelope decreases as R increases, meaning that the polarization force effects render weaker the associated DA rogue waves. The DA rogue wave profile is very sensitive to any change in the restoring force acting on the dust particles. The polarization force has emphatic influence on rogue waves profile. It is intensified that results of this investigation may be useful in understanding the nonlinear wave dynamics in the magnetospheres of planets, such as Jupiter and Saturn as observed by the Nozomi satellite.

C5.2-0035-18 SHOCK DYNAMICS IN MULTI-ION DUSTY PLASMAS: THEORY VERSUS SIMULATIONS

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We introduce an analytical model for shocks in dusty plasma mixtures, taking into account collisionality and kinematic viscosity. A multicomponent plasma configuration is considered, consisting of positive ions, negative ions, electrons and a massive charged component in the background (dust). The model relies on the derivation of a dissipative hybrid Korteweg de Vries/Burgers equation, whose analytical shock-type solutions are derived analytically and tested numerically.

A comprehensive series of numerical simulations based on a semi-spectral algorithm are undertaken to test our analytical predictions against arbitrary step-like functions used as initial conditions.

The dependence of the shock profile and dynamics on various relevant plasma configuration parameters, including the Havnes dust parameter, in addition to dissipation, is investigated.

C5.2-0036-18 ROLE OF VORTEX DISTRIBUTED ELECTRONS ON LARGE AMPLITUDE DUST ION ACOUSTIC WAVES

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Depending on plasma environments, dust particles can be positively or negatively charged and the presence of charged dust in a usual electron-ion plasma generates a new type of wave mode called dust ion-acoustic mode and the waves associated with this mode have speed larger than the usual ion-acoustic mode. Also, instead of Boltzmann distribution, electrons in plasma may follow other distributions such as vortex/trapped distribution due to wave particle interaction. The vortex-like distribution plays a vital role in modifying the basic features of nonlinear electrostatic structures in many laboratory and space plasma. In present investigation, propagation properties of dust ion acoustic solitary waves are investigated in plasma with cold fluid ions, stationery negatively charged dust and trapped/vortex distributed electrons. Sagdeev pseudopotential method has been used to derive energy balance equation and the existence conditions for the formation of solitary structures in terms of Mach number are determined. The Sagdeev pseudopotential expression is a function of various physical parameters such as dust concentration, trapping parameter for electrons etc. These parameters significantly influence the basic features of dust ion-acoustic solitary structures. The results of present investiga- tion shall be useful to understand the various nonlinear phenomena in space and astrophysical environments, where charged particles obeying vortex-like distribution have been observed.

C5.2-0037-18 EFFECT OF DENSITY GRADIENT ON NONLINEAR STRUCTURES IN A DUSTY PLASMA

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Non-thermal particle distributions are ubiquitous in the solar-wind and near Earth space plasma, their presence having frequently been confirmed by interplanetary missions. Such distributions represent suprathermal deviations from the Maxwellian equilibrium and are expected to exist in any low-density plasma in the Universe, where binary collisions of charges are sufficiently rare. The suprathermal populations are well parameterized by the so-called Kappa () index. Moreover, inhomogeneity may arise in plasma from the equilibrium dust density gradient. Even if the dust density is kept uniform, the plasma density gradient can still significantly affect dust acoustic solitary waves (DASWs) through the equilibrium dust charge because the dust grain charge is self-consistently determined by plasma charging currents that depend on plasma densities. In this case, the equilibrium dust charge instead of density becomes spatially non-uniform. In such a case, inhomogeneity is generated by electron and ion density gradients in the plasma and the amplitude of DASWs is mainly affected by density inhomogeneity rather than the electrons' energy. We investigate dust acoustic nonlinear structures in unmagnetized, inhomogeneous dusty plasma containing superthermal electrons and ions. In this model, the electrons and ions are described by the kappa distribution function and dust-neutral collisions have been taken into account. Using the reductive perturbation method, Modified Burger's equation will be derived. Our study would be useful for understanding different nonlinear features of localized electrostatic disturbances in a number of astrophysical dusty plasma systems, namely, planetary rings, cometary environments, and the interstellar medium where density inhomogeneity of charged particles is prevalent.

C5.2-0038-18 LOW FREQUENCY NONLINEAR WAVES IN A PAIR-ION QUANTUM DUSTY PLASMA

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Pair-ion plasmas consist of particles having equal mass and opposite charges, where the negative ions may occur naturally or may be injected from external sources. Moreover, dust being ubiquitous component in laboratory and space plasma environments, gets charged and influences the dynamics of nonlinear plasma waves. The in-situ observations of polar mesosphere have revealed positively charged nanoparticles, positive-negative ions and electrons where the number density of negative ions is considerably large. The possible applications of pair-ion plasmas in Earth's ionosphere, mesosphere, solar atmosphere and in the microelectronics plasma processing reactors have been proposed by different investigations. Quantum effects play an important role in dense astrophysical environments such as white dwarfs, neutron stars etc. However, dilute charged particle systems may also exhibit quantum features provided the dimensions of the system are comparable to the de Broglie wavelength of the charged particles. The Quantum hydrodynamic (QHD) model is considered for describing the linear and nonlinear properties of charged quantum particles. We use QHD model to investigate dust-ion aocustic nonlinear waves in a three-fluids quantum pair-ion dusty plasma using Sagdeev Pseudopotential method with a new approach to derive the energy-integral equation. The dust and pair-ion species are considered as inertial fluid whereas the inertialess electrons are assumed to show quantum effects. The influence of various physical parameters such as quantum parameter, Mach number etc. has been investigated on the properties of dust ion acoustic waves (DIAWs). The findings of this investigation may give physical insights on nonlinear phenomenon occurring in quantum dusty pair-ion plasmas in space and laboratory environments.

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Space Plasmas in the Solar System, including Planetary Magnetospheres (D)

COSPAR 2018
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SPACE PLASMAS IN THE SOLAR SYSTEM, INCLUDING PLANETARY MAGNETOSPHERES (D)

OVERVIEW TALKS (D0.1)

D0.1-0001-18 CORONAL MASS EJECTIONS AND SPACE WEATHER EFFECTS

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Earth-directed coronal mass ejections (CMEs), with their embedded magnetic fields and shocks ahead, compress and reconnect with the Earth's magnetic field and are the main drivers of strong geomagnetic storms. The impact of strong events may endanger critical ground-based infrastructure like power grids or disrupt communication and navigation systems. Due to such Space Weather effects, CMEs and related phenomena are an area of intense research interest. Important scientific knowledge could be achieved by closely monitoring and investigating the Sun-to-Earth "chain of action" of solar activity (evolution of surface magnetic fields, flares and CMEs), measurements of near-Earth space (in-situ plasma and magnetic field, energetic particles) and geomagnetic activity (response of the magnetosphere and different atmospheric layers down to ground-induced currents). This overview talk covers and discusses our recent understanding of the physical processes about the initiation and propagation of CMEs, their interaction with the solar wind and other ejecta, and consequences for Space Weather.

D0.1-0002-18 DISCUSSION

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Discussion

D0.1-0003-18 MULTI-WAVELENGTH OBSERVATIONS OF ASTROSPHERES ACROSS THE HERTZSPRUNG-RUSSELL DIAGRAM

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During the last 20 years, observation of the circumstellar material around stars, and specially bow-shocks (and bow-waves) allowed the investigation of the mass loss properties and mass loss histories of very different stellar types. It also opened new avenues to determine the interaction mechanisms and properties of the surrounding circumstellar and interstellar medium, and their magnetic fields. In this talk I will review the current state of multi-wavelength observations of astrospheres / bow shock nebulae. While most observations of bow-shock nebulae concentrated on the MIR and FIR emission up to now, I will especially discuss the power of UV, optical, and NIR line emission to characterize circumstellar environments / astrospheres. Further, I discuss the observational properties for different temperature, mass loss properties, and evolutionary state of the stars, as well as the effects of different interstellar environments. Some recent observations imply that bow shock may be particle accelerators and modulators. I therefore will include a critical look at the current observational knowledge of non-thermal radio emission, as well as X-ray, and cosmic rays from astrospheres beyond our solar system.

D0.1-0004-18 DISCUSSION

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D0.1-0005-18 MMS HIGHLIGHTS AFTER TWO YEARS OF OPERATIONS

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The NASA Magnetospheric Multiscale (MMS) mission, launched in March 2015, uses four closely-spaced spacecraft to investigate magnetic reconnection in the boundary regions of the Earth's magnetosphere by measuring charged particles and electric and magnetic fields at the electron scale for the first time in space. The prime mission was conducted in two phases, the dayside magnetopause and the magnetotail, with four spacecraft in a tetrahedron formation with separations adjustable from 160 km down to 7 km in a lowinclination, highly elliptical orbit with apogee at 12 Earth radii on the day side and 25 Earth Radii in the tail. Reconnection at the dayside magnetopause is asymmetric with different plasma and magnetic conditions on either side of the current layer. As predicted by plasma simulation, the electron stagnation point is located Earthward of the reconnection X line. In the tail, magnetic fields and plasma densities are equal in both inflow regions, and the electron stagnation point and the X line are coincident. Another important difference is the much lower plasma density in the tail, which results in much higher magnetic energy per particle available for acceleration. Early results confirmed the prediction of agyrotropic crescent-shaped electron distribution functions at the stagnation point of dayside reconnection. These distributions carry the out-of-plane current and are accelerated by the reconnection electric field, which is mainly generated by divergence of the electron pressure. In this way, reconnection is driven by electron dynamics, which is initiated by acceleration of magnetosheath electrons through the X-line magnetic null by the well-known ambipolar normal electric field at the magnetopause. Conversion of magnetic energy to electron energy occurs mainly at the stagnation point for small guide fields but equally at the X line for large guide fields. The physics of reconnection in the tail is similar in that electron crescent distributions are observed in the electron diffusion region but different in that their source is electrons from the neutral sheet rather than from the inflow regions and in the fact that the tail crescents are multiple (double or triple) resulting from a longer residence time in the current layer where multiple acceleration by the reconnection electric field occurs along meandering orbits. MMS has also observed the unexpected occurrence of reconnection inside of flux transfer and Kelvin-Helmholtz events as well as in the magnetosheath where at the smallest scales it proceeds by electron dynamics only with no participation by ions. These and other findings of MMS during its prime mission are discussed in this paper.

D0.1-0006-18 DISCUSSION

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Discussion

D0.1-0007-18 FLUX TRANSFER EVENTS AT EARTH AND THE OTHER PLANETS

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Flux transfer events (FTEs) are twisted flux tubes created by multiple X-line reconnection in the magnetopause current sheet at Earth and the other magnetized planets. One end is anchored in the magnetosphere and maps to one of the magnetospheric cusps, while the other is connected to the interplanetary magnetic field. These structures are generally well-modeled as force-free flux ropes moving in response to the stress exerted by the end of the FTE embedded in magnetosheath flow. Spacecraft passing through the FTE observe a strong core magnetic field along its central axis surrounded by weaker helical fields. If the spacecraft remains outside of the FTE, then it encounters only the interplanetary or magnetospheric magnetic field that is draped and compressed about the FTE. This signature is referred to as a traveling compression region. This review compares and contrasts the FTEs observed at Mercury, Earth, Jupiter, and Saturn with special attention to their frequency of occurrence and magnetic flux content. The possible implications of these comparative FTE analyses for our understanding of magnetic reconnection at the different planets and the role of FTEs in driving magnetospheric dynamics will be considered and assessed. Finally, the new opportunities for progress in understanding FTE formation, evolution and dynamics presented by the Multiscale Magnetospheric mission and new global magnetohydrodynamic simulations with reconnection regions captured by embedded particle-in-cell codes will be briefly discussed.

D0.1-0008-18 PARKER SOLAR PROBE: A NASA MISSION TO TOUCH THE SUN

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The newly renamed, Parker Solar Probe (PSP) mission will be the first mission to fly into the low solar corona, revealing how the corona is heated and the solar wind and energetic particles are accelerated, solving fundamental mysteries that have been top priority science goals since such a mission was first proposed in 1958. The scale and concept of such a mission has been revised at intervals since that time, yet the core has always been a close encounter with the Sun. The primary science goal of the Parker Solar Probe mission is to determine the structure and dynamics of the Sun's coronal magnetic field, understand how the solar corona and wind are heated and accelerated, and determine what mechanisms accelerate and transport energetic particles. PSP uses an innovative mission design, significant technology development and a risk-reducing engineering development to meet the science objectives. In this presentation, we provide an overview of the mission science and design, and an update on the progress of the Parker Solar Probe mission as we prepare for the July 2018 launch.

D1.1-0001-18 OBSERVATIONS OF WIDESPREAD SOLAR ENERGETIC ELECTRON EVENTS: WHAT CAN WE LEARN FROM ANISOTROPIES AND SPECTRA?

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The two STEREO spacecraft in combination with close to Earth observatories have provided us with a wealth of multi-spacecraft solar energetic particle (SEP) observations. Among these, surprisingly wide longitudinal SEP distributions have been observed which still challenge the current acceleration, injection, and transport theories. An indispensable observation to disentangle different mechanisms and to shed some light on the specific scenarios is the anisotropy observed at different positions throughout the same event. We will present anisotropy observations which suggest that no overall scenario can explain every widespread event but that different types of events exist. We will also show spectra of near-relativistic electrons observed at multiple spacecraft during widespread events and discuss if different source populations might be present at the same time.

D1.1-0002-18 MODELLING OF NON-DIFFUSIVE TRANSPORT OF SOLAR ENERGETIC PARTICLES

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Solar Energetic Particles (SEPs), accelerated during solar eruptions, are typically observed with in situ instruments in the interplanetary space. They propagate in the interplanetary medium permeated by turbulent magnetic field, and their transport is typically modelled with a Fokker-Planck (FP) equation as diffusive propagation along and across the mean magnetic field. Cross-field diffusion is often considered small or negligible, as transport theory gives small values for cross-field diffusion coefficient in the solar wind. However, recent multi-spacecraft SEP observations made with the STEREO, SOHO and ACE spacecraft have shown that SEPs have access to wide range of heliolongitudes, across the mean Parker field spiral field, with transport model fits of the observations implying much stronger cross-field diffusion than what the current transport theory allows. Our recent studies using full-orbit test particle simulations offer a possible explanation for the fast cross-field transport of SEPs as early non-diffusive propagation of SEPs. Our studies show that charged particles remain on their initial meandering field lines for considerable time, comparable to particle's mean parallel scattering time, τ. Within these timescales, particle propagation with respect to the mean field direction is nondiffusive, with the particles each propagating back and forth along their initial meandering field lines. Subsequently, particles begin to decouple from their initial field lines, and only after 10 τ their propagation propagation across the mean field can be described as diffusion. For 10 MeV protons in interplanetary turbulence environment, observed at 1 AU from their source location, this results in a wide extent of the SEPs already at the onset of an SEP event. Crossfield diffusion begins to dominate the particle distribution only after tens of hours. Using an extended FP model that accounts for the early non-diffusive propagation, we are able to explain the observed wide SEP events even with a narrow SEP source. We discuss the implications of our new model approach to SEP event modelling, and for improving our understanding of SEP origins.

D1.1-0003-18 HEAVY ION CHARACTERISTICS OF SOLAR ENERGETIC PARTICLE EVENTS RESULTING FROM FILAMENT ERUPTIONS

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Solar energetic particles (SEPs) can be accelerated near the Sun both by flare-related reconnection processes and shocks driven by coronal mass ejections (CMEs). As the latter is believed to dominate in large SEP events, understanding the details of shock acceleration is critical to accurate space weather prediction and as well as directly impacting our understanding of the variability of SEP events. Unfortunately, it is often difficult to identify which SEP event characteristics are controlled by shock acceleration and which are a result of related flare processes as large flares and fast CMEs frequently occur together. SEP events associated with filament eruptions typically have no or weak soft X-ray flares and so provide the best opportunity to study shock acceleration near the Sun without the added complication of flare-associated acceleration. Recent studies of such events have found associated fast CMEs and type II radio bursts observed both near the Sun and in the interplanetary medium, indicating the presence of a strong and long-lasting shock able to accelerate particles. The formation of the shocks appears to occur significantly higher in the corona than is standard for typical SEP events and the resulting energetic proton spectra are substantially softer. We present the characteristics of heavy ion properties (e.g., spectra and composition) in ten such events and compare them to those typical for large SEP events.

D1.1-0004-18 ACE/EPAM ELECTRON EVENT CATALOG (1997-2017)

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In the present study, a list of solar energetic electron events in solar cycle 23 and 24 in the energy range 103-315 keV is given. We collected and analyzed the observed in situ electron data from the Advanced Composition Explorer (ACE) spacecraft located near Earth using the Electron, Proton and Alpha Monitor (EPAM) instrument, and more specifically the deflected electron (DE) suite. This event list is considered as the first comprehensive catalog for electrons during the period 1997-2017. We identified the onset times, peak times and peak intensities of the electron events, and the characteristic quantities of the associated solar activity, namely solar flares and coronal mass ejection. We performed linear and partial correlation analysis of the properties of electron events and the associated eruptive solar phenomena in order to distinguish between the effects from the different particle accelerators. This catalog can be employed by the space weather community in studying the effect of the solar energetic particles on man-made systems and on climate changes. Correlation study is essential ingredient of models used to predict solar events. Thus, hazard effects of solar energetic particles can be mitigated.

D1.1-0005-18 ANOMALOUS TRANSPORT OF ENERGETIC ELECTRONS IN SOLAR FLARES.

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The transport of the energy contained in suprathermal electrons plays a key role in our understanding of many aspects of flare physics, from the spatial distribution of hard X-ray emission and energy deposition in the ambient atmosphere to global energetics. More generally, the study of energetic electrons during flares may prove very valuable to understand the genesis of anomalous transport in astrophysical plasmas. We will show that a satisfactory treatment of the diffusion of suprathermal electrons during flares require the consideration of non-local effects, so that the electron flux depends not just on the local gradient of the electron distribution function but on the value of this gradient within an extended region encompassing a significant fraction of the scattering mean free path. Our analysis applies to a variety of scattering mechanisms including turbulent scattering. We will show that the transport of energetic electrons along the magnetic field of a flaring loop can be modeled as a Continuous Time Random Walk with velocity-dependent distributions of jump sizes and occurrences, both of which can be expressed in terms of the scattering mean free path.

D1.1-0006-18 MAGNETIC CAVITIES, CURRENT SHEETS AND MAGNETIC ISLANDS AS LOCAL SOURCES OF ENERGETIC PARTICLES IN THE SOLAR WIND

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ISSI International Team 405 "Current Sheets, Turbulence, Structures and Particle Acceleration in the Heliosphere"; http://www.issibern.ch/teams/structpartaccel/

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Recent studies of particle acceleration in the heliosphere have revealed a new mechanism that can energize particles up to several MeV/nuc locally in the solar wind. It has been found that stream-stream interactions as well as the heliospheric current sheet - stream interactions produce huge magnetic cavities, which resemble tokamaks in terms of solving the confinement problem. Such cavities are usually filled with dynamical small-scale magnetic islands (SMIs) with a typical width of 0.01 AU or less, which are produced by magnetic reconnection at strong current sheets representing the borders of magnetic cavities. SMIs experience compression and merging due to dynamics of the entire system, which leads to trapping and re-acceleration of energetic particles in the confined region according to predictions based on the theory describing stochastic particle energization in the supersonic solar wind via numerous dynamically interacting SMIs (Zank et al. ApJ, 2014, 2015; le Roux et al. ApJ, 2015, 2016). Since SMIs cannot escape, acceleration of energetic particles occurs in the most effective way. As a result, crossings of magnetic cavities are associated with unusual variations in the energetic particle flux up to 1-2 MeV/nuc near the Earth's orbit. These energetic particle flux enhancements called "atypical energetic particle events" (AEPEs) are observed at timescales from sim1/2 hour to several hours, sometimes, against the background of classical solar energetic particle events or before/after energetic particle enhancements associated with corotating interaction regions, but mostly in the relatively quiet solar wind (Khabarova et al. ApJ, 2015, 2016,

Khabarova Zank, ApJ, 2017). AEPEs possess energies that overlap SEP events and can be an important component in understanding space weather. Since both SMIs and current sheets of various origins are a manifestation of turbulence, the study of temporal and spatial evolution of these structures links dynamical processes in different plasmas and particle acceleration in the heliosphere. This work is partly supported by the International Space Science Institute (ISSI) in the framework of International Team 405 entitled "Current Sheets, Turbulence, Structures and Particle Acceleration in the Heliosphere.

D1.1-0007-18 PARTICLE ACCELERATION IN A RECONNECTING CURRENT SHEET: COALESCENT AND SQUASHING MAGNETIC ISLANDS

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We investigate particle acceleration in 3D reconnecting current sheets (RCSs) containing multiple Oand X-nullpoints and different topologies: coalescent (moving towards each other) and squashed islands using a test particle and particle-in-cell (PIC) approach. The inclusion of multiple O-nullpoints, or magnetic islands, reveals that acceleration of protons and electrons in a current sheet with strong guiding field remains asymmetric towards the midplane, e.g. electrons and protons are ejected into the opposite directions from the midplane. Both types of particles (electrons and protons) mainly gain energy in a vicinity of X-nullpoints or inside O-nullpoints and, depending on their initial energy, these gains can reach relativistic energies in a single island. Accelerated particles with critical energies can escape O-nullpoints, or magnetic islands, only through neighbouring X-nullpoints escape along the midplane. As result, there are electron clouds formed between the magnetic islands while electrons gain the critical energy to break from an RCS. The energy gains in coalescent islands are much smaller than from the squashed ones. Electrons are shown to form clouds about X-nullpoints between the magnetic islands where they become ejected after gaining the critical energies required to break from the RCS magnetic topology. Particle acceleration in 3D RCSs with multiple Xand O-nullpoints is probed with some observational features in the solar corona and heliosphere. This research is funded by the US Airforce grant.

D1.1-0008-18 REGULARIZED KAPPA-DISTRIBUTIONS WITH NON-DIVERGING MOMENTS

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For various plasma systems the so-called κ-distribution is widely used to describe suprathermal (non-relativistic) particle components exhibiting a power-law behaviour in velocity or energy. Despite its success the concept of the standard κ-distribution remains disputable because the latter is defined only for κ > 3/2 and possesses only a finite number of velocity moments vl (with the integer l defining the l-th moment), some of which, i.e., l > 2κ1, are diverging. In order to resolve these limitations we introduce the regularized κ-distribution. After a discussion of its properties and its relation to the standard κas well as to the Maxwellian distribution, we provide a general analytical expression that enables to calculate all of its moments, and illustrate that only fluid results, that critically depend on these moments will change, but not those obtained within the framework of kinetic theory.

D1.1-0009-18 NON-LINEAR DIFFUSIVE SHOCK ACCELERATION: THEORY AND OBSERVATIONS

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The process of diffusive shock acceleration is likely the most commonly invoked particle acceleration mechanism in Astrophysics. It is thought to operate in several other environments, with very different physical properties, such as the Earth bow shock, interplanetary shocks, extragalactic radio sources, galactic and intergalactic shock waves and more. Diffusive acceleration at the shock waves produced by Supernova explosions is thought to be responsible for the energization of the bulk of cosmic rays in the Galaxy. In this particular environment the efficiency of the process has long been implied to be of order 10-15%, high enough to force the scientific community working on the subject to take into account non-linear effects, namely the back reaction of the accelerated particles on the accelerating system.

In this talk I will summarize our current knowledge of non-linear diffusive shock acceleration. I will discuss all the elements that go into the state-of-the-art description of this process, such as dynamical and thermodynamical effects on the ambient plasma, magnetic field amplification and implications for the spectrum and maximum energy achievable by the accelerated particles. I will then discuss how theory compares with observations of Cosmic Rays and Supernova Remnant shocks, and what the current challenges are, finally mentioning the possible extension of this kind of modeling to the heliospheric environment.

D1.1-0010-18 ANISOTROPY OF TEV COSMIC RAYS

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A number of experiments have conclusively determined a low level of 0.1% anisotropy in the angular variations of TeV cosmic ray intensities. Although there is an overall dipole component, the anisotropy pattern contains a significant amount of fluctuations on smaller angular scales, making it appear to be quite complicated. One source of the observed anisotropy is the heliosphere because TeV cosmic rays are significantly deflected by the nonuniformity of the magnetic field and suffer energy changes by the electric field of plasma flows. We have developed a method of using the Liouville theorem to map out particle distribution function to Earth from the local interstellar medium. In this paper, selected results of our calculations with the mapping technique will be presented. Based on the Tibet ASγ measurements, we are able to determine the truly pristine cosmic ray anisotropy in the local interstellar medium. It turns out the interstellar anisotropy pattern of TeV cosmic rays is much simpler than it is observed. We can also determine the amount of distortion caused by the heliosphere. We can locate the anisotropy features that are associated with the plane perpendicular to the interstellar magnetic field, hydrogen deflection plane, heliotail, and solar corona. The distortion may account for some of the observed small-scale anisotropies.

D1.1-0011-18 THE EFFECT OF MAGNETIC TURBULENCE ON PITCH-ANGLE ANISOTROPIES OF INTERSTELLAR PICKUP IONS ACCELERATED BY THE SOLAR WIND TERMINATION SHOCK

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It will be discussed how time variations in the turbulent magnetic field affect the solar wind frame pitch-angle distribution of interstellar pickup ions accelerated by the nearly perpendicular solar wind termination shock. For this purpose, fluctuations in the magnetic spiral angle, modeled as a q-Gaussian distribution, and fluctuations in the magnetic field strength, simulated as a log-normal distribution, were introduced as a time series in a focused transport model of pickup ion acceleration by the termination shock. The results show that varying the standard deviation of the spiral angle distribution and of the field strength distribution can significantly affect pitch-angle distributions of pickup ions both upstream and downstream of the termination shock. In the simulations, pitch-angle distributions upstream varied from beam-like to pancake distributions whereas downstream distributions were altered from nearly isotropic distributions to pancake distributions.

D1.1-0012-18 LOW-ENERGY ELECTRONS IN THE VERY LOCAL INTERSTELLAR MEDIUM

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Voyager 1 has been observing electrons down to 4 MeV, from ahead of the position of the termination shock (TS), through the inner heliosheath, up to the heliopause (HP) and beyond. As predicted, this very local interstellar spectrum (or heliopause spectrum) exhibits a power-law down to the mentioned energy. The behaviour of these electrons are investigated further with a numerical, shock-acceleration model from the TS up to the HP, focussing on the question that comes up about what the Galactic electron spectrum is below 4 MeV and how it may differ from the HP spectrum.

D1.1-0013-18 ENERGETIC PARTICLE TRANSPORT AND ACCELERATION AT INTERPLANETARY SHOCKS

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Interplanetary (IP) shocks, especially those with high Mach numbers, are associated with significant enhancements in high-energy charged particles. The observed variation of energetic particle intensities, energy spectra, and composition near these shocks, along with observations of the solar wind and magnetic field, provide important constraints on theories of possible acceleration mechanisms and particle transport in irregular magnetic fields. In this talk, I will give an overview of our current theoretical understanding of the acceleration and propagation of energetic particles near IP shocks. I will also present some new observations of the evolution of the ion energy spectrum (with energies below the thermal peak to the high-energy tail) from a few hours before the shock until after its passage with a resolution of 12 minutes. On the one hand, these new observations solve some previously unanswered questions; but, on the other hand, they also presents new puzzles.

D1.1-0014-18 PROLONGED ACCELERATION OF NON-THERMAL ELECTRONS IN A HIGH MACH NUMBER SHOCK TRANSITION REGION

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We discuss recent three-dimensional (3D) particle-in-cell simulation results for high Mach number quasi-perpendicular shocks. At very high Mach numbers relevant to supernova remnant shocks, we show that the shock internal structure is filled with large-amplitude magnetic turbulence generated by the Weibel instability driven unstable by the reflected ion beam. At the same time, however, clear coherent electrostatic waves are also found at the leading edge of the shock. We demonstrate that the both of them contribute to the production of non-thermal electrons. We find that upstream low-energy particles entering into the shock transition region are first accelerated through the interaction with the coherent electrostatic waves, and then suffer a further energization in the Weibel-generated turbulent region in a deeper shock transition region. The former may be understood as the shock-surfing mechanism, which thus has finally proved to be effective in 3D for the first time. We consider the latter mechanism as a shock drift acceleration (SDA) but modified by the Weibel-generated turbulence. We show that, in contrast to the classical adiabatic SDA for small-gyroradius particles, stochastic pitch-angle scatterings during the acceleration process efficiently confine the particles in the acceleration region. As a result, a power-law energy spectrum is formed with its index independent of detailed properties of the scattering. The same mechanism, which we call a stochastic SDA, may be applicable to moderate Mach number shocks where, instead of the Weibel turbulence, high-frequency whistler waves may play the role of pitch-angle scattering. We also discuss implication for recent high temporal resolution in-situ measurements of the Earth's bow shock by the Magnetospheric Multiscale (MMS) spacecraft.

D1.1-0015-18 ION ACCELERATION IN NON-RELATIVISTIC QUASI-PARALLEL SHOCKS USING FULLY KINETIC SIMULATIONS

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Shocks in collision-less space plasma are now widely studied using hybrid and kinetic simulations. Their formation and dynamics are mostly understood and there have been advances in the understanding of particle acceleration by these shock fronts. From observation we know however that not only electrons and protons – the most abundant species in the solar wind – are strongly affected by the shock but that also rare, heavier species, such as different helium isotopes, are scattered and accelerated. We therefore used fully kinetic particle-in-cell simulations to model non-relativistic quasi-parallel shocks in a collision-less plasma that contains a small fraction of heavier ions species to study their energy spectra. A fraction of the heavier ions is reflected at the shock front and is able to modify the upstream plasma before it actually reaches the shock itself.

D1.1-0016-18 LOW-ENERGY IONS INJECTION AND ACCELERATION AT INTERPLANETARY SHOCKS WITH FOCUSED TRANSPORT MODEL

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There are strong evidences that a small portion of suprathermal particles from hot coronal material or remnants of previous solar energetic particle (SEP) events serve as the source of large SEP events. Here we present a test particle simulation on the injection and acceleration of lowenergy suprathermal particles by Laminar nonrelativistic oblique shocks in the framework of the focused transport theory, which is proved to contain all necessary physics of shock acceleration, but avoid the limitation of diffusive shock acceleration (DSA). We first characterize the role of cross-shock potential (CSP) on pickup ions (PUIs) acceleration. The CSP can affect the shape of the spectrum segment at lower energies, but it does not change the spectral index of the final power-law spectrum at high energies. It is found that a stronger CSP jump results in a dramatically improved injection efficiency. Our simulation results also show that the injection efficiency of PUIs is mass dependent, which is lower for species with a higher mass. The injection efficiency as the function of Mach number, obliquity, injection speed, and shock strength is also calculated. It can be proved that the focused transport theory is an extension of DSA theory with the capability of predicting the efficiency of source particle injection.

D1.1-0017-18 A STOCHASTIC SHOCK DRIFT ACCELERATION OF ELECTRONS IN THE SHOCK TRANSITION REGION

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The acceleration of non-thermal particles is one of the most important problems in astrophysics. Galactic cosmic rays with energies below 1015eV are believed to be accelerated by the Diffusive Shock Acceleration (DSA) at supernova remnant (SNR) shocks. However, it is well known that the DSA is not efficient for non-relativistic electrons. Radio and X-ray observations of SNR shocks implies that there exists an efficient pre-acceleration mechanism that injects thermal electrons to relativistic energies. The shock accelerated non-thermal electrons have also been observed at the planetary bow shocks. A statistical analysis of in-situ satellite observations of the Earth's bow shock showed that the whistler critical Mach number of the shock regulates the acceleration efficiency of energetic electrons (Oka et.al., 2006). This may be understood as the condition required for the self-generation of whistler waves by energetic electrons (Amano and Hoshino 2010). These results indicate that whistler waves play a role for the acceleration of sub-relativistic electrons.

We here propose a new acceleration mechanism that takes into account the effect of stochastic pitch-angle scatterings by whistler waves during the course of the Shock Drift Accelerations (SDA), which is an adiabatic acceleration process for small-gyroradius particles at a quasiperpendicular shock. To simplify the analysis, we focus only on spatially integrated spectra and employ a box model in which only the dependence on the energy and pitch-angle of the distribution function is considered. We theoretically analyzed the energy spectrum of electrons in the limit of strong scattering. In this case, the pitch-angle distribution is isotropic and the energy spectrum becomes a power-law. We show that the spectral index is independent of the strength of pitch-angle scatterings, and is roughly consistent with those measured in the bow shock. We also discuss Monte-Carlo simulation results for the proposed model to take into account the effect of an anisotropy in the pitch-angle distribution which should appear in general, in particular at around the maximum energy cutoff. We demonstrate that the simulation results agree quite well with the theoretical prediction in the strong scattering limit. We find that the maximum energy attainable through the proposed mechanism scales linearly with the pitch-angle diffusion coefficient.

D1.1-0018-18 TIME-DEPENDENT PERPENDICULAR TRANSPORT OF ENERGETIC PARTICLES

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The motion of energetic particles in magnetic turbulence across a mean magnetic field can be explored analytically. The approach presented in this talk allows for a full time-dependent description of the transport, including compound sub-diffusion. For the first time it is shown systematically that as soon as there is transverse structure of the turbulence, diffusion is restored even if no Coulomb collisions are invoked. Compared to other non-linear theories the new approach has the advantage that a diffusion approximation is no longer part of that theory. Criteria for sub-diffusion and normal Markovian diffusion are discussed as well. A comparison with test-particle simulations is also shown.

D1.1-0019-18 SUPERDIFFUSION OF ENERGETIC PARTICLES IN MHD TURBULENCE: EFFECTS ON PROPAGATION AND ACCELERATION

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Turbulent magnetic field lines exhibit superdiffusive behavior at the scales less than the turbulent injection scale. As a result, first of all, the subdiffusive propagation of energetic particles gets essentially impossible. More importantly, the processes of propagation cannot be described by the diffusion equation on the scales smaller than the injection scale. This entails important consequences for the particle acceleration. I shall discuss how the diffusive shock acceleration and the acceleration in magnetic reconnectin sites changes in the presence of the superdiffusion at hand.

D1.1-0020-18 FROM BALLISTIC TO DIFFUSIVE PROPAGATION OF ENERGETIC PARTICLES USING AN EXACT SOLUTION OF FOKKER-PLANCK EQUATION

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Propagation of energetic particles through magnetized turbulent media is reconsidered using an exact solution to the Fokker-Planck equation. It strictly applies to isotropic scattering but it captures all relevant propagation regimes, from ballistic to diffusive, for arbitrary spaceand time-scales relative to the particle mean free path and collision time. It is found that an intermediate (transdiffusive) propagation regime lasts for a (surprisingly) long time, about five particle collision times while starting as early as at a one-half of that. Since the particle scattering strongly depends on its energy, there always are particles that propagate neither ballistically nor diffusively. Their treatment should utilize the exact solution of Fokker-Planck equation. Problems with the application of often used approaches based on the telegraph equation and fractional diffusion are also briefly discussed.

D1.1-0021-18 ENERGETIC PARTICLE TRANSPORT IN THE PRESENCE OF MAGNETIC TURBULENCE: INFLUENCE OF SPECTRAL EXTENSION AND INTERMITTENCY

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The transport of energetic particles in the presence of magnetic turbulence is an important but unsolved problem of space physics and astrophysics. Here we aim at advancing the understanding of energetic particle transport by means of a new numerical model of magnetic turbulence, which allows to reproduce an isotropic turbulence spectrum with large spectral extension at a reasonable computational cost. The synthetic turbulence model, that consist in a superposition of wavelet-like functions at different scales, allows for the first time to reproduce a spectrum longer than four decades and to change the level of intermittency, implemented through a pmodel. Considering simulation parameters close to those of the solar wind at 1 AU, we inject 1 MeV protons in the turbulence realization and compute the parallel and perpendicular diffusion coefficients as a function of spectral extension, turbulence level, and intermittency level. While a number of previous results are recovered in the appropriate limits, including anomalous transport regimes for low turbulence levels, we find that long spectral extensions tend to reduce the value of the diffusion coefficients. Further, we find that intermittency has an influence on parallel transport but not on perpendicular transport, with the parallel diffusion coefficient increasing with the level of intermittency. We also obtain the distribution of particle inversion times for parallel velocity, which is found to be a power law for more than one decade, and compare it with the pitch angle scattering times observed in the solar wind.

D1.1-0022-18 ANOMALOUS AND GALACTIC COSMIC RAY INTENSITY VARIATIONS AT 1 AU THROUGHOUT THE SOLAR CYCLE

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Anomalous cosmic rays (ACRs) and galactic cosmic rays (GCRs) probe energetic particle transport conditions throughout the heliosphere. At 1 AU, measured ACR intensities generally track GCR intensities but with differences between solar polarity cycles: at high rigidities, GCRs reach higher peak intensities during A<0 cycles, while ACRs have been higher at A>0 solar minima. During the present approach to an A>0 solar minimum, ACR oxygen above 8 MeV/nucleon as measured by the Advanced Composition Explorer (ACE) is still 40% below the levels seen in 1997 during the last A>0 minimum (but has already reached the peak intensities seen during the 2009 A<0 solar minimum). Conversely, the GCR iron intensity at 300 MeV/nucleon is presently slightly greater than that in 1997 (but remains 10% below its record-setting 2009 value). Drift effects play an important role in the modulation of both ACRs and GCRs. Positively charged ions drift inward along the heliospheric current sheet (HCS) during A<0 cycles and their intensities are thus sensitive to the HCS tilt angle, which remained high for much of the last solar cycle. We have previously shown that both ACR and GCR intensities were significantly higher for a given HCS tilt angle during the 2000-2012 A<0 cycle than they were during the prior (1980-1990) A<0 cycle, and this trend appears to be continuing into the new A>0 cycle. But while GCR intensities in 2009 reached the highest levels recorded during the last 50 years, ACR intensities were only similar to those in the 1980's A<0 minimum. This observation, along with the higher GCR intensities but lower ACR intensities at present compared with 1997, indicate that 1-AU ACR intensities are being suppressed relative to GCRs in recent solar minima, despite the overall reduction in heliospheric

modulation. Contributing factors may include greater sensitivity of the ACRs to the HCS tilt angle due to their source distribution in latitude, a reduction in the acceleration efficiency of ACRs, or a drop in abundance of ACR seed material (pick-up ions) resulting from weaker solar activity.

We present more than 20 years of ACR and GCR intensity data acquired by ACE throughout two complete solar cycles, with emphasis on the recent observations, and discuss possible reasons for the differences in the relative behavior of ACRs and GCRs in the different solar cycles.

D1.1-0023-18 SOLENOIDAL IMPROVEMENTS FOR THE JF12 GALACTIC MAGNETIC FIELD

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The popular JF12 (Jansson & Farrar 2012) analytic model provides a quantitative description of the Galaxy's large-scale magnetic field that is widely used in various astrophysical applications. However, both the poloidal X-type component and the spiral disk component of JF12 exhibit regions in which the magnetic divergence constraint is severely violated. We first propose a cure for this problem, resulting in a truly solenoidal large-scale field. Second, the otherwise straight field lines of the X-type component exhibit kinks in the Galactic plane that, while not unphysical, may pose difficulties for, e.g., numerical tracing of cosmic-ray particles. We propose and discuss two possible strategies to mitigate this problem. All corrections are kept as minimal as possible in order not to destroy the agreement to observational data that the unmodified JF12 field was based on. Furthermore, the performance of our improved version of the field model is quantitatively assessed by test simulation using the CRpropa Galactic cosmic-ray propagation code.

D1.1-0024-18 PITCH ANGLE RESOLVED DIFFUSION COEFFICIENTS FROM MHD SIMULATIONS

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A crucial part of understanding particle events is an understanding of the particle transport processes that shape the measured spectra. Since charged particles are of primary interest, a description of the magnetic field structure and development in the heliosphere coupled with an adequate depiction of the resonant wave-particle interaction processes play a vital role.

The correct interpretation of anisotropic particle distributions measured by satellite experiments requires a resolution in pitch angle of at least the essential transport parameters. Under the assumption that (re-)acceleration of particles occurs only in specific magnetic field configurations, particle diffusion becomes crucial, with the change of the particle pitch angle μ as the predominant effect of particle scattering on magnetic irregularities.

This work extends the numerical methods introduced in Ivascenko et al. 2016 to the calculation of pitch angle dependent spacial perpendicular diffusion coefficients $D_\perp(\mu)$ (as opposed to the angle-averaged coefficient $\kappa_\perp$ widely used in QLT) and applies these methods to test-particle data from simulations of heliospheric conditions with our spectral MHD code GISMO. We present the μ-resolved perpendicular coefficients for multiple particle energies in heliospheric MHD conditions from these self-consistent turbulence simulations.

D1.1-0025-18 TEN MILLISECOND MEASUREMENTS OF THE FULL 3-D VDF WITH THE FAST IMAGING SOLAR WIND ION COMPOSITION SPECTROMETER (FISWICS)

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We describe an instrument (FI-SWICS) that will measure the full 3-D velocity distribution function (VDF) of solar wind protons and solar wind alpha particles as fast as every 10 milliseconds. FI-SWICS combines the SWICS ion identification system with a novel, highly symmetric Concentric Spheres Electro-Static Deflection Analyzer (CONSESA) driven by a rapidly swept (or stepped) deflection voltage, Vdef <5 kV between the outer mechanical collimator (OMC) at ground and the inner mechanical collimator (IMC) at -Vdef. Each collimator is an assembly of n wedges of angular width $\Delta\phi=2\pi/n$. Each of the n identical wedges has m tunnels with specified look direction, ϑm, and desired angular width, $\Delta\vartheta m$. Position sensing detectors are used to identify the specific tunnel and wedge through which a positively charged particle has entered, and thus the entrance direction of the particle. With dimensional changes only, larger versions of this instrument will also measure the full 3-D VDF of suprathermal, pickup and tail ions of protons, 4He++, 3He++, 4He+ and an additional 70 heavy ion species with different mass-(mass/charge), such as O+6, Fe+10, etc. every few seconds to minutes. Three such FISWICS instruments of different dimensions on a spacecraft similar to ACE would provide data that would resolve many outstanding problems concerning local particle acceleration by shocks and turbulence at 1 AU.

D1.1-0026-18 INVESTIGATION OF ANISOTROPY OF SOLAR WIND AND ENERGETIC PARTICLES USING ASPEX MEASUREMENTS ONBOARD ADITYA-L1

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Many aspects of the origin, acceleration and anisotropy of solar wind and energetic particles in the interplanetary medium are poorly understood till date. These particles (energy ranging from few keVs to MeVs) are originated during solar flares, during the passage of interplanetary coronal mass ejections (ICME) or corotation interaction regions (CIR) through the heliosphere and produced by the terrestrial bow shock. As a consequence, these particles can arrive at the first Lagrangian point (L1) of the Sun-Earth system from a number of directions. Further, thermal anisotropy of the solar wind particles along and across the Parker spiral direction is also reported in the past. In order to understand the origin, acceleration and anisotropy of the solar wind energetic particles, it is, therefore, essential to have multi-directional measurements of both low and high energetic particles. The measurements of He++ and H+ fluxes can be used to test the efficacy of the alpha-proton ratio in the solar wind as a possible precursor for the arrival of ICME, CIR at the earth's orbit. Keeping these aspects in mind, Aditya Solar wind Particle EXperiment (ASPEX) experiment has been selected to fly onboard Aditya-L1 mission, the first Indian mission for the study of the Sun from the Sun-Earth L1 point. ASPEX will make the in-situ, multidirectional measurements of the slow fast solar wind, supra-thermal particles and solar energetic particles in the energy range of 100 eV to 20 MeV/n using its two sub-systems: Solar Wind Ion Spectrometer (SWIS) and the Supra Thermal Energetic Particle Spectrometer (STEPS). SWIS instrument is a low energy ion spectrometer consisting of hemispherical electrostatic analyzer and magnetic mass analyzer for the identification of the He++ and H+ and energy measurement in the range of 100 eV to 20 keV. While the STEPS uses customized Si-PIN detector and plastic scintillator in the delta E-E configuration mode for energy measurement and identification of the species (H+ and He++) in the energy range of 20 keV/n to 20 MeV/n. To have multidirectional measurements, SWIS has two units THA-1 and THA-2 looking in and across the ecliptic planes respectively. While STEPS has six directional measurements which include radial (towards the Sun), Parker (along the Parker

Spiral), intermediate (between radial and Parker), Earthward (from Earth side) and across the ecliptic plane in the northward and southward directions. In this talk, overall configuration of the ASPEX instrument and its salient features will be discussed. Developmental status of the engineering model and its preliminary results will also be presented.

D1.1-0027-18 FORBUSH DECREASE MECHANISM IN A MAGNETIC CLOUD

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Using back tracing we research galactic cosmic ray propagation in a moving magnetic cloud having the shape of magnetic loop. It is obtained that the inductive electric field of an extended magnetic cloud decreases particle energy. Both energy losses and long particle trapping by a magnetic loop produce Forbush decrease. The calculation results of particle density and the components of uniand bidirectional anisotropies are shown. The calculation results generally agree with measurements.

D1.1-0028-18 EXPLORATION OF THE EDGE OF HELIOSPHERE THROUGH STRATEGICALLY PLACED SOLAR-SAIL PROPELLED STATELLITES

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For over five decades, the shape and interaction of the heliosphere with the neighborhood interstellar medium have been discussed concerning two contending models: magnetospheric and symmetric bubble. Voyagers 1 and 2 crossed the termination shock, north and south of the ecliptic plane at 94 AU and 84 AU in 2004 and 2007, respectively, and discovered the reservoir of ions and electrons that constitute the heliosheath, while Cassini remotely imaged the heliosphere for the first time in 2003. This paper presents a much faster way to reach the interactive layer of the heliosphere, as compared to the time taken by the Voyagers 1 and 2, using a dynamic inter-planetary constellation of satellites that shall propel two Solar Sails using a controllable push-type propulsion by LASER. Besides previous missions, a more extensive study of the heliosphere will test the mankind's drive for deep space exploration, as exotic means of travel are needed. This paper will take a futuristic case study of the event and various possibilities of space travel will be discussed in detail. Comprehensive tables and graphs will be given, which will depict the amount of time that will pass at each stage of the mission and more importantly some idea on the cost in terms of energy, as well as money, will be discussed within today's context. Even though the possibility of such a mission is probably nonexistent for this decade, it is essential to do these exercises in order to unfold the mysteries of the universe. In addition, this paper hopes to establish some general guidelines for such exploring missions.

D1.1-0030-18 THEORETICAL MODELING OF THE DIURNAL ANISOTROPY IN PERIODS MINIMA AND NEAR MINIMA OF SOLAR ACTIVITY (CYCLES: 23 - 24)

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We study behavior of diurnal anisotropy in period's minima and near minima of solar activity (SA) for two cycle 23 and 24. Parker's transport equation is numerically solved in order to obtain three components Ar, $A\vartheta$ and $A\phi$ of the anisotropy vector. We used in mathematical model with few physical parameters corresponding to the given minimum of SA as, tilt angle δ of the Heliospheric Neutral Sheet (HNS), module B of the Heliospheric Magnetic Field (HMF) and changing the sign of the global magnetic field of the Sun (A>0) (positive polarity magnetic field lines are directed away from the Sun's northern hemisphere, 23 cycle); (A<0) (negative polarity magnetic field lines are directed towards the Sun's northern hemisphere, 24 cycle). The results of the theoretical modeling were compared with the changes of the diurnal anisotropy based on hourly data of galactic cosmic rays (GCR) intensity from the global network of neutron monitors using harmonic analysis. We received a satisfactory agreement of the theoretical results with the experiment.

D1.1-0031-18 CHARGED PARTICLES SURFATRON ACCELERATION AT SIMULTANEOUS INTERACTIONS WITH TWO ELECTROMAGNETIC WAVES IN SPACE PLASMA

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Resonant wave-particle simultaneous interactions with two electromagnetic waves in space plasmas at the presence of weak constant magnetic field are studied. Special attention is paid to the electrons surfatron acceleration interactions with two electromagnetic waves in space plasmas. The theory of this phenomenon, basic differential equations and their transformations are presented in a separate section of this work. Particles relativistic equations of motion are analyzed for this type of interactions. The final form of second order nonlinear, nonstationary equation for the wave phase at the particle's trajectory, describing interactions with two electromagnetic waves is outlined and presented. In the next stage the task is reduced to the exact numerical solution of equations for different sets of initial particles' and waves parameters. The particles are assumed as weakly relativistic electrons acting simultaneously with two electromagnetic waves with a low phase velocity. Based on large number calculations for different initial waves' phases, the probability of the electron trapping by the waves is estimated. The influence of the variations in differences between two waves phase velocities on the particle capturing process is examined. Numerical experiments demonstrate that no particle trapping occurs in the cases when two modes phase velocities are too close to each other. For every numerical experiment the capture probability results are presented in tables. Particles maximal energy gained through the acceleration process is assessed. Additional calculation results as particle relativistic factor, phase plane structure of the captured particle and particle's velocity components are graphically presented. Conclusions about charged particles surfatron acceleration at interactions with two electromagnetic waves are made.

D1.1-0032-18 STUDY OF PARTICLE ACCELERATION IN KH DRIVEN TURBULENCE IN SOLAR CORONAL LOOP TOPS VIA COUPLED MHD-PIC SIMULATIONS

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Solar coronal loops are heated at their foot-points by particles accelerated in solar flares. This heat deposition causes strong upflows that meet and interact at the coronal loop tops. As these are sheared flows, they lead to Kelvin Helmholtz (KH) instabilities which produce turbulence. This can lead to turbulent acceleration of particles at these sites. We study this process by using a coupled MHD-PIC simulation. The global coronal loop is simulated with a fluid magnetohydrodynamics (MHD) code, while the loop top where the turbulence occurs is simulated with a kinetic, particle-in-cell (PIC) code, in 2.5 dimensions. The embedded PIC domain receives its initial and boundary conditions from the MHD simulation. We will present and compare the turbulent spectrum from the MHD and PIC regions. The particle energy spectrum will also be presented with a focus on the particle acceleration mechanisms. This is relevant for explaining hard X-rays observed near the coronal loop tops after solar flares.

D1.1-0033-18 A NUMERICAL SIMULATION OF THE SPATIAL PROFILES OF ENERGETIC PARTICLES UPSTREAM AND DOWNSTREAM OF INTERPLANETARY SHOCKS

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The spatial distribution of energetic particle accelerated at shocks depends on the transport properties of those particles. In the case of standard diffusion, it can be easily shown that an exponetial decay for the energetic particle intensity is obtained upstream of the shock, and a constant profile downstream. However, these kind of profiles are rarely observed by spacecraft at interplanetary shocks. We set up a numerical simulation to compute the energetic particle profile both upstream and downstream of the shock: particles are injected at the shock and then propagate according to a Gaussian random walk in the case of normal diffusion and according to a Levy random walk in the case of superdiffusion. The latter is characterized by a nonlinear growth of the mean square displacement of particles and by a power law distribution of free path lengths. A Langevin type equation is solved numerically, and energetic particle spatial profiles are obtained by means of a further integration over time. A number of solutions are obtained while varying the exponent of superdiffusion, and it is found that power law upstream profiles and nonconstant downstream profiles are obtained. These results are compared with previous analytical and numerical studies, and with interplanetary shock observations by the ACE spacecraft.

D1.1-0034-18 ON THE FRACTIONAL PARKER EQUATION FOR THE TRANSPORT OF COSMIC RAYS: STEADY-STATE SOLUTIONS

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The acceleration and transport of energetic particles in astrophysical plasmas can be described by the so-called Parker equation, which is a kinetic equation comprising diffusion terms both in coordinate space and in momentum space. In the past years, it has been found that energetic particle transport in space can be anomalous, for instance, superdiffusive rather than normal diffusive. This requires a revision of the basic transport equation for such circumstances. Here, we extend the Parker equation to the case of anomalous diffusion by means of fractional derivatives that generalize the usual second-order spatial diffusion operator. We introduce the left and right Caputo fractional derivatives in space. These derivatives are one of the tools used to describe anomalous transport. We consider the case of steady-state solutions upstream and downstream of a planar shock. An analytical solution of the steady-state fractional Parker equation is given by the Mittag-Leffler functions, which correspond to a power-law profile for the energetic particle intensity far upstream of the shock, in agreement with the results obtained from a probabilistic approach to superdiffusion. These functions also correspond to a stretched exponential close upstream of the shock. These results can help to model more precisely the measured fluxes of energetic particles that are accelerated at both interplanetary shocks and supernova remnant shocks.

D1.1-0035-18 STRUCTURE OF INTERSTELLAR CLOUDS INCLUDING THE EFFECTS OF COSMIC RAYS AND WAVES

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The energy densities of thermal gas, magnetic field and cosmic ray in the Milky Way are comparable. Cosmic ray would exert significant influence on the structure of thermal gas clouds. The interaction of cosmic ray with thermal plasma is facilitated through hydromagnetic fluctuations or waves embedded in the plasma. We adopt a hydrodynamical model to study the dynamical effect or feedback of cosmic ray on the thermal plasma. The model comprises four fluids, thermal plasma, cosmic rays and two oppositely propagating self-excited Alfven waves. We examine the ways that cosmic rays and waves affect the structure and properties of the cloud.

D1.1-0036-18 UNIFYING THE MULTIPLE-FIELD-LINE-ADVECTION MODEL FOR PARTICLE ACCELERATION WITH ALFVEN WAVE TURBULENCE

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A study of Solar Energy Particle (SEP) events is an important topic in space physics. Extreme events are not only dangerous to instruments onboard spacecraft in deep space, but they are also very harmful to astronauts, because SEPs can easily penetrate spacesuits and high radiation doses can even kill astronauts. It is important to predict the arrival time of SEP events so that we can better prepare and mitigate the hazards brought by such events.

The Multiple-Field-Line-Advection Model for Particle Acceleration (M-FLAMPA) within the Space Weather Modeling Framework (SWMF), which solves the kinetic equation for SEPs along a multitude of interplanetary magnetic field lines, has been proven to be a powerful tool for the predication. However, there are some certain limitations of the current M-FLAMPA, for example, the code currently uses a physics-based but phenomenological pitch angle scattering coefficient.

In this study, we plan to introduce a more realistic and quantitative pitch angle scattering coefficient, which is calculated from the amplitudes of Alfven waves obtained from the AlfvenWave-driven Solar Model (AWSoM) as well as the Outer Heliosphere (OH) model, all being the parts of the SWMF. With such an improvement, M-FLAMPA should be able to better describe the SEP transport and predict their arrival time.

D1.2-0001-18 ASTROSPHERES AND STELLAR BOWSHOCKS

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Like our sun, each star (or binary system) has a surrounding region in which all physical processes are dominated by the central star(s). This area is known as the astrosphere.

Astrospheres are fascinating objects. Because they are formed through the interaction between the stellar feedback (wind and radiation) and the interstellar gas, they can tell us a great deal about both. Furthermore, because they are shaped over time they provide us with a window into the past. This is of particular interest for the study of stellar evolution, because the astrosphere reflects changes in the properties of the stellar wind, which relate directly to the properties of the star. A special sub-class of astrospheres, the stellar bow shocks, occur when the progenitor star moves through the surrounding medium at supersonic speed. Because the properties of the bow shock relate directly to both the stellar wind and the interstellar medium, the shape and size of the bow shock can be used to determine the current state of the stellar wind, rather than its history.

Beyond the study of astrospheres themselves, their influence is also felt when investigating certain high energy phenomena, such as core-collapse supernovae and long gamma-ray bursts which occur at the end of the evolution of massive stars. Because they originate within the astrosphere any study of these objects will have to involve an understanding of the characteristics of the astrosphere.

Using state of the art numerical codes it is possible to simulate the interaction between the stellar wind and radiation and the interstellar medium. These results can then be compared to observations. They can also be used to predict the type of observations that are best suited to study these objects. In this fashion, computational and observational astronomy can support each other in their efforts to gain a better understanding of stars and their environment.

D1.2-0002-18 THE INTERSTELLAR MAGNETIC FIELD FROM GALACTIC SCALES DOWN TO THE HELIOSPHERE

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I will review the observational properties (strength, direction, and spatial distribution) of the interstellar magnetic field of our Galaxy, starting from the large Galactic scales and gradually zooming in towards the Sun. I will show that the large-scale magnetic field in the Galaxy disk has a strength of a few microGauss and a predominantly azimuthal direction. While the magnetic field appears to maintain a microGauss strength in to the edge of the heliosphere, its azimuthal direction is completely lost in the perturbed small-scale interstellar surroundings of the Sun. I will discuss these perturbations, introduced by nearby bubbles, the Local Bubble, and the very local clouds within the Local Bubble.

D1.2-0003-18 THE SUN'S DUSTY INTERSTELLAR ENVIRONMENT

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The Sun and the heliosphere are embedded in the Local Interstellar Cloud that consists of partially ionised gas, and for about 0.5-1% of its mass is in interstellar dust (ISD). Because of the relative motion of the solar system with respect to this cloud, at speeds of ca. 26 km/s, many of the dust particles enter the heliosphere and can be measured in situ, using spacecraft dust detectors.

In 1993, such ISD particles were for the first time detected using the Ulysses cosmic dust detector. The mission provided a total of 16 years of ISD data and thus covered almost one Hale cycle. The Hale cycle is important for understanding the dust data, since the interstellar dust trajectories are shaped not only by solar radiation pressure force and gravity, but also by Lorentz forces as a result of the (charged) interstellar particles that move through the heliosphere's magnetic fields. Also, the heliosphere boundary regions play a large role in the measured dust size distributions in the solar system.

By using Monte Carlo computer simulations of dust trajectories, the interpretation of these spacecraft data allows us to constrain the particle properties, and it teaches us about the role of the heliosphere for dust transport.

In this talk, we review the latest developments in the study of "local" interstellar dust, with astronomical, in-situ, and sample return techniques. We explain the dynamics of the ISD as it moves through the heliosphere, and finally, we elaborate on how we can use computer simulations and spacecraft data for constraining the ISD properties and for studying the heliosphere.

D1.2-0004-18 WHAT ARE COSMIC RAYS TELLING US ABOUT THE FAR OUTER STRUCTURES OF THE HELIOSPHERE?

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The behaviour of cosmic rays (CRs), as very energetic charged particles, reflects local heliospheric conditions of where they are observed, and global conditions which they had experienced during their propagation up to the place of observation. A testimony for this is the set of CR observations made by the two Voyager spacecraft since their launch 40 years ago, from the Earth, along their different trajectories to the solar wind termination shock, into the heliosheath, and for Voyager 1 beyond the heliopause. Using a variety of CR transport models, together with appropriate MHD models, a parameter set is tuned to reproduce observations from the Earth, over large radial distances, up to the heliopause. The computed CR flux can be used to make conclusions about the far outer structures of the heliosphere, e.g. a well-defined and large flux-jump could be the signature of the spacecraft crossing the HP. They also indicate that the outer heliosheath must be included in modulation models to accurately describe CR transport near and across the HP.

D1.2-0005-18 AN INVESTIGATION INTO A GENERALIZED FISK-TYPE HELIOSPHERIC MAGNETIC FIELD

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The existence of a Fisk-type heliospheric magnetic field (HMF) has been questioned since it was proposed by Fisk more than two decades ago. Fisk-type fields are believed to occur when polar coronal holes are well developed, and are the result of photospheric differential rotation, superradial expansion of the solar magnetic field, and rigid rotation of polar coronal holes at the equatorial rotation rate. Theoretically the net result is that the footpoint of magnetic field lines that form the HMF, move in circles about an axis that is offset from both the solar rotation and the solar magnetic field axis. This circular motion leads to a meridional field component, and combined with the rotation of the Sun, leads to notable differences between Fisk-type fields and Parker-type fields. We present a generalized Fisk-type HMF that retains information about the solar differential rotation rate where the field line originates on the photosphere, in contrast to the average value used in other models. It differs from the Fisk-Parker hybrid field approach of Burger and co-workers since it does not assume a combination of Fiskand Parker fields at different heliographic latitudes. Open-field line origination in polar coronal holes is Fisk-type while others are Parker-type. By using the statistical approach developed by Forsyth and co-workers, we show that this newly-developed HMF is significantly better at explaining the magnetic field winding angles observed by the Ulysses spacecraft during its first solar orbit (1992 - 1998) than the traditional Parker field. We also show that the signature of a Fisk-type field may well be present in 26-day recurrent cosmic-ray variations seen in neutron monitor data from the global network.

D1.2-0006-18 SOLAR MAGNETIC FIELD STRENGTH AND THE COSMIC-RAY SUN SHADOW OBSERVED BY THE TIBET AIR SHOWER ARRAY

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We analyze the displacement of the Sun shadow observed in 5 240 TeV cosmic-ray intensity with the Tibet air shower array during 10 years between 2000 and 2009, and compare with the MC simulations based on the coronal magnetic field model and Parker's spiral interplanetary magnetic field model. We find that the observed North-South displacement is significantly larger than the prediction of the simulations. This result uniquely suggests the underestimation of the average field strength between the Sun and the Earth in our model. In order to identify the source of this underestimations, we investigate the influence of the coronal and interplanetary magnetic fields separately on the Sun shadow. In this presentation, we will discuss the results by changing independently each strength in the interplanetary and coronal magnetic fields.

D1.2-0007-18 MAPPING MAGNETIC FIELD LINES FOR AN ACCELERATING SOLAR WIND

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A new accelerating solar wind [Tasnim et al., 2018] is developed that includes conservation of angular momentum, deviations from corotation, and non-radial intrinsic velocity and magnetic field components from an inner boundary to beyond 1 AU. We fit the model to near-Earth observations of the Wind spacecraft for the solar rotation period between 19 April to 15 May 1995 (CR 1895). Later, we employ this accelerating solar wind to predict the magnetic field vectors and map the magnetic field lines. Note that magnetic field line mapping is important to trace the paths of solar energetic particles and electron beams in type III radio burst since superthermal beams move along the field lines from the Sun towards the Earth and even beyond. We map the magnetic field lines from the source surface towards 1 AU using the field line mapping algorithm developed by Li et al. [JGR,2016]. We compare these magnetic field lines with the field lines predicted by Li et al. [JGR,2016] using Schulte in den Baumen et al. [JGR,2012]'s model. The maps for accelerating and constant speed models are very similar. However, close comparisons show that the magnetic field lines for the radial speed model move further out than the accelerating wind model. The obvious interpretation is that the accelerating solar wind is slower at small heliocentric distance (r) and so travels less far outward than the constant speed solar wind.

D1.2-0008-18 IBEX (INTERSTELLAR BOUNDARY EXPLORER) OBSERVATIONS OF OUR EVOLVING HELIOSPHERE

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The Interstellar Boundary Explorer (IBEX) has made nearly continuous observations of Energetic Neutral Atoms (ENAs) coming in from the outer heliosphere over the past decade. These observations have reshaped our fundamental understanding of the outer heliosphere and its interaction with the local interstellar medium. In this talk we summarize some the IBEX discoveries and examine how the ENAs have evolved over time. For most of this time there has been an overall reduction in the ENA fluxes at all energies, reflecting a generally deflating heliosphere. The Ribbon, which is likely generated beyond the heliopause, in the outer heliosheath, has evolved differently from the globally distributed flux (GDF), which is primarily produced in the inner heliosheath, between the termination shock and heliopause. Most recently, IBEX has observed the initial response of the heliosphere to a persistent increase in the solar wind dynamic pressure that was observed at 1 AU in the second half of 2014. This enhanced pressure has arrived at the outer heliosphere as indicated by a strong enhancement in the ENAs returning from the closest regions of the inner heliosheath, and is re-expanding our heliosphere, with the termination shock and heliopause already driven outward in their locations closest to the sun.

D1.2-0009-18 MODELING THE TIME EVOLUTION OF THE IBEX RIBBON OVER THE SOLAR CYCLE

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The IBEX ribbon is an arc-like enhancement of the Energetic Neutral Atom (ENA) fluxes in the sky, discovered by IBEX. Among many potential sources proposed to explain the ribbon, the secondary ENA mechanism has been shown to explain most of the observed features of the ribbon. In this mechanism, the ribbon originates in the outer heliosheath where the lines of the local interstellar magnetic field are almost perpendicular to the line-of-sight. The main component of the primary ENA flux, which is an input to the secondary ENA mechanism, is the neutralized supersonic solar wind. The IBEX ribbon reveals energy-dependent structure in the relative intensity along its circumference. It has been shown that the ribbon's position in the sky can be approximated by circles or ellipses in the sky, and the centers of these figures show a monotonic trend with a shift of 10° between the lowest and highest energy observed by IBEX-Hi. We have recently shown that this finding can be explained by the helio-latitudinal structure of the supersonic solar wind.

In this contribution, we model the IBEX ribbon fluxes using a semi-analytic model of the secondary ENA mechanism. We adopt a timeand latitude-dependent model of the speed and density of the supersonic solar wind based on observations, and we account for the time-delay between the solar wind emission and the observation of the secondary ENAs. Next, we fit circles to the modeled position of the IBEX ribbon. The positions of the circle's centers show a time-dependence related to the evolution of the solar wind during the solar cycle. The smallest changes with time in the position of the ribbon center are expected for the energy step of 1.7

keV. For higher and lower energies, the modeled solar cycle amplitudes of the positions of the ribbon's centers are up to ~2°.

D1.2-0010-18 TRANSPORT OF SUPRATHERMAL PROTONS IN THE INNER HELIOSHEATH

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A quantitative understanding of the phase-space transport of suprathermal protons in the inner heliosheath is highly desirable, as it represents the basis for the modelling of so-called energetic neutral atoms (ENAs) observed with the Interstellar Boundary Explore (IBEX). A consistent modelling of all-sky maps of ENA fluxes at different energies will provide insight into the large-scale structure of the outer heliosphere, which is a welcome supplement to the in-situ measurements made with the Voyager spacecraft. Numerical solutions of the transport equation of supratherml protons will be presented. These solutions allow to compute the ENA production rate in the inner heliosheath and, subsequently, the resulting energy-dependent flux from a given direction.

D1.2-0011-18 THE LOCAL INTERSTELLAR MEDIUM REVEALED BY IBEX OBSERVATIONS OF INTERSTELLAR NEUTRAL ATOMS

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Interstellar neutral (ISN) atoms penetrate the heliosphere and allow for remote sensing of plasma in the local interstellar medium (LISM) in the vicinity of the Sun. The charge-exchange processes between the ionized and neutral components provide that both components have similar bulk flow and temperatures. For hydrogen and helium, charge exchange reactions between the ions and atoms of the same chemical element dominate (H + H+ and He + He+, respectively). Consequently, protons and hydrogen atoms equilibrate at scales of several hundred of astronomical units, whereas helium ions and atoms at scales of a few thousand of astronomical units. The flow of the plasma is significantly disturbed around the heliosphere at scales smaller than necessary to obtain the equilibrium. Therefore, the ensemble of ISN atoms are considered as a sum of (1) the primary ISN population from the undisturbed LISM and (2) the secondary ISN population created in the outer heliosheath.

IBEX-Lo observes ISN atoms in the Earth's orbit. These observations allowed to identify the primary ISN He population and an additional population of ISN He atoms, called the Warm Breeze. In the earlier studies, we modeled these populations, assuming two separate MaxwellBoltzmann distributions that are propagated from the heliopause into the inner heliosphere to the observing spacecraft. We found that the inflow directions of the two populations are co-planar with the center of the IBEX ribbon, which, in the meantime, has been shown to be most likely due to the secondary ENA emission mechanism. In this mechanism, the center of the ribbon is close to the direction of the unperturbed interstellar magnetic field (ISMF), which is the main factor distorting the heliosphere from axial symmetry. This result suggested that the Warm Breeze is the secondary ISN He population. This supposition was later confirmed by combining MHD modeling of the plasma flow in the outer heliosheath with solutions of the charge-exchange production and loss balance equation along the trajectories of these helium atoms.

In this contribution, we show results of the modeling the ISN He signal using the MHD heliosphere simulation precisely conforming with those used to establish the direction and strength of the ISMF from the observations of the IBEX ribbon. We find that the resulting signal is sensitive to the ionization degree of the interstellar helium. We compare the IBEX-Lo observations with the modeled signal and determine the relative abundance of helium ions and atoms in the outer heliosheath. We conclude that most

likely, the ionization degree of interstellar helium in the LISM is significantly lower than previously thought. Moreover, we model the ISN He using various directions and strengths of the ISMF, complementing the interpretation of the IBEX ribbon and Voyager observations.

D1.2-0012-18 VOYAGER: THE OUTER HELIOSPHERE AND VERY LOCAL INTERSTELLAR MEDIUM

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Now approaching six years beyond the heliopause and 143 AU from the sun, Voyager 1 has been observing the intensity gradient and pitch-angle anisotropy of galactic cosmic rays and the associated perturbations in the local interstellar medium. Now at 118 AU, Voyager 2 continues to observe plasma pressure pulses from merged interaction regions, laminar flow of the solar wind parallel to the heliopause, and modulation of galactic cosmic rays in the heliosheath. The increasing intensity of galactic cosmic ray electrons suggests that Voyager 2 may reach the heliopause in several years. An overview and update of recent observations and interpretations will be presented.

D1.2-0013-18 PLASMA AND MAGNETIC FIELD INTERACTIONS IN THE HELIOSHEATH

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Voyager 2 have been in the heliosheath for almost 11 years providing the first plasma data from this region. This region shows time variation on scales from tens of minutes up to the 11-year solar cycle. This paper concentrates on the relationship between changes in the plasma and magnetic field; an initial investigation of MHD waves covered only data from 2007 and early 2008 (Gutynska et al., ApJ 722, L228). We use data the most recent data available, to at least 2015. The 48-sec magnetic field data will be compared with 192-sec plasma data on varying time scales and the resulting correlations will be discussed.

D1.2-0014-18 VOYAGER PLASMA OBSERVATIONS IN THE HELIOSHEATH

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Voyager 2 is now 34 AU beyond the termination shock and still in the heliosheath; the width of the heliosheath in the Voyager 1 direction was 27 AU. We present recent observations, compare with observations from Voyager 1, and compare with model predictions. The speed of the flows observed by Voyager 2 in the heliosheath have been, on average, remarkably constant at 150 km/s. The flow angle rotated to about 60circ from radial but has not changed for the past 15 AU; more of the turning occurred in the RT than RN planes. Recent data have been dominated by pressure pulses correlated with increases in the temperature and energetic particle fluxes. These pulses may drive shocks such as those observed by V1 through the interstellar medium.

D1.2-0015-18 SURVEY OF COMPRESSIONS AFTER TERMINATION SHOCK AT VOYAGER (IN SHEATH & LISM)

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Examples of the plasma compression as it is observed in the solar wind at 1 AU with the suite of instruments in the SC Wind, and after the termination shock with both Voyager SC, as well as with Voyager 1 in the local interstellar medium (LISM) are presented. The work will focus on similarities and differences in the observations at the different locations. At priory is fair to mention that the 4 regions differ in several aspects. At 1 AU the solar wind (SW) flow is mostly alfvenic. In the sheath after the termination shock the possibly subsonic solar wind is mostly compressional but fluctuation modes in scales of one hour are much less observed at Voyager 1 than at Voyager 2 path. Finally Burlaga and Ness1 documented the nature of the compressional flow in the 'depletion' layer at the start of the LISM as well later in this medium, showing the low plasma-beta character of this LISM region in Voyager 1 path. 1Burlaga L.F., and N. Ness, ApJ, 784, 146 (14pp), 2014.

D1.2-0016-18 SHOCKS AND TURBULENCE IN THE VERY LOCAL INTERSTELLAR MEDIUM

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The influence of the solar wind does not stop at the heliopause, but continues into the surrounding very local interstellar medium (VLISM). The motion of the heliopause in response to incident coherent structures, such as merged interaction regions, as well as weaker random ensembles of waves injects waves and fluctuations into the VLISM where they continue to propagate through the subsonic partially ionized plasma in the direction of the bow wave. It is thought that the abrupt increases and subsequent gradual decreases in magnetic field strength measured by Voyager 1 are produced by pressure waves incident on the heliopause that transform into a triangular pulse with a shock at the leading edge. However, these shock like structures are far broader than the characteristic width of subcritical resistive shocks. The weak Kolmogorov turbulence measured in the VLISM during the first two years of observations was primarily compressive, with the maximum variance direction aligned with the mean magnetic field. Two years later, however, the fluctuations became primarily transverse, similar to those in the solar wind. We discuss collisionless and collisional dissipative processes that could be responsible for broadening of the shock waves and the decay of the compressive magnetic fluctuations.

D1.2-0017-18 THEORY AND TRANSPORT OF NEARLY INCOMPRESSIBLE MAGNETOHYDRODYNAMICS TURBULENCE. III. EVOLUTION OF POWER ANISOTROPY IN MAGNETIC FIELD FLUCTUATIONS THROUGHOUT THE HELIOSPHERE

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A theoretical model that describes the evolution of the power anisotropy in the energy-containing and inertial ranges throughout the heliosphere is developed for three possibilities: (i) no in situ sources of turbulence; (ii) stream-shear sources of 2D and slab turbulence; and (iii) a fully driven turbulence model that includes both streamshear driving and a pickup ion source of slab turbulence. At the inner boundary (1 au), we assume that the ratios of the 2D to slab fluctuating magnetic energy variances in the energy-containing range are 80:20, 70:30, 60:40, and 55:45. For case (i), <B2D > / < b2lab > intheenergy−containing range increases monotonically throughout the heliospher containing range ratio increases initially and then remains approximately constant and ordered beyond 2au, ac 20 case increases with heliocentric distance, whereas for the 70: 30, 60: 40, and 55: 45 cases, the rations incr 20au, and then generally decrease at larger heliocentric distances. For case (iii), the energy−containing and in

D1.2-0018-18 INTERSTELLAR HE FLOW ANALYSIS OVER THE PAST 10 YEARS WITH VARYING POINTING STRATEGIES

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The Sun's motion relative to the surrounding interstellar medium leads to an interstellar neutral (ISN) wind through the heliosphere. This wind is moderately depleted by ionization and can be analyzed in-situ with pickup ions and direct neutral atom imaging. Since 2009, observations of the ISN wind at 1 AU with the Interstellar Boundary Explorer (IBEX) have returned a very precise 4-dimensional parameter tube for the flow vector (speed it VISN, longitude it lambdaISN, and latitude it betaISN) and temperature it TISN of interstellar He in the local cloud, which organizes it VISN, it betaISN, and it TISN as a function of it lambdaISN, and the local flow Mach number (it VThISN /it VISN). Typically, the uncertainties along this functional dependence are larger than across it. Here we present important refinements of the determination of this parameter tube by analyzing the spin-integrated ISN flux for its maximum as a function of ecliptic longitude for each year through 2018. We include a weak energy dependence of the sensor efficiency by comparing the response in all four energy steps that record the ISN He flow. In particular, we make use of an operational extension, with which we let the spin axis pointing of IBEX drift to the maximum offset west of the Sun, which we used for the first time during the entire ISN observation season in 2018. This expansion of the IBEX viewing results in an additional constraint that helps breaking the degeneracy of the ISN parameters along the 4D tube. This constraint is part of the complement of drivers effective in the full Chi-square-minimization to obtain the ISN parameters by comparison with a detailed model of the ISN flow. It is also complementary to an independent determination of ISN using the longitude dependence of the He+ pickup ion cut-off speed with STEREO PLASTIC and ACE

SWICS.

D1.2-0019-18 IDENTIFYING SOLAR WIND STRUCTURES IN THE NEW HORIZONS SOLAR WIND AROUND PLUTO (SWAP) OBSERVATIONS BETWEEN 20 AND 40 AU

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Here, we present our work automating the identification of shocks/waves, and Interplanetary Coronal Mass Ejections (ICMEs) in the Solar Wind Around Pluto on the New Horizons between 20 and 40 AU. New Horizons is a planetary mission designed to study the Pluto system and the Kuiper Belt; therefore, the prime instruments are geared towards optical observations. The spacecraft does not have a magnetometer so many standard techniques for finding shocks and ICMEs cannot be performed. We developed a simple algorithm to find all the steep rises in the speed, and we check for coincident changes in the solar wind density, temperature, and pressure. We have already found that beyond 20 AU most of the shocks/waves have only small jumps in speed. This likely reflects the lower activity level for this solar cycle, and that the solar wind is highly processed prior to reaching 20 AU owing to faster and slower wind parcels interacting with one another en route. The SWAP instrument is a top hat electrostatic analyzer and measures count rates as a function of energy per charge. In the outer heliosphere the solar wind proton and alpha peaks are often well separated since the temperature is lower. While acquiring solar wind observations, SWAP is in a mode where a coarse energy sweep is performed over the full energy range followed by a fine sweep centered on the energy step where the peak counts were observed in the coarse sweep. The fine sweep provides excellent energy coverage for the solar wind protons, but does not provide this level of coverage at higher energies where the alphas occur. Consequently, we only have coarse sweep measurements for the alphas. Here, we test estimating the alpha to proton density ratio (na/np) using a normalized ratio of the count rates for the proton and alpha peaks. We identify times when this na/np ratio is high and determine if those are associated with shocks or any anomalously low temperature intervals because high na/np, shocks, and low temperature are often associated with ICMEs. Being able to estimate na/np is very useful since this ratio should not evolve significantly as the solar wind propagates outward. Without a magnetometer our next best ICME indicator is anomalously low temperatures; however, as solar wind structures merge and are worn down this method of identifying ICMEs will likely break down.

D1.2-0020-18 TIME-VARYING PROCESSES IN THE OUTER HELIOSPHERE

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For the purposes of definition, we will assume that the outer heliosphere in this presentation is the region at and beyond the heliospheric termination shock (HTS), extending into the very local interstellar medium (VLISM). We will focus on two aspects of the temporal heliosphere. 1) The response of the outer heliosphere to interplanetary disturbances and long-term variability: we will describe theoretically, using large-scale models, and observationally the temporal structure of the HTS and inner heliosheath in response to interplanetary shocks; we will analyze the response of the heliopause (HP) to disturbances that impinge on it from the inner heliosheath, including the transmission of shocks into the VLISM, and we will discuss the location of the HP as deduced from global models that incorporate a temporal solar wind ram pressure during solar minimum and solar maximum, incorporating the periodic presence of global merged interaction regions. 2) Shock waves observed in the VLISM appear to be far broader than their interplanetary medium counterparts. Until recently, no theoretical explanation had been provided to explain the observed structure. We will discuss the model developed by Mostafavi et al. 2018 that shows that the VLISM is collisional and thermal collisional heat conduction and viscosity are responsible for determining the structure of VLISM shocks. The characteristic shock thickness is determined by the heat conduction length scale.

D1.2-0021-18 HELIOSHEATH ENA IMAGES BY CASSINI/INCA AND IN-SITU HOT PLASMA ION MEASUREMENTS BY VOYAGERS SUGGEST A BUBBLE SHAPE FOR THE HELIOSPHERE

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The advent of Energetic Neutral Atom (ENA) imaging, (the result of charge-exchange with energetic ions), has revealed the global nature of the heliosheath (HS) at both high (> 5 keV, Cassini from 10 AU) and low (< 6 keV, IBEX from 1 AU) energies. Voyager 1 (V1) entered the HS in December 2004 at 94 AU and crossed the heliopause (HP) in August 2012 at 121.6 AU, while Voyager 2 (V2) has been in the HS since August 2007. Thus, the properties of the HS along the V1, V2 trajectories are now well-established. Portions of the global HS have been imaged by the Cassini/ INCA (Ion and Neutral CAmera) since 2003 with a full image available since 2009, when IBEX global imaging observations also became available. The presence of the two Voyagers measuring ions locally in the HS contemporaneously with INCA global imaging through ENA in overlapping energy bands provides a powerful tool for examining the spatial, temporal, and spectral evolution of the source hot plasma ions and the global variability of the neutral component. Some of the key findings from the Voyagers and INCA measurements are as follows: (a) The HS contains a hot plasma population that carries a substantial part (30-50 %) of the total pressure at E > 5 keV, the rest residing below that range, resulting in a beta (particle/magnetic pressure) always > 1, typically >10. (b) The width of the HS in the direction of V1 is 27 AU, but is > 33 AU in the southern ecliptic where V2 currently travels.

The ENA intensities at E > 5 keV exhibit a correlation with the solar cycle (SC) over the period 2003 to 2017, with minimum intensities in the anti-nose direction observed 2.5 years after solar minimum followed by a recovery thereafter, and (d) The in-situ ion measurements at V2 within the HS also show a similar SC dependence. The totality of the observations, together with the near-contemporaneous variability in intensities of ions in situ in the HS and ENA in the inner heliosphere shows that the source of such emissions at E > 5 keV is in the HS. These observations

constrain the shape of the HS and suggest a Parker "bubble" configuration rather than the heretofore assumed comet-like tail (Dialynas et al. 2017, Nature Astronomy, 1, 0115).

D1.2-0022-18 THE EFFECTS OF PICK-UP IONS ON THE SHAPE OF THE HELIOSPHERE

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As the Sun moves through the surrounding partially-ionized medium, neutrals hydrogen atom penetrate the heliosphere and through charge-exchange with the supersonic solar wind create a population of hot pick-up ions (PUIs). With the crossing of the termination shock by Voyager 2 it became clear that the heliosheath pressure is dominated by the PUIs while the bulk thermal solar wind is much colder. Recently the shape of the Heliosphere is being challenged by theoretical and observation work (Opher et al. 2015; Diyalinas et al. 2017). Previously we had explored the effects of PUIs in the termination shock crossing (Zieger et al. 2015). In this work, we explore the effects of PUIs on the shape of the heliosphere. We present global magnetohydrodynamic simulations that treats the PUIs a separate fluid. Most global models treat the PUI and thermal component as a single fluid. We comment on the effect of the global structure as well as the properties of the heliosheath.

D1.2-0023-18 KINETIC-MHD MODELS OF THE GLOBAL HELIOSPHERE

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Current state of art in the kinetic-MHD modeling of the solar/stellar wind interaction with the local interstellar medium (LISM) will be reviewed. New model results will be presented as well as compared with currently available observations from both Voyagers and Interstellar Boundary Explorer (IBEX). Differences between model and observations will be discussed. Especial discussion will be on the recently suggested two-jet structure of the heliosphere.

D1.2-0024-18 PHYSICAL PROCESSES AT THE HELIOSPHERIC INTERFACE

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The heliosphere is formed due to interaction between the solar wind (SW) and local interstellar medium (LISM). The interplay between the asymmetrizing effect of the interstellar magnetic field and charge exchange between ions and neutral atoms plays an important role in the SWLISM interaction. By performing 3-D, MHD plasma / kinetic neutral atom simulations, we describe the structure of the outer heliosheath (OHS) - the LISM plasma region affected by the presence of the heliosphere - and analyze quantitatively the distributions in front of the heliopause. It is shown that charge exchange modifies the LISM plasma to such extent that the contribution of a shock transition to the total variation of plasma parameters becomes small even if the LISM velocity exceeds the fast magnetosonic speed in the unperturbed medium. By performing adaptive mesh refinement simulations, we show that a distinct boundary layer of decreased plasma density and enhanced magnetic field should be observed on the interstellar side of the heliopause. We show that this behavior is in agreement with the plasma oscillations of increasing frequency observed by Voyager 1. Numerical results are presented that reproduce shocks that pass by Voyager 1 in the OHS. We demonstrate that Voyager observations in the inner heliosheath between the heliospheric termination shock and the heliopause are consistent with dissipation of the heliospheric magnetic field. The effect of pickup ions is discussed in the context of in situ measurements. MHD instabilities and magnetic reconnection at the heliopause are analyzed. We also show that TeV cosmic ray anisotropy can serve as an imager of the heliosphere. The choice of LISM parameters in this analysis is based on the simulations that fit observations of energetic neutral atoms performed by IBEX. The effect of pickup ions born in the outer heliosheath on the IBEX ribbon is discussed.

D1.2-0025-18 MAGNETIC RECONNECTION AT THE HELIOPAUSE: PREDICTED ELECTRON AND ION BULK HEATING EFFECTS IN THE PLASMA DEPLETION LAYER AND OUTER HELIOSHEATH

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Magnetic reconnection is a well-known source of electron and ion bulk heating, as well as energetic particles, in the solar system. Examples include solar flares and reconnection at Earth's magnetopause and in Earth's magnetotail. Several authors have suggested that reconnection occurs at the heliopause. The primary focus of this paper is to predict the amount of electron and ion bulk heating for heliopause reconnection, using the empirical relations of T. Phan and colleagues between the changes in electron and ion temperature and an Alfven speed VA,R,A. This Alfven speed depends on the strengths of the reconnecting magnetic fields and includes asymmetries in the magnetic fields and densities on the two inflowing sides of the reconnection region. For the undisturbed interstellar flow the predicted VA,R,A 25 km/s and the pre- dicted changes in electron and ion temperature are ΔTe 1000 K and ΔTi 6000 K. These changes are relatively small and not important for the dynamics at the heliopause. However, a plasma depletion layer (PDL) is predicted beyond the heliopause, analogous to the PDLs observed sunwards of the magnetopauses of Earth, Mercury, Jupiter, and Saturn. In the PDL, the interstellar (ISM) magnetic field lines drape over the heliopause. Plasma ions and electrons with relatively large parallel temperatures escape along the field, increasing the field strength, decreasing the plasma density, and increasing the Alfven speed. In the region of the PDL where these effects are strong, the expected field and density changes are a factor of 4 and ¼, respectively, increasing VA,R,A by a factor close to 3 and the temperature changes by almost a factor of 10. Thus, heliopause reconnection in a strong PDL is predicted to increase the electron and ion temperatures by up to 104 K and 8 x 104 K, respectively, corresponding to changes by factors of order 1.5 and 11 compared to the predicted ISM temperature of 7 x 103 K. Thus, the effects of bulk heating in heliopause reconnection regions should only be important for plasma inside or magnetically connected to the strong region of the heliopause's PDL. The effects of this heating on electrons and ions accelerated by shocks beyond the heliopause and on associated Langmuir waves will also be discussed.

D1.2-0026-18 COMPARISON OF SOLAR CYCLE 23 AND 24: A DECLINE TREND IN SOLAR ACTIVITY

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Impetus to look into the nature of solar activity and variability has increased importance in recent years because of their terrestrial association. The variability in solar indices has played a key role in understanding of solar activities and their interpretations. In the present work we have compared some solar parameters observed during solar cycles 23 and 24. To that end, we have considered sunspot numbers, F10.7 cm solar flux, Lyman alpha index and Mg II index as input parameters. Sunspot numbers during solar cycle 23 was observed from 1.04 to 246.56 while during the solar cycle 24 it varied from 4.54 to 146.6. F10.7 cm solar flux was observed from 71.76 to 238.04 during the solar cycle 23 while it varied from 69.61 to 159.73 during the solar cycle 24. Similarly the Lyman solar index varied from 3.57 to 5.89 during the 23rd solar cycle while it varied from the value of 3.54 to 4.95 during the solar cycle 24 and the variations in Mg II index occurred from 0.2629 to 0.2886 for the solar cycle 23 while it varied from the value 0.2631 to 0.2836 for the present solar cycle. On the basis of above changes in various solar parameters we inferred about 40.54 % decline in maximum value of sunspot numbers, 32.89 % of decrement in F10.7 cm index, 0.15 % decrement in Lyman alpha index while in Mg II index decrement of 1.73 % was observed in cycle 24th as compared to cycle 23rd. By comparing above considered solar parameters we have concluded that the solar activity has declined during the cycle 24 as compared to cycle 23 and it may further decline during the next cycle 25.

D1.2-0027-18 INTERSTELLAR NEUTRAL OXYGEN IN THE HELIOSPHERE: ANALYSIS OF IBEX DATA ON THE BASIS OF THE KINETIC MODEL

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Quantitative analysis of the interstellar heavy (oxygen and neon) atom fluxes obtained by Interstellar Boundary Explorer (IBEX) suggests the existence of the secondary interstellar oxygen component. This component is formed near the heliopause due to charge exchange of interstellar oxygen ions with hydrogen atoms as was predicted theoretically. A detailed quantitative analysis of the fluxes of interstellar heavy atoms is only possible with a model that takes into account both filtration of primary and production of secondary interstellar oxygen in the boundary region of the heliosphere as well as a detailed simulation of the motion of interstellar atoms inside the heliosphere. This simulation must take into account photoionization, charge exchange with the protons of the solar wind and solar gravitational attraction. We present the results of modelling interstellar oxygen and neon atoms through the heliospheric interface and inside the heliosphere based on a three-dimensional (3D) kinetic-MHD model of the solar wind interaction with the local interstellar medium and analysis of the IBEX data on the basis of the kinetic model.

D1.2-0028-18 RIGIDITY SPECTRUM OF THE LONG-TERM COSMIC RAY VARIATIONS DURING SOLAR ACTIVITY CYCLES 19-24

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The monthly rigidity spectrum of cosmic ray (CR) variations in the 19-24 cycles of solar activity was obtained by the global survey method using the data of continuous ground and near-Earth monitoring of CRs, exempted from atmospheric and local effects. The changes of the spectrum, first obtained for such a long period, made it possible to reveal the features of large-scale effects in CR modulation, the presence of 22-year and 11-year CR variations in the spectrum, and confirm an abnormal spectrum change in the 70s. The paper assumes a rigidity spectrum of CRs, given in a three-parameter form. Analysis of the obtained long-term CR variations for particles with rigidity R = 10 GV shows that the amplitude of the 22-year wave in the CR intensity increases from cycle to cycle and reaches its maximum value at the minimum of 23/24th solar activity cycle. Gradual softening of the spectrum at the cycle minima has been revealed for the negative polarity of the solar magnetic field (A<0). The reasons for the abnormally high CR density at the minimum of the 24th cycle and the spectrum features in the 70s are discussed. The spectrum of long-term CR variations in the 19-24 solar activity cycles, determined from the experimental data, makes it possible to verify some conclusions of the theory of heliospheric CR modulation concerning the role of the magnetic drift of particles in cycles with the different polarity of the solar magnetic field. In particular, we propose the explanation for the observed R-2 spectrum of the variations in the minima of the negative solar activity cycles, related with the scattering of particles in the vicinity of the neutral current sheet.

D1.2-0029-18 CHARACTERIZING CORONAL STRUCTURE: CONTEXTUAL PREDICTIONS FOR PARKER SOLAR PROBE FROM GLOBAL MHD SIMULATIONS WITH DYNAMICAL TURBULENCE MODELING

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As the solar plasma flows out from the corona and transitions into the solar wind, it transforms from a magnetically structured, subsonic, and sub-Alfvénic regime into a supersonic and superAlfvénic flow dominated by hydrodynamics. Recent analysis of remote imaging observations in solar minimum conditions by DeForest et al. (2016) has described the early stages of this transition, which may also coincide with the onset of large-scale turbulence in the solar wind. Here we extend this analysis to global magnetohydrodynamic simulation of the corona and solar wind based on inner boundary conditions that emulate solar minimum, in anticipation of the first phase of Parker Solar Probe (PSP) observations, which are expected during solar minimum as well. Taken together with the imaging analysis, the simulation results provide more detailed expectations for locations of the Alfvén critical surface and the first plasma beta unity surface moving from the corona into the dynamically active solar wind. The turbulence parameters computed from the simulations also enable estimations of the characteristic scales at which in-situ turbulence may influence the dynamics of the solar wind. Estimations of relevant parameters along a simulated PSP trajectory are presented. Issues pertaining to the use of Taylor's frozen-in hypothesis with PSP perihelion data are discussed.

D1.2-0030-18 CHARACTERIZATION OF THE TURBULENCE AROUND COROTATING INTERACTION REGIONS FOR INVESTIGATING THE GALACTIC COSMIC RAYS MODULATION

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Corotating interaction regions (CIRs) are large-scale structures that occur when the slow solar wind is overtaken by the fast wind. CIRs consist of a compression region ahead in the slow wind and a rarefaction region behind which are separated by a stream interface and are usually accompanied by a crossing of the heliospheric current sheet. It is well known that cosmic rays intensities are modulated around these structures. In this work, using WIND spacecraft plasma data, we have examined CIRs in the period from 2007 to 2009, near solar minimum activity. The spectral analysis of magnetic field turbulence is performed for intervals of 5 days before to 5 days after each CIR for 4-hour sub-intervals and then a superposed epoch analysis is applied over the results which report of a peak at the turbulence at the stream interface. We have linked our findings of the characteristics of the turbulence around CIRs to the galactic cosmic rays modulations from the data obtained from CRIS instrument of the ACE spacecraft with the purpose of investigating the cosmic ray diffusion transport. The results also compared with the MHD model simulations performed by Guo Florinski 2016.

D1.2-0031-18 GEOMAGNETIC CUTOFF RIGIDITIES OF COSMIC RAYS AND THEIR SECULAR CHANGES.

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In the proposed work with an annual resolution for the period 1950 2015 and the forecast to 2050 by the method of trajectory calculations, geomagnetic cutoff rigidities for vertical and inclined directions of the World Network of detectors were obtained. Geomagnetic cutoff rigidities were obtained using the International Geomagnetic Reference Field (IGRF 12) model. The results of the calculations indicate the manifestation of two World Anomalies: in the zone of one, the rigidity of the geomagnetic cutoff decreases, in the zone of the other - increases, but globally rigidity of the geomagnetic cutoff decreases by approximately 7% per century. For inclined directions, an irregular course is observed in the time dependence of the rigidity of geomagnetic cutoff: for northwest directions for detectors of the South Atlantic anomaly zone and directions south for the detectors of the zone of the North Atlantic anomaly. Such an irregular course is most likely due to the large variability of the penumbra zone for such inclined directions.

D1.2-0032-18 VOYAGER 1/UVS LYMAN-ALPHA MEASUREMENTS AT DISTANT HELIOSPHERE (90-130 AU): UNKNOWN SOURCE OF ADDITIONAL EMISSION

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Voyager 1/UVS measurement of the Lyman α intensities at the distant heliosphere is a unique source of information on the interstellar hydrogen distribution at the heliospheric boundary. In 2003-2014 (at 90-130 AU from the Sun) Voyager 1 measured the Lyman α emission at an almost fixed direction close to the upwind (i.e. toward the interstellar flow). The data show an unexpected behavior in 2003-2009: the ratio of observed intensity to the solar Lyman α flux at Earth orbit is almost constant. We performed a numerical modeling of these data in the frame of a state-of-the-art self-consistent kinetic-MHD model of the heliospheric interface. The model results, for various interstellar parameters, predict a monotonic decrease of intensity not seen in the data. We propose two possible scenarios that explain the data qualitatively. The first is the formation of a dense layer of hydrogen atoms near the heliopause. Such a layer would provide an additional backscattered Doppler-shifted Lyman α emission, which is not absorbed inside the heliosphere and may be observed by Voyager. About 35 R of intensity from the layer is needed. The second scenario is an external nonheliospheric Lyman α component, which could have a galactic or extragalactic origin. Our parametric study shows that about 25 R of additional emission would be enough to provide a good qualitative agreement between the Voyager 1 data and the model results.

D1.2-0033-18 A FRESH LOOK AT THE GLOBAL HELIOSPHERE USING ANALYTICAL MHD MODELS

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The analytical magnetohydrodynamic (MHD) model for the local interstellar magnetic field in the vicinity of the heliopause by Röken et al. (2015) is an exact solution of the induction equation of ideal MHD for an interstellar magnetic field being passively advected in a Rankine-type heliospheric flow. After a review of the model's basic properties, two recent generalizations are presented and discussed: First, the use of so-called distortion flows allows for the formerly circular heliotail to be deformed into a more realistic, ellipsoidal cross section while maintaining the exactness of this more involved, but still fully analytical MHD solution. Second, the generalization from incompressible to mildly compressible flow further improves the model's degree of realism by introducing an extended region of compressed magnetic field, as well as a pile-up of mass ahead of the heliopause, The usefulness of these still analytical solutions as approximations to self-consistent magnetic field configurations obtained numerically from the full set of MHD equations is illustrated by quantitative comparisons.

D1.2-0034-18 EXPERIMENTAL STUDY OF DELAY TIME PROBLEM IN GALACTIC COSMIC RAYS FLUX IN DIFFERENT EPOCHS OF SOLAR ACTIVITY: 1964-2008

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We analyzed long period changes in different epochs of Solar Activity (SA). A purpose of this paper is to carry on a study the delay time τ between changes of GCR intensity on the one hand, and various parameters characterizing conditions in heliosphere, on the other. We proof an existence of a varying delay time τ between changes of GCR intensity and various parameters characterizing conditions in heliosphere. Base on the experimental investigation we obtained delay times different for various solar cycles: 20, 21, 22 and 23. The analyses of solar cycles show different delay time in different epochs of SA. We concludes that observed delay time is very important factor to study of GCR transport in the heliosphere.

D1.2-0035-18 THEORETICAL INVESTIGATION OF DELAY TIME IN GALACTIC COSMIC RAYS FLUX IN DIFFERENT EPOCHS OF SOLAR ACTIVITY

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Based on the Parker's Transport Equation (PTE) we expand three dimensional (3-D) time dependent model describing a propagation of the energetic astroparticles - Galactic Cosmic Rays (GCR) in heliosphere. The Parker's PTE contains a well-known four major processes: diffusion, convection, drift and adiabatic cooling responsible for modulation of the GCR flux in heliosphere. We analyzed long period changes in different epochs of Solar Activity. We study four last solar cycles: 20, 21, 22 and 23. We implement in numerical simulation of PTE few physical parameters as, tilt angle delta of the Heliospheric Neutral Sheet (HNS), module B of the Heliospheric Magnetic Field (HMF) and changes of drift effect of the GCR particles upon SA. The idea in present modelling is connected with the using for implementation of two independent parameters as the gamma and nu. The proxies gamma and nu are calculated from different sources, gamma - from neutron monitors (NMs) daily data, and nubased on the HMF's hourly data. The solutions of PTE obtained from numerical models are compared with the changes of the GCR flux measured by NMs. Base on the investigation we obtained delay times different for various solar cycles. We received a satisfactory agreement of the theoretical results with the experiment

SPACE PLASMAS IN THE SOLAR SYSTEM, INCLUDING PLANETARY MAGNETOSPHERES (D)

ACCELERATION AND TRANSPORT OF ENERGETIC PARTICLES IN THE HELIOSPHERE AND BEYOND: FROM PICKUP IONS TO COSMIC RAYS (D1.3)

D1.3-0001-18 THE NOT SO FAST AND FURIOUS - WHAT CAN SLOW ENERGETIC NEUTRAL ATOMS AND INTERSTELLAR NEUTRAL HYDROGEN TELL US ABOUT THE HELIOSPHERE?

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The Interstellar Boundary Explorer (IBEX) is a NASA satellite in a highly elliptic Earth orbit. IBEX has been observing interstellar neutral matter entering the heliosphere and energetic neutral atoms (ENAs) from the heliosheath for almost one solar cycle, starting at the end of 2008.

In this presentation, we will give a short overview of IBEX observations starting from solar wind energies down to the lowest energies accessible with the IBEX-Lo sensor (1 keV - 10 eV). We will focus on heliospheric ENAs and interstellar neutral hydrogen. ENAs of this energy range originate from solar wind or pickup protons and mostly reveal processes in the inner heliosheath (the vast region of the heliosphere between the termination shock and the heliopause). The interstellar neutral hydrogen provides information on the interstellar matter, on the interaction between interstellar plasma and neutral gas in the outer heliosheath, and on losses inside the heliosphere due to ionization and deflection from Keplerian trajectories by radiation pressure.

Observations at these energies are challenging to interpret because the neutral atoms are very sensitive to ionization loss and radiation pressure, and compete with strong background sources. Nevertheless, these IBEX observations are very helpful to constrain the parameters of heliospheric models, such as the dimensions, the plasma pressure, the neutral density, the solar radiation pressure, and UV fluxes.

D1.3-0002-18 THE PICKUP ION CUTOFF SHIFT IN STREAM INTERACTION REGIONS AND GENERALLY VARIABLE SOLAR WIND CONDITIONS

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We present the first systematic analysis to determine pickup ion (PUI) cut-off speed variations, both during compression regions identified by their structure, and during times of highly variable solar wind (SW) speed or magnetic field strength. This study is motivated by the attempt to remove or correct these effects on the determination of the longitude of the interstellar neutral gas flow from the flow pattern related variation of the PUI cutoff with ecliptic longitude (Moebius et al. 2015 ApJ 815, 20). Using 2007-2014 STEREO A PLASTIC observations we identify compression regions in the solar wind and analyze the PUI velocity distribution function (VDF). Characterizing individual compression events programmatically and combining them in a superposed epoch analysis allows us to analyze the PUI population in similar interplanetary conditions and find the local cut-off shift with adequate statistics. This method yields positive cut-off shifts in compression regions whose values increase with the strength of solar wind speed gradients. Also, through sorting the entire set of PUI VDFs at high time resolution we obtain a noticeable correlation of the cut-off shift with the magnitude of gradients in the SW speed and interplanetary magnetic field strength. This effect may be understood in terms of motional electric fields in SW velocity gradients, similar to those produced at quasi-perpendicular shock fronts, causing PUI's to be accelerated along the plane of the compression. Alternatively, increases in the PUI cut-off in these compressions could be understood by invoking conservation of the first adiabatic invariant along with a transformation between the local frame where the electric field vanishes and the observer frame. Fundamentally, this study sheds light on the physical mechanisms that lead to energy transfer between the SW and the embedded PUI population, while providing criteria to select time periods when the PUI cut-off reflects most closely the interstellar flow velocity rather than SW related effects.

D1.3-0003-18 PICKUP IONS IN THE OUTER HELIOSPHERE

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Pickup ions (PUIs) are created when a neutral atom in the heliosphere becomes ionized. It is then ionized and picked-up by the heliospheric magnetic field and swept outward. These ions are not in equilibrium with the solar wind (SW) ions and therefore are also called nonthermal. PUIs originate from the inner source neutral atoms and also from those of interstellar origin. PUIs are quickly isotropized and acquire the bulk velocity of the ambient SW. The distribution function of PUIs is unstable and produces turbulence that heats up SW ions. This effect becomes especially prominent when the thermal SW protons reach some minimum temperature at about 10 AU. Their temperature is further increasing until they reach the heliospheric termination shock. However, most of thermal energy carried by the SW plasma belongs to PUIs. Shock crossing is a kinetic process for PUIs and therefore it is hard to be modeled in global, data-driven, MHD simulations. In this talk we describe a few basic approaches to model PUIs in the turbulent SW. Numerical simulations are compared with New Horizons, Voyager, and Ulysses measurements. In addition, we show previously unpublished distributions of pickup protons observed by Ulysses. Numerical simulations are extended to Neptune, Pluto, and further towards the termination shock. The effect of PUIs on the latter is also discussed.

D1.3-0004-18 EVALUATION OF COMPETING DYNAMIC SMALL-SCALE FLUX-ROPE ACCELERATION SCENARIOS FOR ENERGETIC PROTONS NEAR EARTH

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Recent observations near 1 AU suggest that dynamic small-scale flux-rope structures are a much more common occurrence than previously thought (Zheng et al. 2018) and are linked to enhanced energetic particle fluxes (e.g., Zank et al. 2015; Khabarova and Zank 2017). In response we recently developed a system of coupled equations involving a kinetic focused transport equation with Fokker-Planck scattering coefficients for energetic charged particles coupled to a MHD turbulence transport equation for coherent, quasi-2D magnetic island structures based on NI MHD turbulence theory (Zank et al. 2017). The coupled equations can be used to model the self-consistent acceleration of suprathermal charged particles interacting with and traversing numerous dynamic (contracting and merging) quasi-2D small-scale flux ropes with cross-sectional sizes belonging to the inertial range. The particles are restricted to gyro radii smaller than flux-rope size (quasi-trapping of particles in these structures). Both coherent and stochastic energetic particle acceleration rate expressions were derived for four small-scale fluxrope acceleration scenarios present in focused transport theory: (1) Combined curvature drift and generalized betatron energization in small-scale flux ropes contracting and merging in the compressible limit (Zank et al. 2014; le Roux et al. 2015), (2) unified curvature drift energization and generalized betatron energy loss in small-scale flux ropes contracting and merging in the incompressible limit (e.g., Drake et al. 2006, 2013), (3) parallel guiding center motion energy gain and energy loss by the parallel reconnection electric field force generated in merging (reconnecting) flux ropes (e.g., Oka et al. 2010; Zank et al. 2014; Dahlin et al. 2016), and (4) parallel guiding center motion energy gain and energy loss produced by a non-inertial force associated with the acceleration of the plasma flow in dynamic small-scale flux ropes. Estimated test-particle suprathermal proton acceleration rates for the different flux-rope acceleration scenarios in the supersonic solar wind near 1 AU will be compared and discussed.

Dynamic flux-rope induced energetic particle pitch-angle scattering and stochastic acceleration rates will also be compared to the corresponding rates for parallel propagating Alfven waves.

D1.3-0005-18 PARTICLE ACCELERATION IN COALESCENT AND SQUASHING MAGNETIC ISLANDS: TP AND PIC APPROACH

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We investigate particle acceleration in 3D reconnecting current sheets (RCSs) containing multiple Oand X-nullpoints and different topologies: coalescent (moving towards each other) and squashed islands using a test particle and particle-in-cell (PIC) approach. The inclusion of multiple O-nullpoints, or magnetic islands, reveals that acceleration of protons and electrons in a current sheet with strong guiding field remains asymmetric towards the midplane, e.g. electrons and protons are ejected into the opposite directions from the midplane. Both types of particles (electrons and protons) mainly gain energy in a vicinity of X-nullpoints or inside O-nullpoints and, depending on their initial energy, these gains can reach relativistic energies in a single island. Accelerated particles with critical energies can escape O-nullpoints, or magnetic islands, only through neighbouring X-nullpoints escape along the midplane. As result, there are electron clouds formed between the magnetic islands while electrons gain the critical energy to break from an RCS. The energy gains in coalescent islands are much smaller than from the squashed ones. Electrons are shown to form clouds about X-nullpoints between the magnetic islands where they become ejected after gaining the critical energies required to break from the RCS magnetic topology. Particle acceleration in 3D RCSs with multiple Xand O-nullpoints is probed with some observational features in the heliosphere. This research is funded by the US Airforce grant.

D1.3-0006-18 MODELLING THE INJECTION AND ACCELERATION OF ENERGETIC PARTICLES AT TRAVELLING SHOCKS

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Propagating shocks are observed to form ahead of the solar material expelled into interplanetary space following coronal mass ejections (CMEs). During the passage of these CME-driven shocks, spacecraft often observe energetic particle enhancements commonly associated with particle acceleration. In this study, the acceleration of energetic particles at halo-CME-driven shocks is investigated, with a particular focus on the acceleration of particles from the suprathermal solar wind (SW). A set of stochastic differential equations, derived from the Parker transport equation and including the effects of diffusive shock acceleration, is solved numerically to model this process. The SW particle velocity distribution is described by a Kappa distribution in the solar wind frame and prescribed as a source function at the shock. The injection energy is calculated from first principles, but can also be changed to investigate the effect thereof on model solutions. With the further application of physically representative transport coefficients, the model results are presented and their accuracy evaluated against how well they reproduce observations of protons and heavier ions during selected shock passage events.

D1.3-0007-18 ALPHA PARTICLES SURFATRON ACCELERATION IN SPACE PLASMA

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A theoretical study on the alpha particles strong surfatron acceleration by an electromagnetic wave in space plasmas is performed. Based on numerical calculations for the wave phase on the particle trajectory we analyze the phenomenon of the interaction of the wave with the alpha particle when the wave propagates across weak constant magnetic field. The capture conditions of alpha particle and ultrarelativistic surfatron acceleration for different initial energies are studied. Wave phase dynamics on the trapped alpha particle trajectory, relativistic factor, energy growth rate and the final particle energy estimation are given. The phase plane structure and its different stages of the captured alpha particle are illustrated graphically. Particles velocity components dynamics during surfatron acceleration and their asymptotic values are also presented. Numerical simulations point that capture of the alpha particles by the wave in an effective potential well occurs immediately or after a relatively short period of time. The additional calculations results provided in tables and charts allow conclusions to be drawn about resonant interactions efficiency in space plasmas. The surfatron acceleration of alpha particles in space plasma can explain the appearance of a strong temporal and spectral feature in the experimental data.

D1.3-0008-18 ENERGETIC PARTICLES MEDIATED HELIOSPHERIC SHOCK WAVES

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The structure of heliospheric parallel, perpendicular, and oblique shocks is often determined by the mediation of energetic particles. Energetic particles (such as interstellar pickup ions (PUIs), solar energetic particles (SEPs), and cosmic rays) contribute significantly to the dissipative process that determines the structure of shock waves. The mediation effectively introduces a form of heat flux and viscosity (due to particle pitch angle scattering by magnetic field fluctuations), similar to those of classical fluid dynamics, but now appropriate to a collisionless magnetized plasma. Webb (1983) showed that in some Mach number regimes (even for a cold plasma), the energetic particle heat flux is insufficient to determine the shock structure, and a gas sub-shock needs to be added to ensure a shock transition. However, the presence of the energetic particle viscosity can further smooth a shock transition and ensures a complete smooth solution. We present a general theoretical model of parallel, perpendicular, and oblique shock mediation by energetic particles and we compare the theoretical results with observations. Russell et al. (2013) and Lario et al. (2015) showed that some interplanetary shocks within 1 AU can be dominated dynamically by energetic particles whose pressure exceeds that of the background thermal plasma and the magnetic field. Voyager 2 observations revealed that the heliospheric termination shock (HTS) is very broad and mediated by energetic particles (Richardson et al. (2008)). We show that the thermal gas remains cold through the HTS and does not provide the dissipation needed to account for the deceleration of the supersonic solar wind. Instead, PUIs are the primary dissipation mechanism and gain most of the solar wind kinetic energy through the HTS.

D1.3-0009-18 VOYAGER 1 OBSERVATIONS OF PITCH-ANGLE-DEPENDENT COSMIC RAY ANISOTROPY EVENTS IN THE LOCAL INTERSTELLAR MEDIUM

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Unexpected decreases in the intensity of > 211 MeV galactic cosmic ray protons were revealed by Voyager 1's Low Energy Charged Particle instrument in 2013, upon crossing into the local interstellar medium (LISM). Decreases, lasting from 100 to 630 days have also been observed by Voyager 1's Cosmic Ray Subsystem (CRS) in its omnidirectional (20 MeV) and bi-directional

(70 MeV) proton intensities. Between late 2012 and early 2017, three durable episodes occurred, and are known to arise from a reduction of particles with pitch angles near 90°. However, there is no evidence of pitch angle anisotropy in cosmic ray electrons with energies of 5 to 105 MeV. Results from using a simple model to characterize the anisotropy are presented and an interpretation of the physical mechanism is discussed.

D1.3-0010-18 COSMIC RAY MODULATION IN THE OUTER HELIOSHEATH

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Voyager 1 observations show that the intensity of Galactic cosmic rays exhibits a peculiar pattern of variation and anisotropy at the heliopause and in the outer heliosphere. One of the most interesting features is the deficit of intensity near the 90° pitch angle to the magnetic field. The intensity of particles near the 90° pitch angle undergoes variations far stronger those at the small angles to the field. It is possibly caused CME shock waves passing through heliopause and continuing to propagate in the interstellar magnetic field of the outer heliosheath. In this paper, we present our model calculation results of cosmic ray modulation caused by the traveling waves and associated rarefaction region. We demonstrate how a combination of particle trapping and adiabatic cooling the rarefaction region affect the cosmic ray variations and anisotropies.

D1.3-0011-18 COSMIC RAYS IN THE VERY LOCAL INTERSTELLAR MEDIUM

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The behavior of energetic particles at the heliopause encountered by Voyager 1 in 2012 was by and large consistent with the expectations from theory and models. Namely, the low energy heliospheric ions have disappeared and the high energy galactic cosmic rays reached a steady plateau reflecting their ambient intensity in the local interstellar space. Nonetheless, a fraction of the heliospheric ions was evidently able to overcome the magnetic shear at the heliopause and escape into interstellar space. These ions' contribution to the overall pressure balance at the heliopause can be questioned, on account of the extremely large mean free path in the interstellar medium where the level of magnetic fluctuations is exceptionally low. Some possible effects of this pressure deficit on the structure of the heliosphere are examined. The second outstanding problem is the origin of the episodic depletions in the distributions of galactic cosmic rays at the 90 degree pitch angle. We discuss several physical processes that could account for the observed depletions, including drifts of trapped cosmic ray ions and shadowing by the heliopause.

D1.3-0012-18 GLOBAL MODULATION OF COSMIC RAYS IN A QUIET HELIOSPHERE

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In 2008 to 2009, cosmic ray intensities were at their highest levels since the beginning of the space exploration era. Since then solar activity has followed the 11-year cycle but with the Sun considerably quieter than before. This provides the opportunity to study and test modulation theory under such quiet heliospheric conditions, especially charge-sign-dependent modulation. This can be done from minimum to maximum solar activity, and over a solar magnetic field reversal from a so-called $A < 0$ polarity cycle to an $A > 0$ cycle. Drift theory predicts that the intensity of positively and negatively charged particles should show different behaviour in terms of responding rates during the solar cycle and during the magnetic field reversal period. This is now testes with the precise measurements made by the PAMELA and AMS-02 missions of electrons and positrons. The global features of cosmic ray modulation have been studied with comprehensive, three-dimensional, drift models and compared to PAMELA proton spectra from 2006 to 2014 to authenticate the modelling approach and subsequently to make predictions of how cosmic ray protons, electrons, and positrons are differently modulated down to 1 MeV. These solutions are based on new very local interstellar spectra.

D1.3-0013-18 COMBINED GLOBAL MODULATION OF JOVIAN AND GALACTIC ELECTRONS IN THE HELIOSPHERE

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A three-dimensional, numerical model is used to study the total modulation of Jovian and Galactic electrons, from 1 MeV to 50 GeV and from the Earth into the heliosheath. For this purpose the Jovian electron source and the very local interstellar spectrum, or heliopause spectrum, are revisited. The latter can be computed with confidence since Voyager 1 already crossed the heliopause. Modeling results are compared with Voyager 1 observations in the outer heliosphere, including the heliosheath, as well as observations at or near the Earth, e.g. from ISSE3 and Ulysses for 1991 and 1992, and in particular the 2009 spectrum from the PAMELA space mission. Making use of the observations at Earth and a new source function for the Jovian electrons, the energy range over which the Jovian electrons dominate the Galactic electrons is determined so that the intensity of Galactic electrons at Earth below 100 MeV is calculated.

D1.3-0014-18 GALACTIC COSMIC RAY RATIO OF FREE PATHS NORMAL AND PARALLEL TO MEAN IMF AT HIGH RIGIDITIES

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Data from the Nagoya Vertical muon telescope are used to compute the east-west and radial components of the solar diurnal anisotropy of galactic cosmic rays for 1970-2016, covering three sunspot cycles (21-23) and parts of the other two (19, 24). The ratio (alpha) of the diffusion coefficients perpendicular and parallel to the mean interplanetary magnetic field is computed and compared with corresponding values for the global network of the neutron monitors. Preliminary results for alpha, its rigidity dependence and correlation with solar activity for positive (p-) and negative (n-) intervals of solar polar field at 1 au are noted. The results challenge the validity of some old results and conceptual understanding of the modulation processes in the heliosphere.

D1.3-0015-18 TURBULENCE IN THE OUTER HELIOSPHERE AND VERY LOCAL INTERSTELLAR MEDIUM

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Low-frequency turbulence in the supersonic solar wind plays a key role in determining the propagation of anomalous and galactic cosmic rays into the heliosphere. It is also critical in determining the internal energy of the large-scale solar wind flow. In the distant heliosphere, the levels of turbulence and its subsequent dissipation is influenced strongly by the creation of pickup ions (PUIs) from interstellar neutral hydrogen that has crossed the heliospheric boundaries into the supersonic solar wind. In this regard, the physics of the solar wind is profoundly modified by interstellar processes. It also transpires that turbulence in the very local interstellar medium (VLISM) may be influenced by the nature of turbulence in the inner heliosheath i.e., by processes in the subsonic solar wind. In this presentation, we will review three aspects of the turbulence in the outer heliosheath and VLISM. 1) We will describe recent models that describe the transport of turbulence in the distant solar wind, identifying the contribution from the creation of PUIs, and the associated heating of the solar wind. 2) Based on the turbulence transport models, we will summarize their effect on cosmic ray modulation through the evaluation of the cosmic ray spatial diffusion tensor and the corresponding parallel, perpendicular, and drift mean free paths. 3) Finally, Voyager 1 observations of low-frequency turbulence in the VLISM close to the heliopause suggested that the dominant component was compressible. We will review these observations briefly and present a theoretical model that shows that fastmode waves are transmitted from the inner heliosheath into the VLISM, where they may be responsible for the observed compressible fluctuations.

D1.3-0016-18 TIME-DEPENDENT COSMIC RAY MODULATION IN THE HELIOSPHERE

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Cosmic ray intensities are computed in the inner and outer heliosphere using a two-dimensional, time-dependent modulation model. Results are compared to IMP-8, Ulysses, Voyager 1 and Voyager 2 observations for compatibility. A time-dependence for the assumed transport parameters are constructed by incorporating recent theoretical advances. This approach gives results which compared well with the traditional compound approach of Ferreira and Potgieter (2004) and also to the observations along Voyager 1, Voyager 2 and at Earth on a global scale. However, for extreme solar maximum conditions the computed step-like modulation is not as pronounced as observed, indicating that some merging in the form of global interaction regions is needed.

D1.3-0017-18 A STUDY OF ELECTRON FORBUSH DECREASES WITH A 3D STOCHASTIC DIFFERENTIAL EQUATION (SDE) NUMERICAL MODEL

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The precise measurements of the cosmic ray electron flux from PAMELA and AMS02 have made it possible to record electron Forbush decreases (Fds) for the first time. This is motivation to perform a numerical study of electron Fds, utilizing a three-dimensional (3D), time-dependent SDE model to simulate and study the main features of electron Fds. A newly developed electron Local Interstellar Spectrum is also included. The model is validated by first reproducing the observed PAMELA electron spectrum at the Earth over an energy range from 80 MeV to 100 GeV. In the process, all modulation parameters are refined. Subsequently, electron Fd profiles at different rigidity are simulated, first with particle drifts turned off. It was found that the magnitude of a Fd is determined by changes in the local values of the three main diffusion coefficients so that the observed magnitude of these Fds may shed light on the rigidity dependence of these diffusion coefficients. If these diffusion coefficients are to be almost constant at low kinetic energies (a few hundred MeV), as predicted by main stream diffusion theory, the magnitude of electron Fds should not change much over this energy range. Additionally, by solving the relevant transport equation including global particle drifts, electron Fd profiles during the two periods of different solar magnetic polarity have been simulated and compared to the profiles of proton Fds at the same rigidity. These studies indicate that drifts can cause a charge-sign dependence effect on the profiles of Fds, especially on their recovery times, even for these small scale phenomena.

D1.3-0018-18 THE TIME DEPENDENCE OF THE COSMIC RAY FLUXES MEASURED BY THE PAMELA EXPERIMENT.

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It was the 15th of June of 2006 when the PAMELA satellite-borne experiment was launched from the Baikonur cosmodrome in Kazakstan. Then, for nearly ten years, PAMELA has been making high-precision measurements of the charged component of the cosmic radiation opening a new era of precision studies in cosmic rays and challenging our basic vision of the mechanisms of production, acceleration and propagation of cosmic rays in the galaxy and in the heliosphere. The study of the time dependence of the various components of the cosmic radiation from the unusual 23rd solar minimum through the maximum of solar cycle 24 clearly shows solar modulation effects as well as charge sign dependence. In this talk the solar modulation of the proton, helium and deuteron galactic cosmic ray component will be presented.

D1.3-0019-18 DATA-CONSISTENT MODEL OF THE FORBUSH DECREASE. APPLICATION OF THE APPROXIMATE BAYESIAN COMPUTATION TO ESTIMATE MODEL PARAMETERS.

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Accurate modeling of the complex phenomena as Forbush decrease of the galactic cosmic ray intensity is a quite challenging task. One aspect is a numerical solution of the Parker transport equation in five-dimensional space (three spatial variables, the time and particles energy). The second difficulty arises from a lack of detailed knowledge about the spatial and time profiles of the parameters responsible for the creation of the Forbush decrease. Among these parameters, the central role plays a diffusion coefficient. Assessment of the correctness of the proposed model can be done only by comparison of the model output with the experimental data of the galactic cosmic ray intensity. We present the method of evaluating the model of the Forbush decrease by assessing its capability of reproducing the neutron monitors data. To do so the set of model parameters is estimated with use of the Approximate Bayesian Computation (ABC) methodology. The ABC method is becoming increasing exploited for dynamic complex problems in which the likelihood function is costly to compute. The main idea of all ABC methods is to accept samples as an approximate posterior draw if its associate modeled data is close enough to the observed one. In this paper, we present application of the Sequential Monte Carlo Approximate Bayesian Computation algorithm scanning the space of the diffusion coefficient parameters in the vicinity of the space where the Forbush decrease is created. The proposed algorithm is adopted to create the model of the Forbush decrease observed by the neutron monitors at the Earth in November 2004. The model of the Forbush decrease is based on the stochastic approach to the solution of the Parker transport equation.

D1.3-0020-18 QUASI-PERIODIC CHANGES OF THREE DIMENSIONAL SOLAR ANISOTROPY OF GALACTIC COSMIC RAYS FOR 1965-2014

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We study features of the three dimensional (3D) solar anisotropy of galactic cosmic rays (GCR) for 1965-2014 (almost 5 solar cycles 20-24). We analyze the 27-day variations of the two dimensional (2D) GCR anisotropy in the ecliptic plane, and the north-south anisotropy normal to the ecliptic plane. We study the dependence of the 27-day variation of the 3D GCR anisotropy on the solar cycle and solar magnetic cycle. We demonstrate that the 27-day variations of the GCR intensity and anisotropy can be used as an important tool to study solar wind, solar activity and heliosphere. We use the components Ar, Aϕ and At of the 3D GCR anisotropy found based on hourly data of neutron monitors (NMs) and muon telescopes (MTs) using the harmonic analyses and spectrographic methods. We correct 2D diurnal (24-hours) variation of the GCR intensity for the influence of the Earth magnetic field. We derive the north-south component of the GCR anisotropy based on the GG index calculated as the difference in GCR intensities of Nagoya multidirectional MTs. We show that behavior of the 27-variation of the 3D anisotropy verifies an existence of a stable long-lived active heliolongitudes on the sun. This finding illustrates usefulness of the 27-day variation of the GCR anisotropy as a unique proxy to study solar wind, solar activity and heliosphere. We distinguish a tendency of the 22-year changes of the amplitudes of the 27-day variation of the 2D anisotropy connected with the solar magnetic cycle. We demonstrate that the amplitudes of the 27-day variation of the north-south component of the anisotropy vary upon the 11 year solar cycle, however, a dependence of the solar magnetic polarity hardly can be recognized. We show that the 27-day recurrences of the GG index and At component are in a high positive correlation, and both are highly correlated with By component of the heliospheric magnetic field.

D1.3-0021-18 COMPARING THE RECURRENCE OF COSMIC RAY INTENSITY AT SOLAR ROTATION PERIOD IN SOLAR CYCLES 23 AND 24

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After the sunspot maximum and the solar polarity reversal in 2014, the Sun commenced the descending phase of cycle 24. Shortly after the polarity reversal, the galactic cosmic ray intensity, measured by neutron monitors at several latitudes, experienced a period of enhanced variability at the solar rotation period. It started in mid-2014 and continued until the beginning of March 2015. Some parameters of solar activity, like sunspot number and F10.7 radio flux, also experienced similar exceptional variation, which started slightly before than observed by neutron monitors. Several solar wind features also showed this variability, even though less steadily and during a shorter interval. We relate this strong periodicity in cosmic rays to the prompt development of an asymmetric southern polar coronal hole, which lead to a very asymmetric magnetic field configuration at midto highheliolatitudes.

We present here a detailed analysis of the above described period of recurrence and compare it with another similar period in 2007-2008, at the end of solar cycle 23, noting on differences and similarities. We show that in both periods a source of the recurrence was an asymmetric structure of a large coronal hole.

D1.3-0022-18 THE 2015 - PRESENT RISE OF THE GCR AS OBSERVED BY RAD ON MARS

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The radiation exposure due to galactic cosmic rays has been rising since early 2015 and is reaching some of the highest levels observed in the space age. This observation is not limited to the near-Earth space environment, but is also seen at Mars in measurements performed by the highly capable Radiation Assessment Detector (RAD) on NASA's Curiosity rover. We will discuss the increased radiation exposure at Mars and elsewhere, put into the larger heliospheric context and discuss implications for human exploration.

D1.3-0023-18 A STUDY OF THE COSMIC RAY PROTON FLUX LEVELS FOR A TRANSIT ORBIT TO MARS: A DATA-CONSTRAINED NUMERICAL APPROACH

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Since the AMS02 cosmic ray detector began its operation in May, 2011, highly accurate proton fluxes have been observed at the Earth. These precise measurements provide an opportunity for a refinement of numerical models for the transport of cosmic rays in the heliosphere. In this study, we constructed a modulation model by numerically solving the relevant transport equation. The model contains all four major physical modulation processes: convection, diffusion, global particle drifts and adiabatic cooling. Current sheet drifts are incorporated by utilizing Parker's magnetic field model. Driven by a time-dependent current sheet tilt angle and interplanetary magnetic field magnitude, the measured monthly proton fluxes can be reproduced by adjusting the three main diffusion coefficients. After fine-tuning this numerical model, it has been applied to calculate the cosmic ray proton flux along the transit orbit to the planet Mars. Some initial results will be presented.

D1.3-0024-18 NEAR-EARTH COSMIC RAY DECREASES ASSOCIATED WITH REMOTE CORONAL MASS EJECTIONS

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Neutron monitor (NM) count rates are modulated by both particle drifts and diffusion associated with solar wind structures. Over time-scales of hours, drops of a few percent in NM count rates (Forbush decreases, FDs) are well known to be associated with the near-Earth passage of solar wind structures, such as corotating interaction regions or transient coronal mass ejections. We present observations of FDs seen at ground-based NMs which cannot be attributed to significant structures in the near-Earth solar wind. Three examples of such FDs are presented. The timing of these is such that STEREO in-situ and remote observations are available to examine the solar wind from three well-separated heliospheric locations. For each example, large CMEs passed the STEREOA spacecraft, which was behind the west limb of the Sun, approximately 2-3 days before the near-Earth FD was observed. Simulations from the solar wind model, ENLIL, suggest that the CMEs combined with pre-existing CIRs, enhancing the pre-existing barriers to GCR propagation. Our observations provide strong evidence for the modulation of GCR flux by remote solar wind structures.

D1.3-0025-18 ENERGY SPECTRA OF CARBON AND OXYGEN WITH HELIOS E6 - RADIAL GRADIENTS OF ANOMALOUS COSMIC RAY OXYGEN WITHIN 1 AU

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HELIOS A and HELIOS B were launched on December 10, 1974 and January 15, 1976, respectively. The two almost identical space probes were sent into ecliptic orbits around the Sun. The Kiel experiment, E6 is one of three particle detectors aboard HELIOS that allows to study the flux of energetic particles in the energy range from 1.3 MeV/nucleon to above 1000 MeV/nucleon for ions and from 0.3 to 8 MeV for electrons. We present here the energy spectra of galactic cosmic ray (GCR) carbon and oxygen, as well as of ACR oxygen during solar quiet time periods between 1975 to 1977, utilizing both HELIOS spacecraft at distances between 0.3 and 1 AU. The radial gradient (Gr 50%/AU of 9-28.5 MeV ACR oxygen in the inner heliosphere is about three times larger than the one determined between 1 and 10 AU by utilizing the Pioneer 10 measurements.

D1.3-0026-18 DIFFERENCES IN THE SOLAR MODULATION OF PROTONS AND ANTIPROTONS

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A comprehensive, three-dimensional drift model is used to study the solar modulation of cosmic ray protons and particularly for anti-protons. Spectra for protons and anti-protons from 1 MeV to 50 GeV are computed based on revisited local interstellar spectra for these cosmic ray particles. This is done for the prolonged period of minimum solar activity from 2006 to 2009, followed by the period afterwards until the recent period of maximum activity. Differences will be highlighted and comparison with observations will be made.

D1.3-0027-18 ISSUES PERTAINING TO THE POSITRON LOCAL INTERSTELLAR SPECTRUM AND ITS SOLAR MODULATION

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The uncertainty in the local interstellar spectra for protons and electrons has largely been solved by the addition of observations made below 100 MeV by the Voyager 1 spacecraft beyond the heliopause. For positrons such observations do not exist and the cosmic ray positron LIS has to be inferred by use of galactic propagation models, solar modulation models and observations at the Earth. By computing spectra simultaneously for galactic electrons, protons, Helium and Carbon, in order to reproduce the Voyager 1 spectra, the corresponding positron LIS is also calculated. This process has shown that while such a LIS can be produced with the GALPROP code, it differs from a positron LIS inferred from modulation studies and might not yet be conclusive. These LIS's and their modulated spectra, computed with a comprehensive three-dimensional solar modulation model, are shown and discussed.

D1.3-0028-18 COMPARISON BETWEEN STATISTICAL PROPERTIES OF FORBUSH DECREASES FROM TWO DIFFERENT TYPES OF SOLAR SOURCES

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Modulations of galactic cosmic rays (GCRs)intensity known as Forbush decrease (FD) have been recorded by network of neutron monitors (NMs)at Earth during the last six solar cycles. In this work, we perform a comparison between properties of FDs connected with two types of solar sources: coronal holes (CHs) and coronal mass ejections (CMEs). We investigate the relationship of FDs parameters (magnitude, decrease rate, anisotropy)with geomagnetic Ap index, solar wind (SW) velocity and interplanetary magnetic field intensity for each source group. The data from created in the Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation (IZMIRAN) database of FDs and interplanetary disturbances (FEID)has been used. FEID database contains FDs parameters obtained by global survey method using the data from the worldwide network of NMs throughout the period from 1957 up to present as well as geomagnetic indices, the OMNI database and solar geophysical data. For each considered in this work FD (from 1997 to 2014) we identified its corresponding interplanetary mass ejection and the related causative CME (207 events, CME group) or corresponding corotating interaction region with the related CH (350 events, CH group). Statistical processing included a distribution analysis and a visual analysis of histograms, box plots and scatter plots as well as computing of descriptive statistics, correlations and multiple linear regression models. Regression analysis of events with similar SW disturbance' power reveals that: a) the CH group is significantly less effective in FDs creating; b) the geomagnetic activity and GCRs variations are statistically independent and their interrelation is determined only by a common source (the same SW disturbance). The CH group is characterized by increased geomagnetic activity, moderately powerful SW disturbances, relatively small FDs and significantly smaller equatorial component of anisotropy. The CME group is characterized by highly skewed FDs magnitude' distribution with the long tail of large values and generally corresponds to events with larger GCRs modulation at the same SW disturbance power.

D1.3-0029-18 NUMERICAL MODELING OF COSMIC RAY PROTON AND HELIUM OBSERVED BY AMS-02 DURING THE SOLAR MAXIMUM OF SOLAR CYCLE 24

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Galactic cosmic rays (GCRs) are affected by solar modulation while they propagate throughout the heliosphere. The study of the time variation of the GCR spectrum observed at Earth can shed light on the underlying physical processes, specifically diffusion and particle drifts. The AMS-02 experiment on board the International Space Station measured with very high accuracy the time variation of the cosmic ray proton and helium flux between May 2011 and May 2017 in the rigidity range from 1 to 60 GV. In this work, a comprehensive 3D steady-state numerical model is used to solve the Parker's transport equation and to reproduce the monthly fluxes observed by AMS-02. Preliminary results on the time dependence of the diffusion coefficient for proton and helium will be presented.

D1.3-0030-18 A MODIFIED FORCE-FIELD SOLUTION TO DESCRIBE COSMIC RAY PROTON AND HELIUM FLUXES OBSERVED BY AMS-02 DURING THE SOLAR MAXIMUM OF SOLAR CYCLE 24

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Galactic Cosmic Rays (GCRs) entering the heliosphere are disturbed by the magnetic field of the Sun, which varies the shape and intensity of their local interstellar spectrum. The AMS-02 experiment on board the International Space Station measured with very high accuracy the time variation of the cosmic ray proton and helium flux between May 2011 and May 2017 in the rigidity range from 1 to 60 GV. The force-field approximation is a popular way of dealing with solar modulation, expecially for studies focused on galactic transport of cosmic rays. The validity of this approach to reproduce modulated GCR fluxes at Earth is tested, showing that the precision of the new AMS-02 data requires a rigidity-dependent modification of the forcefield approximation. A modified force-field solution is presented, based on a more realistic expression of the diffusion coefficient.

D1.3-0031-18 RECOVERY PHASE OF THE GALACTIC COSMIC RAY 11-YEAR MODULATION AT 1 AU FOR THE SOLAR CYCLE 24

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Galactic cosmic-ray (GCR) modulation at 1 au for the recovery phase of the sunspot number (SSN) cycle 24 is studied using data from a global network of surface and underground detectors as well as the balloon measurements of low-energy ions at high latitudes in Russia, covering a wide range of median rigidity of response (Rm) for the detectors. The observed modulation is modest compared to previous cycles, peak of the interplanetary magnetic-field intensity at 1 au reached a much lower value (about 5 nT). The solar polar field in the northern hemisphere reversed in June 2012 and again in March 2014 while that in the southern hemisphere reversed in July 2013. The double field reversal in northern hemisphere after SSN maximum is not expected from the dynamo theory. The rigidity dependence of the cycle 24 modulation is computed. It is a power law, similar to previous solar cycles; the nearly linear dependence of GCR modulation on Rm over a wide range poses a challenge to the quasi-linear theory of GCR modulation.

D1.3-0032-18 HELIOSPHERIC MODULATION OF PROTONS FROM MINIMUM TO MAXIMUM SOLAR ACTIVITY

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Precise measurements of proton spectra between 80 MeV and 50 GeV from 2006 to 2014 by the PAMELA space mission have been a major incentive to test and improve numerical models which describe their transport inside the heliosphere. Starting with a new local interstellar spectrum for protons, placed at 122 AU from the Sun, the solar modulation of these particles is studied and compared to observations at the Earth. This is done from the prolonged solar minimum period up to solar maximum activity in 2014, including the period of the reversal of the polarity of the solar magnetic field during 2013. The insight gained from this comprehensive modelling with a three-dimensional drift model about the relative roles of the four main modulation processes over the mentioned period will be shown and discussed.

D1.3-0033-18 DIFFERENCES IN THE HELIOSPHERIC MODULATION OF ELECTRONS AND POSITRONS

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The solutions of a comprehensive three-dimensional drift model are compared to PAMELA spectra of electrons and positrons in order to describe and understand their different modulation down to 1 MeV. This is based on newly constructed very local interstellar spectra. The focus of the study is on the period of the prolonged solar minimum from 2006 and 2009. The comparison of observations and modelling provides insight into how the three major diffusion coefficients change during such quiet modulation conditions, and to what extent drift effects occur. The electron to positron ratio is computed from 10 MeV to 50 GeV for this period and a prediction is made for what may be observed in terms of spectra during the next solar minimum.

D1.3-0034-18 EFFECT OF SOLAR ACTIVITY ON COSMIC RAY MODULATION DURING SAME PHASES OF 22, 23, AND 24 SOLAR CYCLES

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Abstract During the same decreasing or minimum phases of solar cycles, occurs variability in the nature and magnitude of different parameters of Sun. In a time series analysis of three solar cycles at various conditions, variation has been observed in galactic cosmic-ray radiation. Present study is useful to understand the physics of interaction between the charged particles and space plasma. The dynamics of heliospheric structures are mainly responsible for observed variations and to know about a physical mechanism of modulation of cosmic rays. In this study correlation of galactic cosmic ray intensity with parameters shown abnormality and additional solar wind convection effect has been recorded during the period of minimum solar cycle.

D1.3-0035-18 MEASURING THE LOW-ENERGY ELECTRON AND POSITRON SPECTRUM (20-300 MEV) WITH THE AESOP-LITE BALLOON MISSION

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AESOP-Lite (Anti-Electron Sub-Orbital Payload) is a high-altitude balloon mission poised to launch from Esrange, Sweden in May 2018. It will measure the cosmic rays electron and positron fractions in the energy range of 20-300 MeV. The data will provide a calibrated reference at 1 AU to be compared with Voyager interstellar electron observations and extending the range of measurements made by PAMELA and AMS on the lower end of the spectrum. This novel measurement will be crucial in order to understand the origin and propagation of low-energy electrons in the heliosphere. I will present on the AESOP-Lite science goals, instrument design, and the status of its very first flight.

D1.3-0036-18 GEOEFFECTIVENESS OF SOLAR ACTIVITIES ORIGINATED FROM AR12673 IN SEPTEMBER 2017

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Solar active region (AR) 12673 erupted with a series of flares accompanied by 3 halo CMEs from Sep.4 to Sep.10, 2017. The solar activities cause Forbush Decreases (Fds) on Sep.8 and Ground Level Enhancement (GLE) events on Sep.10, respectively. Based on WIND and DSCOVR observation, we analyze the physical parameters of interplanetary magnetic field and solar wind plasma. The onset time of 8 ground-based NM (Neutron Monitors) counts increasement coincides with the protons flux >100 MeV from GOES 15. Furthermore, we reconstruct the three dimensional plasmas density of the CMEs using genetic algorithm based on the coronagraph observation from STEREO-A and SOHO. Then the reconstruction are put into the Space Weather Modeling Framework (SWMF) to simulate the evolution of interplanetary CMEs. Comparisons of the simulations and in situ measurements from space observation are presented, and we attempt to find the origin of the Fds and GLE. Key words: Coronal Mass Ejections (CMEs), Flare, Ground Level Enhancement (GLE)

D1.3-0037-18 SOLAR MODULATION OF HELIUM FROM MINIMUM TO MAXIMUM ACTIVITY

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Starting with a new local interstellar spectrum for helium, the solar modulation of these particles is studied and compared to observations at the Earth. This is done from the prolonged solar minimum period of 2006 to 2009, up to solar maximum activity in 2014, including the period of the reversal of the polarity of the solar magnetic field during 2013. Computed spectra are compared to the precise measurements of helium fluxes between 90 MeV/n and 25 GeV/n by the PAMELA space mission. Insight gained from this comprehensive modeling with a threedimensional drift model about the relative roles of the four main modulation processes over the mentioned period will be shown and discussed.

D1.3-0039-18 INTERPRETATION OF INCREASED SOLAR ENERGETIC PARTICLE FLUX MEASUREMENTS WITH SEPT ABOARD THE STEREO SPACECRAFT AND CONTAMINATION

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Among others, shocks are known to be accelerators of energetic charged particles. However, many questions regarding the acceleration efficiency and the required conditions are not fully understood. In particular, the acceleration of electrons by shocks is often questioned. Recurrent energetic particle events are caused by the passage of Corotating Interaction Regions (CIRs) that have been extensively analysed by different instrumentation close to Earth. Measurements of the Solar Electron and Proton Telescope aboard the Solar TErrestrial RElations Observatory are utilized in the solar heliospheric community to investigate electron events. Due to its measurement principle, the magnet foil technique, ions can contribute to the electron channel. This effect is well known. During recurrent energetic particle events the averaged helium to proton ration is enhanced to more than 10%. The energy per nucleon spectra are nearly the same for protons and helium. Although the electron intensity profile is influenced by an ion contamination during the shock crossings it is not obvious that electrons are not enhanced during such periods. Computation using a GEANT4 simulation of the SEPT instrument resulted in response function for ions and electrons. These response functions have been utlzed to analyze the recurrent energetic particle event that was was measured by STEREO B on August 9, 2011. Assuming a constant helium to proton ratio and energy spectra described by a Band function we found that electron and ion measurement

can be explained by the contribution of helium and protons with an helium to proton ratio of about 16%. Thus no electron enhancements are needed to explain the SEPT measurements.

D1.3-0040-18 A STUDY OF GALACTIC COSMIC RAY MODULATION IN THE NEGATIVE SOLAR MAGNETIC CYCLES: SOLAR CYCLES 21/22 AND 23/24

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This study focuses on variations in the Galactic cosmic ray (GCR) intensity at two different magnetic cutoff rigidities during the declining to rising phases of the solar cycles 21/22 and 23/24 that are negative solar magnetic cycles. Results reveal that the variations exhibit different features in both cycles and amplitudes of the variations decrease when the magnetic rigidities increase as a power law. In both solar cycles, variation of GCRs exhibit harmonics of 27 days in which the Cycle 23 is more clearly observed. The 27 day variations in the GCR intensity are dominant during the declining and rising phases of the solar activity. In this timescale the variations of GCRs are inversely proportional to the solar wind speed, especially in the Cycle 23 when high speed solar winds are recurrently observed at the Earth. The interplanetary magnetic fields are equally effective for the GCR modulation in both cycles, while the effects are reduced for the high rigidity in the Cycle 23. The tilt angle of the HCS shows a high anti-correlation with the GCR intensity in the Cycle 21, whereas in the Cycle 23, particularly at high cutoff rigidity, the modulation effects by the HCS drift are obscured by the prominent diffusion of GCRs.

D1.3-0041-18 HOW SUN PRODUCES QUASI-BIENNIAL OSCILLATIONS OF COSMIC RAYS?

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Quasi-biennial oscillations (QBO) are the most pronounced midterm periodicity lower than Schwabe cycle and greater than the solar rotation rate. It has been noticed in sunspot number and area, the number of Hα flares, solar radio flux, coronal green line intensity, photospheric magnetic field, solar wind speed, heliospheric magnetic field, solar energetic particle events, cosmic rays, as well as in geomagnetic activity parameters. Although it was intensively studied in the last years the source of the QBO is still unidentified. One of the concepts relates QBO to a high-frequency component of the dynamo operating within the solar interior.

Here we propose that the QBO originates from solar differential rotation. As countless intermediate heliolatitudes rotate with different tempo from 25-27 at the equator to 35-37 days at pools, the effects created on the Sun, being carried by various field lines, might interfere with each other producing oscillations varying from 0.30 to 3.65 years (and their multiples).

D1.3-0042-18 THE STOCHASTIC SOLUTION OF THE PARKER TRANSPORT EQUATION. COMPARISON OF THE BACKWARD-IN-TIME VS. FORWARD-IN-TIME APPROACH IN THE 1D, 2D, AND 3D HELIOSPHERE.

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We present the stochastic simulation of the galactic cosmic ray (GCR) particles transport in the heliosphere based on the solution of the Parker transport equation. The model is grounded on the numerical solution of the set of the stochastic differential equations (SDEs) corresponding to the non-stationary Parker transport equation (PTE). We solve the transport equation applying the forward-in-time and backward-in-time approach. These approaches were applied in the literature by few authors. However, its full comparison in various dimensions was not explicitly discussed up to now. We present the rigidity spectrum, spatial and time profiles of the GCR intensity in one, two and three-dimensional space considering the full 3-D anisotropic diffusion tensor. We compare outputs of the forward and backward approaches and discuss when the outputs of these models coincide with each other.

D1.3-0043-18 GEANT 4 SIMULATION OF THE KIEL ELECTRON TELESCOPE ON BOARD ULYSSES

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Ulysses was the first mission to explore the space environment above the poles of the sun. The mission launched in 1990, made three "fast latitude scans" of the Sun in 1994/1995, 2000/2001, and 2007/2008 providing a wealth of data. The COsmic and Solar Particle INvestigation Kiel Electron Telescope (COSPIN/KET) measures protons and a-particles in the energy range from about 4 to above 2000 MeV/n and electrons in the range from 2 to >300 MeV in dierent energy channels. The telescope consists of two parts: an entrance telescope and the calorimeter, a lead uoride Cherenkov detector and a scintillation detector. The entrance telescope comprises a silica-aerogel Cherenkov detector with an index of refraction of 1.066 inserted between semiconductor detectors. It denes the geometry, selects particles with speeds v/c = b > 0.938 and determines the magnitude of the particle charge. In order to describe the instrument response function we setup a GEANT 4 model and validated it against calibration measurements performed before the launch of the spacecraft. Here we present the model and the corresponding calculations that are in excellent agreement with measurements obtained at different accelerator.

D1.3-0044-18 ANTARCTIC NODE OF THE LAGO COLLABORATION COSMIC RAYS OBSERVATORY: STATE OF THE ART AND RESULTS OF THE 2017-2018 ANTARCTIC CAMPAIGN

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The LAGO (Latin American Giant Observatory) project is a collaborative network formed by eleven countries (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guatemala, Mexico, Peru, Spain, and Venezuela), forming a network of Water Cherenkov detectors (WCDs) with nodes at sites with different rigidity cut-offs and different altitudes. One of the aims of LAGO is to study the flux of secondary particles at ground level, and to link them with the associated primary fluxes to better understand the modulation of galactic CRs in the heliosphere and the properties of solar particles of high energy, the so-called Ground Level Enhancements, GLEs. Another main purpose is to monitor this flux to provide operative Space Weather information. WCDs have shown to be able to reproduce time structures compatible with those observed with neutron monitors (NMs) and its major advantage compared with NMs is that the former ones can discriminate energy channels for the observed secondary charged particles. From numerical simulations, this energy discrimination can be used for a better understanding of the flux of primary CRs arriving to the terrestrial environment. We present here an update of the state of the art of the LAGO Antarctic node, in the Argentine Marambio base, located at the Antarctic peninsula. This node has the minimum rigidity cut-off (Rc 2 GV for quiet geomagnetic conditions) of the Observatory, and it is the only LAGO node able to observe GLEs. We present the LAGO Antarctic campaign of 2017 in Marambio, where a meteorological station, a thermal control system, a magnetometer, and the telemetry system, were installed.

D1.3-0045-18 SOLAR MODULATION OF DEUTERON

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A comprehensive three-dimensional drift model is used to study the solar modulation of cosmic ray deuteron for the prolonged period of minimum solar activity from 2006 to 2009. Spectra for deuteron from 1 MeV to 50 GeV are computed and compared to the proton spectra for the mentioned period. Differences will be highlighted and comparison with PAMELA observations will be made.

SPACE PLASMAS IN THE SOLAR SYSTEM, INCLUDING PLANETARY MAGNETOSPHERES (D)

COORDINATED OBSERVATIONS AND MODELING OF ACCELERATED PARTICLES AT THE SUN AND IN THE INNER HELIOSPHERE (D2.1)

D2.1-0001-18 PARTICLE ACCELERATION AND TRANSPORT IN THE SOLAR ATMOSPHERE

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During periods of sporadic are activity, the Sun releases energy stored in the magnetic field into the plasma of the solar atmosphere. This is an extremely efficient process, with a large fraction of the magnetic energy going into plasma particles. The solar ares are accompanied by prompt electromagnetic emission virtually over the entire electromagnetic spectrum from gamma-rays down to radio frequencies. The Sun, through its activity, also plays a driving role in the SunEarth system that substantially influences geophysical space. Solar are energetic particles from the Sun are detected in interplanetary space by in-situ measurements making them a vital component of the single Sun-Earth system. Although a qualitative picture is generally agreed upon, many processes solar are processes are poorly understood. Specifically, the processes of acceleration and propagation of energetic particles interacting on various physical scales remain major challenges in solar physics and basic plasma physics. In the talk, I will review the current understanding of solar flare energetic particles focusing on recent observational progress in the view of Solar Orbiter and Praker Solar Probe.

D2.1-0002-18 HXI ONBOARD ASO-S: MAPPING SOLAR FLARES IN HARD X-RAY BAND

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The Hard X-ray Imager (HXI) will be mounted in the Advanced Spaced-based Solar Observatory (ASO-S), which is one of Chinese scientific space missions funded by Strategic Pilot Project in Space Science of CAS and to be launched in 2022, with the aim of providing images of solar flaring regions in the energy range from 30 keV to 200 keV. The imaging principle of HXI is based on spatial modulated Fourier synthesis and utilizes about 92 sets of bi-grids sub-collimators and corresponding LaBr3 detectors to obtain Fourier components with an ultimate spatial resolution better than 6 arc sec. HXI is developed to study the mechanism of particle acceleration and energy release of solar flares, thereby understanding the relationships among solar flares, CME and solar magnetic field with help of other two payloads onboard ASO-S, Lyman-alpha Solar Telescope(LST) and Full-Disc Vector Magnetograph (FMG). We will present background, instrument design and a brief status update of HXI.

D2.1-0003-18 AN NEW MHD/KINETIC MODEL FOR EXPLORING PARTICLE ACCELERATION IN SOLAR FLARES

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A novel MHD/kinetic model is being developed to explore magnetic reconnection and particle energization in macro-scale systems such as the solar corona. The model blends the MHD description with a macro-particle description. The rationale for this model is based on the recent discovery that energetic particle production during magnetic reconnection is controlled by Fermi reflection and Betatron acceleration and not parallel electric fields. Since the former mechanisms are not dependent on kinetic scales such as the Debye length and the electron and ion inertial scales, a model that sheds these scales is sufficient for describing particle acceleration in macro-systems. Our MHD/kinetic model includes macroparticles laid out on an MHD grid that are evolved with the MHD fields. Crucially, the feedback of the energetic component on the MHD fluid is included in the dynamics. Thus, energy of the total system, the MHD fluid plus the energetic component, is conserved. The system has no kinetic scales and therefore can be implemented to model energetic particle production in macro-systems with none of the constraints associated with a PIC model. Tests of the new model in simple geometries will be presented and implications for exploring particle acceleration in impulsive flares will be discussed.

D2.1-0004-18 EVIDENCE OF ACCELERATED PARTICLES IN THE RECONNECTION OUTFLOWS ABOVE TWO FLARE CUSPS

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Energetic particles carry a large fraction of released energy in solar flares. Some of them travel downward to the lower atmosphere and heat the local plasma. Others could escape from the corona into interplanetary space and become a component of SEP (Solar Energetic Particles) event. Although particle acceleration have been extensively studied in theory and simulations, observational details of the process in flares are far from complete. The discovery and studies of the above-loop-top source (Masuda et al. 1994, Krucker, Säm Battaglia 2014, Chen et al. 2015) have revealed the acceleration process around the termination shock. Here we report the discovery of above-cusp sources and evidence of accelerated particles therein. The analysis of imaging spectroscopy with RHESSI data and the DEM (Differential Emission Measure) diagnostic with our improved Sparse method (Cheung et al. 2015, Su et al. 2018, submitted) for two flares revealed that the acceleration starts in the current sheet and outflows, at places even higher than the Masuda source. This finding provides important clues for future observations and simulations of magnetic reconnection.

D2.1-0005-18 RADIO OBSERVATIONS OF ENERGETIC ELECTRONS IN ASSOCIATION WITH CORONAL MASS EJECTIONS IN THE SOLAR CORONA

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Coronal mass ejections are large eruptions of plasma and magnetic field from the low solar corona into the heliosphere. These eruptions are often associated with energetic electrons that produce various kinds of radio emission. However, there is ongoing investigation into exactly where, when and how the electron acceleration occurs during flaring and eruption, and how the radio emission can be exploited as a diagnostic of the particle acceleration and CME plasma properties. In this talk I will firstly present recent observations from the Nançay Radioheliograph (NRH) that show the sites and kinds of electron acceleration that take place during flaring and eruption, from the destabilisation of a flux rope to development of a CME. This shows evidence for the tether-cutting model and numerous sites of electron acceleration both external and internal to the CME during its development. Secondly, using an analysis of gyrosynchrotron radiation from NRH and a non-thermal electron diagnostic using X-ray observations, I show that radio emission can be produced internal to the CME from nonthermal electrons of energies >1MeV in a CME core magnetic field strength of 4.4G. Overall, this reveals how different types of radio observations can be used as a diagnostic of the locations and kinds of electron acceleration during an eruptive event, and also how radio may be used to both image CMEs and give new insight into their dynamics and internal plasma properties.

D2.1-0006-18 RAYS AND RADIO COUNTERPARTS OF FERMI LONG-DURATION GAMMARAY EVENTS

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The Fermi spacecraft showed a rather frequent occurrence, and sometimes long duration, of γ-ray bursts at photon energies above 100 MeV. They are ascribed to pion-decay photons, which in turn requires protons to be accelerated to energies above 300 MeV. This raises the question why the Sun, which is thought to be a modestly skilled particle accelerator, accelerates protons to energies above 300 MeV rather frequently, and where this can happen on occasion during several, up to ten, hours. The HESPERIA project, funded between 2015 and 2017 by the European Union (H 2020 programme), endeavoured to shed light on these questions by a systematic investigation of X-ray and radio emission during the gamma-ray events. We found that the Fermi γ-ray events are accompanied by signatures of energetic electron acceleration in the corona during the impulsive phase and the early post-impulsive phase. This points to a common acceleration of the relativistic protons with energetic electrons during about an hour, and is in line with earlier findings. γ-ray emission lasting several hours was found to accompany the decay phase of long-lasting soft X-ray bursts, post-flare loop formation and decametric-tokilometric type II bursts, revealing shock waves in the high corona. The presence of a type II burst may suggest shock acceleration of the relativistic protons. But the acceleration far from the Sun poses the problem of how to transport the protons back to the chromosphere against magnetic mirroring. An alternative is prolonged trapping of protons accelerated during the first hours of the solar event. This has then to be reconciled with the absence of simultaneous X-ray and radio emission.

D2.1-0007-18 HARD X-RAYS OBSERVED ASSOCIATED WITH INSTABILITY OF A COLLISIONAL MHD-DRIVEN COLLIMATED PLASMA JET

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A mechanism for direct acceleration of electrons to extremely high energy in a cold, collisional plasma has been observed. Detailed timeand space-resolved measurements (including highspeed movies) on an experiment at Caltech reveal the following sequence:

A coaxial magnetized plasma gun forms a dense, cold MHD-driven collimated plasma jet (length 10's of cm, duration 20-40 μs, 100 kiloamp current, T = 2 eV).

The jet becomes kink unstable when it attains a critical length (this happens at about 20 – 30 μs and the kink e-folding time is about 4 μs).

The kink lateral acceleration provides a large effective gravity (~ 1010 m s–2) that instigates a secondary Rayleigh-Taylor (RT) instability (the RT e-folding time is ~ 1 μs).

The RT instability instigates a magnetic reconnection manifested by a breaking of the jet at the location of the RT instability and interruption of the electric current

Associated with the reconnection are wave emission, particle heating, EUV emission, and a hard X-ray pulse measured by a plastic scintillator.

The X-ray pulse lasts a fraction of a microsecond, has about 6 keV energy, and coincides with the RT instability. Because the ~1 micron electron collision mean free path is much shorter than the 10 cm long RT region, electron acceleration to high energy was not expected. It is proposed that despite the short collision mean free path, a sub-Dreicer inductive electric field ˜LdI/dt caused by the current disruption accelerates a small electron subgroup to 6 keV energy without these electrons undergoing collisions and that after being accelerated to high energy, these fast electrons suddenly decelerate via collisions and radiate X-rays. Although this subgroup constitutes only a small fraction of all the electrons, because of the high energy per electron, the subgroup contains substantial kinetic energy. This process could be important in solar corona situations where kinks provide sufficient lateral acceleration to drive secondary Rayleigh-Taylor instabilities.

D2.1-0008-18 THE SOLAR RADIO BURST EVENT WITH MUSER IMAGING-SPECTROSCOPY OBSERVATIONS

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The radio bursts at decimetric wavelength may reveal important information on primary energy release sites where particle acceleration process can be studied. However, up to now, the detailed sites of impulsive-phase particle acceleration and radio fine structures are still remains uncertain. Mingantu Spectral Radioheliograph (MUSER) is a solar-dedicated interferrometric array with a frequency range from 400MHz to 15 GHz. There are two arrays of 40 4.5m antennas covering 400MHz -2 GHz, and 60 2m antennas covering 2 - 15 GHz which have been established in Mingantu Town, Inner Mongolia of China. The burst event with some fine structures on June 21, 2015 for a C-class flare was observed by MUSER-I in 400MHz-2GHz. The multi-frequency images in decimeter wave ranges of the burst process and fine structures by MUSER-I are obtained and analyzed.

D2.1-0009-18 SOLAR NEUTRON TELESCOPES AND EARTH ORBITING SPACECRAFT OBSERVATIONS OF THE MARCH 7TH AND SEPTEMBER 25TH OF 2011 EVENTS: SOLAR NEUTRON AND GAMMA-RAYS

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Being associated with a high energy gamma-ray flux with statistical significance of 6.5 observed by the Large Area Telescope of the Fermi orbiting observatory (FERMI-LAT) on March 7, 2011, the Space Environment Data Acquisition Equipment (SEDA-FIB) onboard the International Space Station (ISS) registered solar neutrons with a statistical significance of 7.5. The Solar Neutron Telescope (SNT) in operation at Mt. Sierra Negra, Mexico (4,600 m) detected increases of the fluxes in a channel registering neutral particles, not necessarily neutrons, from 19:49 to 20:02 UT and from 20:50 to 21:01 UT. The significances were 9.7 and 8.5, respectively. On September 25th, 2011 the SNT located at Yangbajing in Tibet (4,300 m) observed signals very similar to those of the referred Sierra Negra event from 04:37 to 04:47 UT with a statistical significance of 8.0 (by the Li-Ma method).Details of both events are presented in this paper in an effort to produce a unified model that can explain these data. We think that these mountain detectors registered gamma-rays from the Sun anda plausible physical explanation of the results is provided.

D2.1-0010-18 SOLAR ORBITER MEASUREMENTS OF THE HIGHEST ENERGY SOLAR ENERGETIC PARTICLES–NEUTRON MONITORS AND SOLAR ORBITER

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Neutron Monitors (NM) have been for over sixty years powerful instruments for measuring GeV-energy solar protons. In that time we have learned much about the nature of ground level enhancements (GLE), the signal on the ground from these high energy ions. However, the processes that govern the acceleration of these particles has their roots close to the Sun. Similarly, the transport of these particles to 1 AU is governed by the plasma conditions in the intervening space. As an example, the transition of a GLE from a highly anisotropic event to an isotropic one may be the result of either self generated turbulence or the delayed influence of the progenitor CME shock. In fact, the question still lingers whether there is a flare component to the GLE, as measured with NMs. Thus, particle and plasma measurements at small heliocentric distances will be critical in answering questions like these. In a related question, we know that CMEs are responsible for Forbush Decreases (FD) that are quantified in terms of the effect on NM rates. However, several critical CME measurements can now only be performed at 1 AU, while the oncoming CME still has effect on the galactic cosmic ray intensity and anisotropy at 1 AU. Performing the critical plasma measurements at the Solar Orbiter radius will certainly aid in interpreting the effects of the approaching CME and FD. In this talk I will review the discovery potential in our study of the highest energy cosmic rays and the synergistic and mutual benefits we expect to realize from correlated and coordinated Solar Orbiter measurements and those performed by NMs.

D2.1-0011-18 COMBINED TREATMENT OF PARTICLE ACCELERATION IN SOLAR FLARES AND ASSOCIATED CME SHOCKS

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Solar eruptive events produce flares in the corona and coronal mass ejections (CMEs). Particles are accelerated both in the coronal reconnection sites and in the CME driven shocks. Traditionally, investigations of these phenomena are carried out independently in two communities. The solar community's focus is on flares and radiation producing particles (RPPs), while the heliospheric community's focus is solar energetic particles (SEPs) and the acceleration in the CME-shocks. However, there is considerable observations, in particular in impulsive-prompt events, indicating a close connection between these two processes. This connection will be the focus of this talk. I will review some relevant observations and describe their modeling based on a hybrid stochastic acceleration at the flare site, and re-acceleration of flare particles injected into the CME environment. Such a model seem to be required to explain Fermi observations of up to several GeV gamma-rays from three behind the limb flares. I will emphasize an important aspect that plays a central role in this scenario, which is the processes of escape of accelerated particles up and down from flare site and from downstream and upstream of the CME.

D2.1-0012-18 GLE 72 ON 10 SEPTEMBER 2017 - AN ANALYSIS USING NEUTRON MONITOR AND SPACE-BORNE DATA

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The first ten days of September 2017 were characterized by intense solar activity, producing several X-class flares and coronal mass ejections (CMEs). The second ground level enhancement (GLE) event of solar cycle 24, namely GLE 72 on 10 September 2017, was related to a X8.2 solar flare. The flare peaked at 16:06 UT, leading to a gradual solar energetic particle event measured by spacecraft up to proton energies exceeding 700 MeV and to a very fast CME erupting over the west limb. The GLE onset was observed by several neutron monitor (NM) stations at about 16:15 UT (FSMT and INVK). However, a clearly distinguishable signal, which allows one to derive the spectral and angular characteristics of SEPs with sufficient precision, was observed at 16:30 UT. The strongest increases were observed at the DOMC/DOMB 10-15 %, SOPO/SOPB 5-8 % and FSMT 6%, above the pre-increase levels. The event was characterized by a typical gradual increase.

Here we perform a precise analysis of spectral and angular features of solar energetic particles (SEPs) on the basis of NM data. The method includes several consequitive steps: detailed computation of assymptotic cones and cut-off rigidity of each NM station used in the analysis, an initial guess of the inverse problem by assuming the apparent source position in a convenient way, application of the NM yield function for detector response modelling and optimization procedure in order to derive spectral and angular characteristics of SEPs. In this study we use the Planetocosmics code and realistic magnetospheric models for computations of assymptotic directions and rigidity cut-offs. Here we present results from analysis of GLE 72, namely SEP spectra and pitch angle distributions, which are obtained in their dynamical development throughout the event. An interpretation of the derived findings is performed.

D2.1-0013-18 SOLAR ENERGETIC PARTICLE EVENTS WITH PROTONS ABOVE 500 MEV BETWEEN 1995 AND 2015 MEASURED WITH SOHO/EPHIN

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The Sun is an effective particle accelerator producing solar energetic particle (SEP) events during which particles up to several GeVs can be observed. Those events observed at Earth with the neutron monitor network are called ground level enhancements (GLEs). In this work, SEP events with protons accelerated to above 500 MeV have been identified using data from the Electron Proton Helium Instrument (EPHIN) aboard the Solar and Heliospheric Observatory (SOHO) between 1995 and 2015. The compliled list of 42 SEP events is discussed based on the fitted spectral slopes and absolute intensities with special emphasis on whether or not an event has been observed as GLE. Furthermore, a correlation between the derived intensity at 500 MeV and the observed increase in neutron monitor count rate has been found for a subset of events.

D2.1-0014-18 THE ORIGIN OF ELECTRONS IN SOLAR ENERGETIC PARTICLE EVENTS AND THEIR RELATION TO PROTONS

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One of the observables that is used to distinguish gradual and impulsive solar energetic particle (SEP) events is the electron to proton ratio. The ratio is higher in impulsive SEP events that are often enriched in 3He and/or heavy ions and are generally attributed to magnetic reconnection in solar flares or jets. But electrons are always present even in gradual SEP events that are due to acceleration at shock waves driven out by coronal mass ejections (CMEs). A question arises as to whether electrons in gradual SEP events have the same (CME-driven shock) origin and injection as protons or they are still produced in the flare site through magnetic reconnection. If CME-driven shocks are responsible for both protons and electrons in gradual SEP events, are they accelerated at the same or different portions of the shock? If not, what is the relation between magnetic reconnection in flares and shock waves driven by CMEs? We study electron events that have different levels of similarities/proportionalities to and differences from concurrent proton events in terms of the peak flux and onset and peak times, using L1 and STEREO observations. We note the comparisons depend on energy ranges both electrons and protons. The characteristics of the source regions and associated flares and CMEs are investigated for SEP events that have different relations between protons and electrons, with additional information such as metric and decametric radio bursts.

D2.1-0015-18 PARTICLE ACCELERATION STUDIES WITH ADITYA-L1 MISSION

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Aditya-L1 is a first dedicated and approved solar mission from India. The main scientific objective of this mission is to study the solar coronal dynamics. The satellite will be placed at the Sun-Earth Lagrangian – L1 in order to observe the Sun uninterruptly. This mission carries seven payloads with four remote sensing and three in-situ instruments. While the remote sensing payloads observe the chrmospheric and coronal dynamics, the in-situ payloads measures the particles and magnetic fields at L1 point which are modified by the activities originating from the Sun. There are two particle payloads and one set of three axis magnetometer for in-situ measurements. In this presentation, the details about the payloads on-board Aditya-L1 will be discussed specifically. The connection between the in-situ payloads along with the X-ray payloads on-board Aditya-L1 will also be brought out. It is also planned to use ground based radio observations of the Sun for the studies related to particle acceleration and propagation. The connection between the in-situ observations along with X-ray and Radio observations will be discussed for the study of heliospheric physics.

D2.1-0016-18 OBSERVATIONS OF THE 3D CME SHOCKS AND THE PRODUCTION OF SOLAR ENERGETIC PARTICLES

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The acceleration source/mechanism of solar energetic particles (SEPs) is still a controversy during the onset of a large SEP event. Here, we present both a case study (Xu, Li Ding, 2017, ApJ, 840, 38) and a statistical investigation (Xu et al. in preparation) to clarify the release of SEPs, the multi-wavelength flare emission, and the 3D CME evolution. Our results show that:

(1) the CME shocks rather than the flares play the key role in particle acceleration during the onset of the large SEP events; (2) the in-situ onset times of electrons are systematically earlier than the protons with an averaged time difference of 15 minutes; (3) the time difference of the in-situ observed electrons and protons probably arises from their scattering propagation in interplanetary space.

D2.1-0017-18 INVERSION OF SOLAR ENERGETIC PARTICLE EVENTS IN THE PARKER SOLAR PROBE AND SOLAR ORBITER ERA

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In past decades, measurements by space-borne instrumentation have been exploited to learn about the sources, the extent and the propagation conditions of solar energetic particles (SEPs). Inversion modeling has revealed to be a powerful tool to unravel the source release time profile of SEPs and characterize their transport in the interplanetary medium. I will review the pros and cons of this methodology, learned from the study of near-relativistic electron (>50 keV) events observed by the ACE, Wind, STEREO and Helios spacecraft assuming focused transport in the heliosphere.

The inversion problem is an optimization problem where the difference between the model and the data points is minimized. One of the powerful aspects of the methodology is that it allows us to infer the source release time profile of SEPs without making any a priori assumption about its onset or functionality. This is done by fitting the evolution of the measured angular distributions (i.e. sectored intensities), taking the angular response of the particle experiment into account. In many cases, the large amount of data makes it a well-constrained problem. However when the range of pitch angles observed by the particle experiment is poor, the results of the inversion are inconclusive. The pitch-angle coverage depends on the particle experiment (i.e. number of sectors or fields of view) and time (due to fluctuations of the interplanetary magnetic field). It can vary from event to event and even during the evolution of one. Thus a careful event selection is needed.

The main obstacle that the methodology has faced so far is the sparsity of the solution when data is noisy, as well as the lack of a quantitative description of the systematic errors. In the new Solar Orbiter and Parker Solar Probe era, denoising and regularization methods should be mandatory to avoid overfitting. In addition, the energy response should be taken into account, which would require the unprecedented public release of the particle detector responses along with the particle angular distributions measured in space.

D2.1-0018-18 ENERGETIC PARTICLE MEASUREMENTS WITH SOLAR ORBITER

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Solar Orbiter, a joint ESA/NASA mission, is designed to study the Sun and inner heliosphere in greater detail than ever before. At the closest point on its heliocentric orbit, the Solar Orbiter spacecraft will be just closer than 0.3 AU from the Sun. In addition to providing high-resolution images of the solar surface, perihelion passes at these distances occur in near co-rotation with the Sun, allowing the instruments to track features on the surface for several days. The mission profile also includes a latitude cranking phase that will allow observations above the solar equator. The combination of near-Sun, quasi-heliosynchronous and out-of-ecliptic observations by remote-sensing and in-situ instruments makes Solar Orbiter a unique platform for the study of the links between the Sun and the inner heliosphere.

Understanding the physical processes operating in Solar Energetic Particle (SEP) events is a major goal of the Solar Orbiter mission because of the importance of acceleration processes in solar system and astrophysical sites, and because of the potential impact of these events on space hardware. The Energetic Particle Detector (EPD) investigation on Solar Orbiter is a suite of four different sensors plus the instrument control unit to measure the energetic particles from slightly above solar wind energies to hundreds of MeV/nucleon. The EPD addresses one of the key science objectives of ssolar Orbiter, namely “How do solar eruptions produce energetic particle radiation that fills the heliosphere?” In addition, EPD tackles three primary goals of Solar Orbiter:

How and where are energetic particles accelerated at the Sun? 2) How are energetic particles released from their sources and distributed in space and time? 3) What are the seed populations for energetic particles?

We describe progress possible with EPD on achieving the science goals of the mission.

D2.1-0019-18 ENERGETIC PARTICLE TRANSPORT AND ACCELERATION WITHIN THE INTERPLANETARY MEDIUM

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The propagation through space of energetic particles accelerated at the Sun and in the inner heliosphere is governed by the characteristics of the interplanetary magnetic field. At large scales, the average Parker spiral configuration, on which transient magnetic structures may be superimposed, dominates the transport, while at smaller scales turbulence scatters the particles and produces field line meandering. This talk will review the classical description of interplanetary transport, mainly applied to Solar Energetic Particles (SEPs), as well as more recent models which allow for effects such as transport perpendicular to the average magnetic field and field line meandering. The recently emphasized role of drifts in the propagation of SEPs will be discussed. The talk will also review processes by which particle acceleration takes place within the interplanetary medium and the overall way in which acceleration and transport shape in-situ observations of energetic particles.

D2.1-0020-18 WHAT THE HIGH-ENERGY FLARES AND CMES OF 2012 MARCH 7 CAN TELL US ABOUT LONG DURATION GAMMA-RAY FLARES

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Two X-class flares occurred on 2012 March 7, an X5.3 and an X1.1. The earlier X5 flare gathered much attention, initiating a powerful and fast CME from the eastern hemisphere. The "forgotten" X1 flare exhibited much smaller CME from the same active region one hour later. However, extended high-energy gamma emission was present for almost the entire day of 2012 March 7. We have resolved the gamma emission into two separate, but overlapping extended occurrences, being from the two sequential X-class flares. Somewhat surprisingly, we find that the later X1 event was twice as prolific in gamma emission, mostly due to its duration, despite being much weaker in soft x rays. We attribute the entirety of the gamma emission from particle precipitation from the footpoints two separate quasi-static large-scale (of order 1 solar radius) coronal loops and not from either of the associated CMEs accelerating the high-energy particles. Using constraints from ancillary data, we estimate the bounds in parameter space of the loop sizes and embedded turbulence necessary to accelerate protons and ions to high energies producing the gamma emission.

D2.1-0021-18 COORDINATED OBSERVATIONS AND MODELING OF ACCELERATED PARTICLES AT THE SUN AND IN THE INNER HELIOSPHERE

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Acute space radiation hazards pose one of the most serious risks to future human and robotic exploration. Large solar energetic particle (SEP) events are dangerous to astronauts and equipment. A fundamental question remains as to how large SEP events are formed, how they are related to coronal mass ejections (CMEs) and active region eruptions, and what factors control the differential

fluxes incident at Earth and other observers during SEP events. The current evolution of the Sun between solar cycles 23 and 24 and during cycle 24 remains highly anomalous compared to previous periods of the space age. The Sun has been abnormally quiet over a relatively long solar minimum when galactic cosmic rays (GCRs) achieved the highest flux levels observed in the space age, and the power, pressure, flux and magnetic flux of the solar wind were at the lowest levels. Despite the continued paucity of solar activity, one of the hardest solar events in almost a decade occurred in September 2017 after more than a year of all-clear periods. The 2017 September event demonstrates the importance of large fluxes of suprathermal seed populations and fast, large CMEs that drive shocks and compressions low in the corona (<5 Rs) where large SEP events are accelerated. The Coronal-Solar Wind Energetic Particle Acceleration (C-SWEPA) modeling effort and the SPE Threat Assessment Tool (STAT) combine the Earth-Moon-Mars Radiation Environment Modules (EMMREM) that describe energetic particles and their effects, with the CORHEL (Corona-Heliosphere) modeling suite developed by the Predictive Science, Inc. (PSI) group. C-SWEPA has also developed coupling between EMMREM and Enlil at the CCMC. The C-SWEPA and STAT projects have resulted in coupled models that describe the conditions of the corona, solar wind, CMEs, associated shocks, particle acceleration, and propagation via physics-based modules. Recent simulations demonstrate how CMEs form powerful compressions and shocks low in the corona that rapidly accelerate high energy particles often up to the GeV energies required for Ground Level Enhancements (GLEs). The most pronounced acceleration of the CME occurs very close to the Sun (<2 Rs) causing extremely strong compression on the flanks and nose of the CME. Results from recent modeling and observational studies demonstrate that the size of the shock or compression limits the break energy and longitudinal distribution of SEPs. The new capabilities afforded by STAT and C-SWEPA highlight the pathway toward prediction for large SEPs, and provide an important resource for answering fundamental new questions likely to arise from Parker Solar Probe and Solar Orbiter measurements.

D2.1-0022-18 THREE-DIMENSIONAL MODELLING OF SOLAR ENERGETIC PARTICLE EVENTS WITH EUHFORIA

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The main sources of solar energetic particles (SEPs) are shock waves propagating in front of coronal mass ejections (CMEs) and solar flares. Once particles escape from their acceleration site, they travel through the heliosphere, spiralling around the interplanetary magnetic fieldlines. On their voyage through space, they may encounter the Earth where they can e.g., disrupt the microelectronics of satellites and produce radiation hazard for astronauts in extravehicular activity. Therefore, it is crucial to understand and thereby build models capable of predicting the characteristics of SEP events.

The trajectories followed by SEPs in interplanetary space are determined by the electromagnetic forces acting on the particles. These forces result from the presence of magnetic fields in the background solar wind, which are a combination of the large-scale magnetic field originating from the sun and small-scale magnetic turbulence due to e.g., Alfvén waves and meandering field lines. One expects thus the properties of SEP events to be strongly influenced by the varying conditions of the solar wind. To study these effects, we developed a three-dimensional (3D) model for the description of SEP events that couples a new Monte Carlo particle transport code to the newly developed data-driven heliospheric model, EUHFORIA. The particle transport code computes heliospheric SEP distributions by solving the focused transport equation with perpendicular diffusion in a stochastic manner, whereas EUHFORIA solves the magnetohydrodynamic (MHD) equations, allowing us to obtain complex solar wind configurations in which we can propagate the energetic particles. In this talk, we present the first results of the coupling of the particle code with EUHFORIA, and in particular we focus on the effects of different background solar wind and scattering conditions on SEP events observed at different positions in the heliosphere.

D2.1-0023-18 PSEUDOSTREAMERS AND WIDELY DISTRIBUTED SEP EVENTS

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Our analysis of the pseudostreamer magnetic topology reveals new interesting implications for understanding SEP acceleration in CMEs. The possible reasons for the wide distribution of some SEP events can be the presence of pseudostreamers in the vicinity of the SEP source region which creates conditions for the existence of strong longitudinal spread of energetic particles as well as an anomalous longitudinal solar wind magnetic field component. We reconstructed the 3D magnetic configurations of pseudostreamers with a potential field source surface (PFSS) model, which uses as a lower boundary condition the magnetic field derived from an evolving surface-flux transport model. In order to estimate the possible magnetic connections between the spacecraft and the SEP source region, we used the Parker spiral, ENLIL and PFSS models. We found that in cases of the wide SEP distributions a specific configuration of magnetic field appears to exist at low solar latitudes all the way around the sun, we named this phenomenon a pseudostreamers belt. It appears that the presence of the well developed pseudostreamer or, rather multiple pseudostreamers, organized into the pseudostreamer belt can be considered as a very favorable condition for wide SEP events.

D2.1-0024-18 PERPENDICULAR DIFFUSION OF SOLAR ENERGETIC PARTICLES IN PLASMA WAVE TURBULENCE; MODEL RESULTS AND IMPLICATIONS FOR ELECTRONS

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The processes responsible for the effective longitudinal transport of solar energetic particles (SEPs) are still not completely understood. We address this issue by simulating SEP propagation using a spatially 2D transport model that includes perpendicular diffusion. By implementing, as far as possible, the most reasonable estimates of the transport (diffusion) coefficients, we compare our results, in a qualitative manner, to recent observations. We illustrate the effects of perpendicular diffusion on the model solutions and discuss the viability of this process as a dominant mechanism by which SEPs are transported in longitude. The streaming SEP electrons can either grow or damp the background solar wind fluctuations; an effect also included in the present model. Our results suggest that wave amplification by streaming SEP electrons is indeed possible and may even significantly alter the background turbulent field. However, the simulations show that this process is much too weak to produce observable effects at Earth's orbit, but such effects may well be observed in future by spacecraft closer to the Sun, presenting an intriguing observational opportunity for either the Solar Orbiter or the Parker Solar Probe spacecraft.

D2.1-0025-18 REMOTE SHOCK CONNECTION CONTRIBUTIONS TO SEP EVENTS

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We recently published comparisons of observed multipoint SEP events with model counterparts (Space Weather, 2017) based on the assumption that ICME shocks in the WSA-ENLIL-cone model represent moving sources where diffusive shock acceleration is taking place, and that observer magnetic connection to those shocks determines their distinctive SEP time profiles. These results also provide information of interest regarding the occurrence of an observed SEP event in the absence of the corresponding shock arrival. We use the events that we have modeled to investigate how common it is for SEP events to occur solely or mainly by remote shock source connections. Such results are of interest for both the identification of observed SEP event sources, as well as for the use of SEP events as a precursor for geomagnetic storms in space weather forecasting.

D2.1-0026-18 3-D MODELLING OF SOLAR ENERGETIC PARTICLE TRANSPORT THROUGH ENLIL FIELDS.

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Solar Energetic Particles (SEPs) are accelerated by solar flares and shock waves driven by coronal mass ejections. SEP events are an important space weather hazard due to the significant radiation doses these particles can impart on humans and human technology in space. In this study, we simulate the transport of SEPs through the heliospheric magnetic field, via a 3-D test particle approach and using magnetic and electric fields from the 3-D ENLIL solar wind model. We compare previous results of the SEP test-particle model, produced using an ideal Parker Spiral magnetic field, with our new simulations. We discuss ways to interpolate the ENLIL outputs for test-particle trajectory calculations. Using the ENLIL model output as input for our SEP simulations, we can study how the energetic particles react to more realistic and spatially inhomogeneous magnetic and electric fields. Our results therefore show the effects of energetic particle drifts and diffusion in the presence of natural curvatures and gradients contained within realistic heliospheric structures from ENLIL, and thus how particle trajectories evolve in the presence of more inhomogenities compared to with a simple Parker spiral geometry. We will discuss how these heliospheric fields could be included operationally, for use in the real-time forecasting of SEP events.

D2.1-0027-18 MULTI-SPACECRAFT OBSERVATIONS OF SOLAR ENERGETIC PARTICLES WITH STEREO

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Multi-point observations by the two STEREO spacecraft in combination with close-to-Earth observers have changed our understanding of the longitudinal distribution of solar energetic particles in the inner heliosphere. The so-called widespread events, which sometimes fill the space all around the Sun, still challenge current acceleration, injection, and transport theory. The strongly varying characteristics of those events suggest that there must be various mechanisms, which can contribute to the wide angular particle spreads. Among these mechanisms i) strong cross-field transport in the interplanetary medium and ii) extended injection regions close to the Sun are proposed. However, more complex scenarios involving the interaction of CMEs can also play a significant role for these events. We will discuss case studies as well as statistical results of solar energetic electron events observed by multiple spacecraft well separated in space.

D2.1-0028-18 MODELLING THE QUIESCENT GAMMA-RAY SOLAR EMISSION AND THE COSMIC RAY ELECTRONS IN THE INNER HELIOSPHERE

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The Sun is a known quiescent gamma-ray source. Its quiescent gamma-ray emission is produced by Galactic cosmic rays (CRs) interacting with its surface (disc component) and with its photon field (spatially extended diffuse component). This extended component, by inverse Compton scattering of CR electrons on the solar photons of the heliosphere, extends to the whole sky and it is above the background even at large angular distances from the Sun. It was studied already with EGRET, and now with Fermi LAT with higher significance. Observations of the inverse-Compton component allow obtaining information of CRs close to the Sun and in the Heliosphere as a function of different periods of solar activity. However, precise model calculations are needed.

StellarICs (Stellar Inverse Compton scattering) is a software to compute gamma-ray emission from inverse-Compton scattering by CR electrons in the Heliosphere and in the photospheres of stars. The software is publicly available and it is under continuing development. After reviewing past and present studies on the solar emission, we will present our software including also up-to-date models.

D2.1-0029-18 ELEMENTAL COMPOSITION IN SOLAR ENERGETIC PARTICLES

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In situ particle composition measurements over a wide range of species and energies in the heliosphere are a powerful tool in investigating the acceleration processes that produce solar energetic particles (SEPs). Minor heavy ions (with atomic number Z > 2) are particularly useful in this regard since they are genuine 'test' particles, too few in number to generate a feedback effect on the acceleration and transport processes. These minor ions also have various chargeto-mass (Q/A) ratios, which serve to identify seed populations and to probe the velocityand rigidity-dependent effects that govern injection, acceleration and transport of SEPs. In this work, an overview of recent key observations and results on elemental composition, derived from the data analysis of numerous missions in the heliosphere will be presented and discussed. Particular emphasis will be placed on the variability of the elemental composition as a proxy for the investigation of the accelerating shock properties as well as the explanation of large SEP events with uncommonly high Fe/O ratios, using measurements from widely separated spacecraft in solar longitude and latitude in the heliosphere. Furthermore, the future expected advances in view of the unique measurements provided by the upcoming Solar Orbiter and Parker Solar Probe missions in the inner heliosphere will be discussed.

D2.1-0030-18 UNDERSTANDING THE SPATIAL SPREADS AND SPECTRAL BREAKS OF GRADUAL SEP EVENTS: APPLYING IPATH SIMULATIONS TO SEP OBSERVATIONS.

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Recent observations from multi-spacecraft including STEREO show that gradual solar energetic particle (SEP) events can have significant longitudinal and radial spreads. One possible explanation is the cross-field transport of energetic particles in the interplanetary medium. Besides a large spatial spreading, spectra of SEP events often show spectral breaks with solar cycle dependence. The spectra breaks observed in cycle 24 are about 3 times lower in energy/nucleon compared with cycle 23.

In this work, we utilize the improved Particle Acceleration and Transport in Heliosphere (iPATH) model to help us understand these observational features. The iPATH model simulates particle acceleration at a CME-driven shock based on the diffusive shock acceleration (DSA) mechanism in a 2D domain. Transport of the accelerated particles is followed using the backward stochastic differential equation method. Both parallel and perpendicular diffusion are included in the transport process. Several large SEP events that are well observed by multiple spacecraft at different locations are examined using the iPATH model, with a focus on examining the role of the cross-field diffusion in the spatial distribution of SEP events. This can help us better predict and explain the Parker Solar Probe observations in the future. We also investigate the nature of the spectral breaks and examine their dependences on some of the solar wind and CME variables, by comparing iPATH simulations with observations.

D2.1-0031-18 SOURCES AND TRANSPORT OF ENERGETIC PARTICLES AT HIGH HELIOLATITUDES

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Understanding the origin and transport of energetic particles of keV-MeV energies throughout the heliosphere still represents one of the biggest problems of space physics. Our knowledge of the propagation of energetic particles is mostly based on theoretical predictions compared with spacecraft observations at low heliolatitudes. Meanwhile, the occurrence of energetic particles at high heliolatitudes is even more puzzling since only one spacecraft, Ulysses, flew over the poles of the Sun and provided information on the energetic particle properties far above the ecliptic plane.

Ulysses observations show that energetic particle flux enhancements occur at heliolatitudes over 40 degrees at both solar maximum and minimum conditions (see, e.g., Smith et al. 2001; Sanderson et al. 2003; Lario et al. 2004; Sanderson 2004; Malandraki et al. 2009). This suggests various scenarios of particle transport. Energetic particles of keV-MeV energies should propagate mainly along magnetic field lines, but if a source is an active region at low latitudes or an ICME, their detection at high latitudes can be explained by particle diffusion across magnetic field lines either in the solar wind or in the corona. In any event, sources of energetic particles observed above the ecliptic during solar maxima are more or less well identified. Interpretations of observations of keV-MeV energetic particles in polar regions during solar minima are more complicated. The association of energetic particle flux enhancements in the polar heliosphere with corotating interaction regions, the main sources of accelerated particles in quiet times, is sometimes unsuccessful since there are no signatures of cross-field diffusion or particle streaming from distant heliocentric distances back to the Sun as it was presumed.

The existence of long-lived conic (or cylindrical) current sheets (CCSs) in the polar solar wind can naturally solve this problem (Khabarova et al. 2017). It has been recently found that CCSs are low-beta and low-speed structures formed within polar coronal holes. CCS stability is supported by the tornado-like magnetic field. The occurrence of magnetic separators near the poles in solar minima is confirmed independently by reconstructions of the coronal magnetic field based on photospheric magnetic field charts. We show evidence for association of energetic particles observed by Ulysses above the pole with reconnection polar jets located at the circleshaped touchdown of a CCS. Therefore, it is demonstrated that CCSs might serve as channels for energetic particles accelerated in the solar corona by magnetic reconnection, which sheds light on the mystery of energetic particles observed at high heliolatitudes.

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Khabarova O.V. et al., High-latitude conic current sheets in the solar wind, The Astrophysical Journal, 836, 108, 1, 2017, https://doi.org/10.3847/1538-4357/836/1/108

D2.1-0032-18 JOVIAN ELECTRONS IN THE INNER HELIOSPHERE: MODELLING WITH A NEW SOURCE SPECTRUM

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Since the early seventies it is known that the Jovian magnetosphere is a source of low MeV electrons dominating the population in the inner Heliosphere. Therefor Jovian electrons have often been utilized as test particles to model charged particle transport and the corresponding transport parameters. It is evident that the results depend on both the assumed source spectrum as well as the general model setup. In our work we present an updated Jovian source spectrum based on flyby data and in agreement with measurements obtained at Earth orbit in the last 30 years. Furthermore we show first results of modelling spacecraft data via a stochastic differential equation (SDE) approach based on CUDA.

D2.1-0033-18 PENETRATING PARTICLE ANALYZER (PAN)

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PAN is a scientific instrument suitable for deep space and interplanetary missions. It can precisely measure and monitor the flux, composition, and direction of highly penetrating particles (> 100 MeV/nucleon) in deep space, over at least one full solar cycle (11 years). A possible mission opportunity is the Deep Space Gateway (DSG). The science program of PAN is multiand cross-disciplinary, covering cosmic ray physics, solar physics, space weather and space travel. PAN will fill an observation gap of galactic cosmic rays in the GeV region, which is crucial for improving our still limited understanding of the origin of cosmic rays, and of their propagation through the Galaxy and the Solar system. It will provide precise information of the spectrum, composition and timing of energetic particle originated from the Sun, which is essential for studying the physical process of solar activities, in particular the rare but violent solar events that produce intensive flux of penetrating particles. The precise measurement and monitoring of the energetic particles is also a unique contribution to space weather studies, in particular to the development of a predictive solar activity model in a multi-wavelength and multi-messenger approach, using observations both space and ground based. As indicated by the terminology, penetrating particles cannot be shielded effectively. PAN will map the flux and composition of these particles precisely and continuously, providing valuable input for the assessment of the related health risk, and for the development of an adequate mitigation strategy. PAN has the potential to become a standard on-board instrument for deep space human travel.

PAN is based on the proven detection principle of a magnetic spectrometer, but with novel layout and detection concept. It will adopt advanced particle detection technologies and industrial processes optimally for deep space application. The device will require limited mass (20 kg) and power (20 W) budget. Dipole magnet sectors built from high field permanent magnet Halbach arrays, instrumented in a modular fashion with high resolution silicon strip detectors, allow to reach an energy resolution better than 10% for nuclei from H to Fe at 1 GeV/n. The charge of the particle, from 1 (proton) to 26 (Iron), can be determined by scintillating detectors and silicon strip detectors, with readout ASICs of large dynamic range. Low power pixel detectors will maintain the detection capabilities for even the strongest solar events. Fast scintillator with silicon photomultiplier (SiPM) readout will provide timing information to determine the entering direction of the particle, and some isotope identification capability of light nuclei. Low noise, low power and high density ASIC will be developed to satisfy the stringent requirement of the position resolution and the power consumption of the tracker.

The PAN instrument concept has been invited for oral presentations at the ESA Deep Space Gateway Science Workshop on December 5-6, 2017 at ESTEC in Noordwijk, The Netherlands, and the NASA Deep Space Gateway Science Workshop on February 27 - March 1, 2018 in Denver, Colorado, USA.

D2.1-0034-18 THE EVOLUTION OF ENERGETIC PARTICLES OVER THE SOLAR CYCLE

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Solar Cycle 24 has been somewhat surprising in that the level of solar activity as measured by the number and fluence of large solar energetic particle (SEP) events has been significantly lower than in the two previous cycles. For example, after the first nine years of cycle 24, the integrated fluence of >10 MeV protons is lower than in cycle 23 by a factor of 3.4; the >100 MeV proton fluence is reduced by a factor of 5.4; and the number of ground-level events (GLEs) is lower by a factor of 6.5. The number of 3He-rich SEP events is also somewhat lower in this cycle. This talk will compare measures of SEP production from the last three cycles and discuss possible solar/interplanetary properties that may explain the lower cycle 24 output, including a weaker interplanetary magnetic field strength, a reduced number of fast CMEs and X-Class flares, and lower densities of suprathermal seed particles. Recent results from the Improved Particle Acceleration and Transport (iPATH) model will be used to test these ideas and illustrate how the upcoming Parker Solar Probe and Solar Orbiter missions can investigate these processes near the Sun.

D2.1-0035-18 SOLAR FLARE PEAK TEMPERATURES AS A FORECASTING TOOL FOR SOLAR ENERGETIC PARTICLE EVENTS

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Solar flare X-ray peak fluxes and fluences in the 1-8 A band are often used in models to forecast solar energetic particle (SEP) events. Garcia (2004) used the 0.5-4 and 1-8 A bands of the Xray instrument on the GOES spacecraft to plot inferred peak flare temperatures versus peak 1-8 A fluxes from 1988 to 2002. Flares associated with SEP events had statistically lower peak temperatures than those without SEP events and therefore offered a possible empirical forecasting tool for SEP events. We have repeated that work over the period 1998 to 2016, comparing the peak ratios of the 0.5-4 and 1-8 A band fluxes of flares > M3 to the occurrence of associated E > 10 MeV proton events with peak intensities Ip > 1 proton flux unit (pfu). We further distinguish small SEP events of 1 to 10 pfu from the larger events of > 10 pfu. We also find statistically lower X-ray band ratios for SEP events, confirming the earlier result. However, the ratio of the two peak X-ray fluxes may be a better diagnostic than their peak ratios.

D2.1-0036-18 THE SUN RADIO INTERFEROMETER SPACE EXPERIMENT (SUNRISE) MISSION CONCEPT

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Radio emission from coronal mass ejections (CMEs) is a direct tracer of particle acceleration in the inner heliosphere and potential magnetic connections from the lower solar corona to the larger heliosphere. Energized electrons excite Langmuir waves, which then convert into intense radio emission at the local plasma frequency, with the most intense acceleration thought to occur within 20 RSun. The radio emission from CMEs is quite strong such that only a relatively small number of antennas is required to detect and map it, but many aspects of this particle acceleration and transport remain poorly constrained. Ground-based arrays would be quite capable of tracking the radio emission associated with CMEs, but absorption by the Earth's ionosphere limits the frequency coverage of ground-based arrays (nu > 15 MHz), which in turn limits the range of solar distances over which they can track the radio emission (< 3 RSun). The state-of-the-art for tracking such emission from space is defined by single antennas (Wind/WAVES, Stereo/SWAVES), in which the tracking is accomplished by assuming a frequency-to-density mapping; there has been some success in triangulating the emission between the spacecraft, but considerable uncertainties remain.

We describe the Sun Radio Interferometer Space Experiment (SunRISE) mission concept, currently a NASA Phase A study: A proposed constellation of small spacecraft in a geostationary graveyard orbit designed to localize and track radio emissions in the inner heliosphere. Each spacecraft would carry a receiving system for observations below 25 MHz, and SunRISE would produce the first images of CMEs more than a few solar radii from the Sun.

Part of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

D2.1-0037-18 RADIO WAVE PROPAGATION IN THE SOLAR CORONA: HIGH-TIME-RESOLUTION WITH LOFAR.

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Using the Low Frequency Array (LOFAR), we analyse the source sizes and locations of the fine frequency structures in a solar radio burst. The high time resolution allows us to determine the location and the size of the radio emission source, and its evolution with time, following the radio emission propagation through the solar corona. It is found that intrinsically very small radio sources have an apparent size that is a thousand times larger than the actual region where the radio waves originate [1]. The observations suggest that it is radio wave propagation effects, rather than the intrinsic properties of the emission source, that determine the observed spatial characteristics of the plasma emission radio bursts. In addition, the observations provide a new opportunity for diagnostics of small-scale plasma fluctuations by imaging the radio source halos as the radio waves move in the solar corona.

[1] Kontar et al.: Imaging Spectroscopy of Solar Radio Burst Fine Structures, Nature Communications 8, Article number: 1515 (2017) DOI: 10.1038/s41467-017-01307-8

D2.1-0038-18 PROTOTYPE DESIGN OF DATA ACQUISITION SYSTEM FOR HXI ON BOARD ASO-S MISSION

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Advanced Space-based Solar Observatory satellite (ASO-S), the first solar observation mission of China, is scheduled to be launched on the eve of the next solar maximum year (about by the end of 2021). HXI is an essential payload for ASO-S, observing the X-ray image of solar flare in 30KeV-200KeV with high energy resolution and high time resolution. It consists of 4 parts: collimator, sun aspect system, calorimeter, and electronics control box. The collimator has a group of grid pairs, providing information about dozens of spatial scales of the X-ray emission. This information will be combined on ground to construct an image of the source in each energy band. The calorimeter contains an array of LaBr3 (lanthanum bromide) sensors and 4 front-end electronics boards, detecting the solar X rays from the collimator, and accumulating energy of each event into energy spectrum for each sensor with 0.1s minimum time resolution. The sun aspect system will offer the coordinates of the solar center during the observation. Electronics control box is mainly responsible for scientific data collection and packaging, telemetry-acquisition, power supply for other parts of HXI, etc. This paper will introduce the whole process of data acquisition, including readout of LaBr3 sensors, pre-process of the readout data (e.g. accumulation of the sensors' energy spectrum, packaging data, and so on), and science data collection from calorimeter and sun aspect system to electronics control box.

D2.1-0039-18 RADIO DIAGNOSTICS OF ENERGETIC ELECTRONS WITH GROUND -BASED INSTRUMENTATION IN SUPPORT OF THE PARKER SOLAR PROBE AND SOLAR ORBITER MISSIONS.

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Ground-based radio observations provide a wealth of information on the energetic electrons produced in the solar corona in association with solar flares or eruptive events. These observations will be complementary to the in-situ measurements of energetic particles that will be obtained aboard the Parker Solar Probe and Solar Orbiter missions as well as to the radio and X-ray diagnostics of energetic electrons provided by the FIELDS and RPW radio experiments on the Solar Probe and Solar Orbiter and the STIX X-ray instrument on Solar Orbiter. Decimetric/metric/ decametric radio observations will be routinely observed in Nançay (Paris Observatory) with a set of three instruments: the Nançay Radioheliograph (NRH) which will provide images of the solar corona between 450 and 150 MHz, and two spectrographs covering the complete frequency band from 1GHz to 10 MHz (with the solar-dedicated spectrograph ORFEES and the Nançay Decameter Array, NDA looking at both solar and jovian emissions). The combination of data from these three instruments can provide unique complementary observations on the propagation of electron beams from the flare site to the interplanetary medium as well as on the onset of coronal mass ejections and shocks. We will show a few examples of the complementarity of the observations and discuss how to coordinate the ground-based observations with satellite measurements.

(presentation on behalf of the NRH, NDA and ORFEES teams of Nançay)

D2.1-0040-18 FULL INVERSION OF ELECTRON EVENTS MEASURED BY HELIOS IN THE INNER HELIOSPHERE

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We present a study of a sample of 300-800 keV electron events observed by Helios-1 and Helios2 in the inner heliosphere during 1976-1982. We model these events taking into account the detailed angular distributions measured by the E6 experiment in eight different sectors. The results of a focused interplanetary transport model combined with an inversion procedure are used to fit the observations. Unlike in previous studies, we consider both the energy and angular responses of the detector. This method allows us to extract the electron release time profile at the source and infer the electron interplanetary transport conditions. We discuss the characteristics of the release time profiles and the values of the electron mean free path, and compare them with the values reported previously in the literature using older approaches. We highlight the importance of revisiting SEP events observed by Helios in order to better characterize the radiation environment that Solar Orbiter and the Parker Solar Probe will encounter.

D2.1-0041-18 PROPERTIES OF ALPHA PARTICLES IN STREAM INTERACTION REGIONS

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A corotating interaction region (CIR) forms when the fast solar wind emanating from coronal holes at low heliographic latitudes pushes up against the slow solar wind ahead of it, creating a compression region in the heliosphere that co-rotates with the Sun. Arising pressure perturbations decrease the speed difference between both streams and the pressure waves steepen into forward and reverse shocks, typically at solar distances larger than a few AU. The shocks can accelerate ions via Fermi acceleration but the accelerated particles are often observed in the stream interaction regions at 1 AU even if boundary shocks are not present. In the paper, we study a behavior of alpha particles in CIR compressed regions, using measurements of the spacecraft in the L1 point. Our study focuses on properties of the solar wind plasma nonequilibrium features: velocity and temperature ratios of alpha particles and protons and their relative flow speed. In the slow solar wind in front of CIRs, the relative helium abundance is low and the alpha-proton differential speed is close to zero. On the other hand, in the high-speed stream, both these parameters are higher and a significant correlation between the proton-alpha velocity ratio and magnetic cone angle is often observed. Inside CIRs, close to the leading edge, the fast solar wind is slowed down and compressed, whereas the accelerated slow solar wind is observed close to the trailing edge. These regions are characterized by large variations of IMF, thus their study sheds a light on the evolution of the alpha-proton differential motion.

D2.1-0042-18 MECHANICAL DESIGN FOR HARD X-RAY IMAGER ONBOARD SATELLITE ASO-S

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Satellite ASO-S (Advanced Space-based Solar Observatory), a Chinese satellite for solar observation during the maximum years of the solar activity cycle 25, is now under developing for the Strategic Priority Research Program on Space Science of Chinese Academy of Sciences. Under CAS's new Innovation 2020 program, the engineering qualification model of ASO-S will be done in next year. Three payloads, Full-disc vector Magneto Graph, Lyman-alpha Solar Telescope and Hard X-ray Imager, are onboard ASO-S to observe solar flares, CMEs and solar magnetic field at the same time. As the largest one of the three payloads, HXI is aimed to get the image of hard x-ray at energy range from 30keV to 200keV with 98 pairs of Fourier collimation units. Prototype mechanical design and finite element analysis of HXI have been done to make the structure of HXI stable against vibrations during launch.

D2.1-0043-18 THERMAL DESIGN FOR HXI ON BOARD ASO-S MISSION

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ASO-S is being developed as a scientific satellite aimed to observe solar flares, CMEs and solar magnetic field at the same time. Hard X-ray Imager (HXI), one of the three major sub-detector, mainly focuses on the solar flares with about 100 pairs of grid stacked by tungsten foil fabricated in different pitches. As the highly accuracy of the HXI collimator (HXI-C in short) for imaging is of vital significance, for example, a relative shift of one grid with respect to the others larger than 6m could change the position of the image, thus, the thermal control design could play a key role for HXI-C in space for the huge impact on the imaging of the deformation. This paper first introduces the major sections of the HXI-C from the viewpoint; in the second part, both the influence of the deformation for HXI-C imaging and the latest thermal design according to physical requirements will be present in detail. Also, some FEM analysis will be performed based on the launch and space environment in accordance with the thermal design. Conclusion will be proposed in the end that HXI collimator could meet the demands while some suggestions of optimization still needs to be carried out in detail.

D2.1-0044-18 ESTIMATES OF THE ENERGETIC PROTON ENVIRONMENT AT L1 POINT

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The interplanetary space is permeated by 'thermal' solar wind plasma and by a higher energy particle component, which increases of several orders of magnitude during Solar Energetic Particle (SEP) events. The estimation of this high energy particle background is essential for any mission profile. For instance, protons with energies in the range 50 - 500 keV (the so called soft protons) are of particular interest for the ATHENA mission, as they enter the mirrors, being concentrated towards the focal plane instruments. Here, proton flux data obtained from both ACE and IMP-8 spacecraft, covering the 1997-2015 interval (solar cycles No. 23 and 24) and the 1973-2001 interval (solar cycles No. 21, 22, and 23), respectively, have been used to estimate the energetic proton environment at L1 point. In particular, cumulative distribution functions (CDFs) have been obtained for the 8 differential energy channels (in the energy range 0.70 - 4.75 MeV) of the EPAM/LEMS120 experiment onboard ACE as well as for two energy channels of CPME experiment on board IMP-8. Since the EPAM/LEMS120 first energy channel (P1') is affected by an unphysical quasi-periodic modulation, it has been filtered by using the HilbertHuang Transform (HHT) approach, based on both Empirical Mode Decomposition (EMD) and Hilbert Spectral Analysis (HSA). In this way, a corrected (filtered) P1' signal has been derived from which CDFs can be properly evaluated, showing that the unphysical modulation tends to increase values of a factor ranging between 1.2 and 2. Moreover, both ACE and IMP-8 proton fluxes are compared on similar energy channels showing a similar CDFs behavior, although solar cycles behavior was different in the different time intervals.

D2.1-0045-18 PROTOTYPE DESIGN OF PIXELATED CALORIMETER FOR HXI ON BOARD ASO-S MISSION

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The Hard X-ray Imager (HXI) is one of the three core instruments on Chinese first Solar Observation Satellite: Advanced space-based Solar Observatory (ASO-S). This satellite to be launched around 2021 belongs to the second batch of missions under the Strategic Pilot Project in Space Science of CAS. HXI applies a Fourier-imaging technique using a set of tungsten grids in front of LaBr3 Calorimeter arrays to provide imaging spectroscopy of solar thermal and non-thermal hard X-ray emissions from 30 to 200 KeV. The calorimeter consists of arrays of LaBr3 crystals & PMTs, Front Ended Electronics and High Voltage Distributers. Prototype design of the calorimeter will be reviewed in this paper with some critical problems & solutions in handling the great changes of solar x-ray flux being discussed. Particular emphasis is given to the Adaptive Spectrum Accumulator & Solar X-ray Burst Trigger System.

D2.1-0046-18 MODELLING OF THE INJECTION FUNCTION OF SOLAR ENERGETIC PARTICLES

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Solar energetic particles (SEPs) are accelerated at the Sun during either short-lived, impulsive events called solar flares or gradual events called coronal mass ejections (CMEs). An injection function is used to model the injection of SEPs from a source region on the Sun into interplanetary space. Previously, injection functions were modelled by using ad-hoc expressions, but it has become increasingly important to base the injection function on more realistic parameters and constrain it with available spacecraft data. This study investigates the particle intensities from transient events by varying parameters related to the injection function used in our SEP transport model. The importance of the onset and decay-times, and the longitudinal extent of the injection function are discussed while comparisons are drawn between single and multiple Gaussian injections from the same active region. We propose that the injection profile can be constrained further by incorporating remote sensing observations using a multi-wavelength approach. Implications for Solar Orbiter and Parker Solar Probe observations will also be discussed.

D2.1-0047-18 THE SOLAR ORBITER ENERGETIC PARTICLE DETECTOR

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Energetic particles in the heliosphere obtain their elevated energetic status after three processes: injection, acceleration, and transport. Suprathermal seed particles have speeds well above the fast magnetosonic speed in the solar wind frame of reference and can vary from location to location and within the solar activity cycle. Acceleration sites include reconnecting current sheets in solar flares or magnetspheric boundaries, shocks in the solar corona and heliosphere and at planetary obstacles, as well as planetary magnetospheres. Once accelerated, particles are transported from the acceleration site into and through the heliosphere. Thus, by investigating properties of energetic particles such as their composition, energy spectra, pitch-angle distribution, etc. one can attempt to distinguish their origin or injection and acceleration site. This in turn allows us to better understand transport effects whose underlying microphysics is also a key ingredient in the acceleration of particles. In this poster we will present the Energetic Particle Detector (EPD) on Solar Orbiter, its status and capabilities, and consider implications for the key science goal of Solar Orbiter and Parker Solar Probe - How the Sun creates and controls the heliosphere.

D2.1-0048-18 AN UPDATED DEFINITION OF GLE AND SUB-GLE EVENTS

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The concept of the ground-level enhancement (GLE, http://gle.oulu.fi) of the neutron monitor (NM) count rate, caused by solar energetic particles (SEP), plays an important role for many statistical and scientific studies. The classical definition says that a GLE has been identified when a near simultaneous increase (typically associated with solar activity) is registered by at least two differently located NMs regardless of their atmospheric and geomagnetic cutoff properties. This included NMs at a high-altitude polar site with the reduced total cutoff (SOPO/B at the Amundsen-Scott station, South Pole, Antarctica, elevation 2835 m asl), and Vostok NM (Vostok station, 3500 m, operating only 1963-1969). However, a new high-altitude polar NM (DOMC/B) was installed at Concordia station (Dome C, Antarctica, elevation 3233 m asl) in 2015. As a result, there is a pair of exceptionally sensitive instruments (SOPO/B and DOMC/B) that can formally register a near simultaneous increase from a relatively weak SEP event below the full atmospheric cutoff, which would have not been detected at any other NM station and, accordingly, not accepted as a GLE before 2015. This would potentially distort the homogeneity of the present GLE list by more frequent detections due to the enhanced sensitivity of the global NM network.

In order to maintain the homogeneity of the events previously listed as ground-level enhancements, we propose to modify the presently used GLE definition as follows: "A GLE event is registered when there are near-time coincident and statistically significant enhancements of the count rates of at least two differently located neutron monitors, including at least one neutron monitor near sea level and a corresponding enhancement in the proton flux measured by a space-borne instrument(s)." We also propose to classify SEP events under the full atmospheric cutoff, which are seen only in data of high-altitude polar NMs, as sub-GLEs. We note that this definition does not affect the present list of GLEs.

D2.2-0001-18 THERMAL INSTABILITY AND GALACTIC PRECIPITATION

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The feedback cycles that regulate the evolution of massive galaxies depend critically on condensation of cold clouds out of hot circumgalactic gas. I will review the observational evidence and theoretical models indicating that condensation and infall of cold clouds–a process sometimes called galactic precipitation–fuels the central supermassive black hole of a massive galaxy, producing energetic outflows that regulate the rate of condensation. Much of that evidence comes from observations and models of the central galaxies of galaxy clusters. Some of these galaxyscale precipitation processes may resemble the production of coronal rain, and I will attempt to compare and contrast those phenomena.

D2.2-0002-18 THE PHYSICS OF THERMAL NONEQUILIBRIUM

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The presence of cool, dense mass in the hot, rarefied solar corona, in the form of prominences, has mystified scientists for over a century. Its more fragmentary and dynamic manifestation, coronal rain, was discovered more recently but has been equally perplexing. Several processes have been proposed to explain this phenomenon: levitation (bulk lifting of chromospheric mass into the corona), injection (bulk expulsion of chromospheric mass), and evaporationcondensation methods. This talk addresses the last category, which has received the greatest quantitative scrutiny over the past 20 years, particularly in the form of thermal nonequilibrium (TNE). Thermal nonequilibrium has specific requirements and observable signatures, which have been explored thoroughly with theoretical analyses, numerical simulations, and comparison with known characteristics of prominences and coronal rain. I will discuss the basic physical processes at the heart of TNE, the parameter studies that have established the strengths and limitations of this mechanism as applied to these solar phenomena, the latest extensions to multidimensional magnetic geometries and more realistic physics, and future research directions.

D2.2-0003-18 EVOLVING CLASSIFICATIONS OF SOLAR PROMINENCES

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Classification schemes with main classes and subclasses began with Sechi in 1875 who categorized prominences mostly from their shapes. With the aid of spectroheliograms and photography, the number of different categories of prominences maximized with Petit from 1925-1950 who added classes according their dynamics, and relationships to active regions and solar flares. With the recognition that not all prominences seen at the limb corresponded to features seen against the disk, many observers began referring to disk prominences as "filaments." With the greater abundance of data enabled by the use of birefringent, interference filters and timelapse photography, many attempts were made through the 1960s to created physically significant prominence (filament) classifications as cited in the two books on solar prominences by Tandberg-Hanssen. Reversal of the trend for increasingly complex classifications began in the 1950s after invention of the magnetograph. Filaments in Hα were all found to lie between areas of opposite polarity, line-of-sight magnetic fields. Features, such as flare loops, spicules, and surges acquired separate identities and no longer needed to be classified as prominences. Observations with increased spatial resolution allowed the identity of fine thread-like structure within the basic spine and barb structure of filaments. The recognition of chirality in the threads of filaments and of fibrils in their filament channels enabled the unifying of all filaments under the name channel filaments (channel prominences). 304Å observations aided detection of greater numbers of coronal cloud prominences, funnel prominences, and coronal rain. Funnel prominences and coronal cloud prominence are deduced to be the same basic structures seen from different perspectives but not all coronal rain comes from coronal cloud prominences. Therefore, prominence classifications are reduced to three physically-different phenomena: channel prominences, coronal cloud prominences and coronal rain. An open question is whether all features called coronal rain are fundamentally the same.

D2.2-0004-18 A MODEL FOR HOW INDUCED REVERSED-CURRENTS FORM CAVITIES ABOVE PROMINENCES

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Solar prominences are often observed to have an associated cavity, i.e., a region of depleted density and twisted magnetic field. Cavities are traditionally assumed to be the projection of a surrounding magnetic flux rope and are observed above both stable and erupting prominences [1]. How cavities form is of particular interest because cavity formation is an observable feature closely associated with the large-scale structure of the magnetic field [1,2].

Existing theories of cavity formation use 1D hydrostatic models along fixed magnetic field lines [1,2]. These theories are limited to specific magnetic equilibria and are characterized by hydrostatic scaling resulting from stratification in the presence of a gravitational field. However, measurements of cavity density have shown that the density depletion relative to the background is maximum at low altitude and minimum or zero at the top of the cavity [3]. This implies that a mechanism independent of gravitational stratification is likely responsible for cavity formation.

We propose a model whereby a dynamic, magnetically driven mechanism is responsible for cavity formation, equilibrium, and evolution. The model is motivated by experimental measurements of cavity formation above an erupting flux rope in the Caltech single-loop experiment and also by matching results from 3D numerical MHD simulations. This model provides a detailed explanation for cavity evolution in terms of the repulsion between primary and induced reverse currents in a prominence. The model explains several observed trends including (i) why cavity density depletion is greatest at low altitude and (ii) why prominences with larger cavities are more likely to erupt.

S. Gibson, Coronal Cavities: Observations and Implications for the Magnetic Environment of Prominences pp. 323-353. Springer International Publishing, 2015

Schmit et al., "Prominence Mass Supply and the Cavity," ApJ, 779, p. 156, 2013

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D2.2-0005-18 FORMATION OF MOLECULAR GAS PROMINENCES IN GALACTIC CENTRAL REGION

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We present the results of magnetohydrodynamic simulations of the formation of molecular loops (loops of dense molecular gas) found by Fukui et al. (2006) in our galactic central region. The length of the molecular loops is several hundred pc, and their height exceeds 100pc. The total mass of a molecular loop is around 106 solar mass. The galactic center molecular loops are similar to solar prominences because dense, cold ($T < 100K$) medium is floating in warm (T 6000K) medium.

Since it is hard to form molecular loops by uplifting dense molecular gas, we considered an in-situ formation model of molecular gas by applying the reconnection-condensation model of solar prominences, in which prominences are formed by cooling instability in helical magnetic flux ropes formed by footpoint motions of the magnetic arch. We conducted two-dimensional and three-dimensional resistive magnetohydrodynamic simulations taking into account the cooling/heating of the interstellar medium. The galactic gravitational field is simulated by using the Miyamoto-Nagai gravitational potential. The simulation region is a local part of the galactic disk corotating with the disk. At the initial state, we assumed force-free magnetic arcades and hydrostatic layer in thermal equilibrium in warm state.

Numerical results indicate that magnetic reconnection taking place in the current sheet formed inside the rising magnetic arcade creates dese blobs confined by helical magnetic flux ropes. Thermal instability in the flux ropes forms dense filaments floating at 100-200pc above the galactic plane. The mass of the filament increases with time and exceeds 105 solar mass. The position-velocity diagram depicted by numerical results reproduces the position-velocity diagram obtained by CO observations.

The region just outside the Central Molecular Zone (CMZ) in our galactic center is the most suitable place for the molecular loop formation because the equilibrium density of the warm gas is high due to the enhanced heating in the galactic center. Strong magnetic fields in the galactic center also helps to sustain the dense loops against gravity.

D2.2-0006-18 THE IMPACT OF MAGNETIC FIELDS ON THERMAL INSTABILITY

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Cold filaments or prominences are ubiquitous in our universe, which exist in a wide range of astrophysical objects from solar corona to galaxy halos and galaxy clusters. In this talk, I will raise thermal instability as a possible mechanism leading to filaments or prominences, and investigate how magnetic fields can significantly enhance thermal instability and modify the structure of multiphase gas, which is applicable for both galaxy halos and galaxy clusters, and is potentially illuminating for the formation of prominences in solar corona.

D2.2-0007-18 A LONG-LIVED CORONAL CONDENSATION SITE LASTING EIGHT MONTHS

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Cool plasma material, such as prominences or coronal rain, can form in-situ by condensation in the solar corona due to a runaway radiative cooling instability (a.k.a. thermal non-equilibrium). Recent observations and numerical simulations suggest that such condensations are quite common. In quiet-Sun regions, they occur preferentially in locations where magnetic field is weak (e.g., null points) or discontinuous (e.g., current sheets). Such events usually have short lifetimes of hours to days. Surprisingly, we observed a high-latitude condensation site lasting over eight months in 2014 with recurrent and episodic condensations fueling a funnel-shaped prominence. Uplifting V-shaped features suggest sustaining reconnection inside the funnel. We analyze the coronal magnetic topology to investigate the necessary condition of such a long-lived condensation site. We find that the site was directly above a poleward photospheric flux surge when the polar field polarity was close to its solar cycle reversal. The large-scale magnetic cancellation front may have sustained interchange reconnection at this location, creating suitable conditions for coronal plasma condensation.

D2.2-0008-18 LARGE-SCALE MAGNETIC FUNNELS IN THE SOLAR CORONA

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The existence of open coronal magnetic fields with peculiar geometry - large-scale coronal magnetic funnels - can be attributed to two main factors: (i) the presence of two or more coronal holes of the same polarity forming coronal pseudostreamers, (ii) specific configurations of closed magnetic field in the low corona - filament channels. The important property of magnetic funnels is their strongly non-monotonic expansion factor below 2 solar radii. In the case study presented here we consider a double pseudostreamer near the equator, formed between a triplet of isolated coronal holes of the same polarity, and harboring two pairs of twin filaments in its base. Following the evolution of these coronal holes we find that the pseudostreamer and, therefore, magnetic funnel topology, changes when two coronal holes have merged together. Using a potential field source-surface (PFSS) extrapolation to compute the coronal field from photospheric maps (SDO/HMI), we show that the funnel - like geometry of the open magnetic field changes to a regular one with monotonic expansion factor after the merging of coronal holes. The presence of coronal magnetic funnels becomes directly visible when sufficient plasma accumulates inside them: when the plasma density grows to become observable, coronal cloud prominences appear in the corona, mostly in 304 A spectral line. We study the evolution of the funnel - like open magnetic fields during several solar rotations and find a direct relation between magnetic funnels and the presence of coronal clouds at great heights in the solar corona. 1D numerical analysis of pseudostreamers with funnel topology shows that the properties of the solar wind from coronal magnetic funnels depend on the presence/absence of filament channels, number of channels and chirality at the pseudostreamer base low in the solar corona.

D2.2-0009-18 THE CORONAL MONSOON: THERMAL NONEQUILIBRIUM REVEALED BY PERIODIC CORONAL RAIN

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We report on the discovery of periodic coronal rain in an off-limb sequence of SDO/AIA images. The showers are co-spatial and in phase with periodic (6.6 hr) intensity pulsations of coronal loops of the sort described by Auchère et al. (2014) and Froment et al. (2015, 2017. These new observations make possible a unified description of both phenomena. Coronal rain and periodic intensity pulsations of loops are two manifestations of the same physical process: evaporation / condensation cycles resulting from a state of thermal nonequilibrium (TNE). The fluctuations around coronal temperatures produce the intensity pulsations of loops, and rain falls along their legs if thermal runaway cools the periodic condensations down and below transition-region (TR) temperatures. This scenario is in line with the predictions of numerical models of quasi-steadily and footpoint heated loops.

This event of periodic coronal rain is compared with a similar event showing only pulsations at coronal temperatures but no significant cool rain fall. For both events we have stereoscopic observations from the SDO and STEREO spacecraft which allows reconstruction of the 3D loop geometries. Comparison with numerical simulations suggest that these two events correspond to two regimes of TNE: one with "full condensations" (coronal rain) and another in which "incomplete condensations" start to develop but are pushed down one loop leg before they can reach chromospheric temperatures.

These new observations impose severe constrains on the spatio-temporal distribution of coronal heating.

D2.2-0010-18 DYNAMICS AND MORPHOLOGY OF SOLAR PROMINENCES FROM MHD SIMULATIONS

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The numerical solution of the magnetohydrodynamic (MHD) equations allows us to investigate prominences/filaments represented by cold and dense plasmas suspended against gravity, and supported by the magnetic field. Our interest is in models that connect the magnetic field to the photosphere and include an overlying arcade. Two basic types of such structures are considered, prominences incrusted in shear magnetic arcades, and prominences embedded in three-dimensional magnetic flux ropes. Depending on the parameters, we find structures that are suspended above the photosphere, but also configurations resembling curtain or hedgerow prominences. During their evolution magnetic Rayleigh-Taylor instabilities and Kelvin-Helmholtz instabilities develop, producing a reach dynamics in the system. Special attention is devoted to all the oscillatory phenomena that takes place during the time evolution of the prominences. Finally, the problem of how the neutral component of the plasma in prominences is supported against gravity is addressed. We find that the system is able to relax in the vicinity of magnetic dips to a stationary state in which both neutrals and ionized species are dynamically suspended above the photosphere.

D2.2-0011-18 NUMERICAL MODELING OF PROMINENCE FORMATION FROM RECONNECTION TO RADIATIVE CONDENSATION

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We briefly review recent progress in numerical modeling for prominence formation and introduce our model, reconnection-condensation model. Origin of cool dense plasmas and mechanism of mass maintenance in the hot tenuous corona is one of the most important subjects in studies of solar prominences. Radiative cooling condensation is a promising process to supply mass for prominences. The formation mechanism of fine structures and turbulence in prominence and their physical role for mass condensation are also unclear.

Numerical modeling is useful to investigate these issues. In previous numerical studies, it is known that chromospheric evaporation driven by parameterized footpoint heating leads to in-situ coronal condensation. The evaporation-condensation model was demonstrated in a three-dimensional flux rope structure using magnetohydrodynamic (MHD) simulations including thermal conduction and radiative cooling, and succeeded in reproducing prominences with fine structures by fragmented condensations. Despite these efforts, the issue on unclear origin of the footpoint heating still remains.

We attempt to consider a different process leading to radiative condensation. In observations, prominences always appear along polarity inversion lines, suggesting that cancelation or reconnection must be related to radiative condensation. In the previous simulations on radiative condensation, self-consistent multi-dimensional reconnection process were absent. We propose reconnection-condensation model and demonstrate it using three-dimensional MHD simulations including nonlinear anisotropic thermal conduction and optically thin radiative cooling. In our model, a flux rope is created by reconnection via converging footpoint motion. By elevation of dense coronal plasmas and topological change in coronal magnetic fields, radiative condensation is triggered inside the flux rope. Our results show clear link between reconnection and radiative condensation, and suggest that evaporation is not always necessary.

Recently, we improved the model to include dynamic fine structures by the Rayleigh-Taylor instability. We found that mass condensation rate is enhanced to balance with mass drainage rate by coupling with the Rayleigh-Taylor instability. We compare the simulation results with observations and discuss remained issues in numerical modeling for prominence formation.

D2.2-0012-18 MULTIDIMENSIONAL SIMULATIONS ON EVAPORATION-CONDENSATION IN COMPLEX CORONAL MAGNETIC FIELD

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We present multidimensional simulations to illuminate that evaporation-condensation process can produce both prominence and coronal rain depending on the complexity of magnetic topology. On a two-dimensional (2D) magnetic arcade, we demonstrate how evaporationcondensation can induce in-situ cross-field condensations which fall along arcade loops as coronal rain. The virtual coronal rain displays the deformation of blobs into V-shaped features and streaming lines. The transition region between cool dense material and hot coronal plasma is revealed with high-resolution simulation. We found shear flows along neighboring loops are siphon flows set up by multiple blob dynamics and they affect the deformation of the falling blobs. On a three-dimensional (3D) weak magnetic bipolar arcade, we found fast in-situ condensation across loop top due to symmetry. The first large-scale condensation on the loop top suffers Rayleigh-Taylor instability and becomes fragmented into smaller blobs. The blobs fall vertically dragging magnetic loops until they enter the lower region with stronger magnetic field and start to fall along the loops from loop top to loop footpoints as coronal rain. On a 2D quadrupolar magnetic system with a coronal null point and four groups of magnetic loops, we present how evaporation-condensation produce a prominence in the dipped magnetic region. And subsequent descending of the prominence triggers magnetic reconnection near null point, which leads to redistribution of prominence material to underlying loops to be coronal rain. In a 3D helical magnetic flux rope, we reproduced a prominence formation as a result of in-situ plasma condensations collected in the dipped magnetic regions of the flux rope. The prominence is born and maintained in a fragmented, highly dynamic state with a continuous reappearance of multiple blobs and thread structures that move mainly downward dragging along massloaded field lines. A plasma circulation is found by self-organized dynamic balance between the drainage of prominence plasma back to the chromosphere and the formation of prominence plasma via continuous condensation. Common features, such as, rebound shocks generated by the siphon inflows during condensation and counter-streaming shearing flows around dynamic condensed blobs, are discussed.

D2.2-0013-18 THE EFFECT OF THERMAL NONEQUILIBRIUM IN STREAMERS

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Thermal nonequilibrium (TNE) is the process in which a solar coronal loop undergoes a nonsteady cycle of condensation formation due to the spatial localization of coronal heating near the loop base. Since the requirements for TNE onset is that the loop length is large compared to the scale of the heating, we investigate the effects of TNE on the largest loops in the corona, those of a helmet streamer. Our numerical study uses a 2.5D MHD code that includes the full magnetic field dynamics as well as the detailed plasma thermodynamics. As in previous 1D loop studies, we find that TNE occurs in coronal loops with sufficiently large length, but in contrast to 1D studies, we find that the process also drives substantial magnetic dynamics, especially near the top of the streamer where the plasma beta becomes of order unity. From the simulation results we determine predictions for spectroscopic and imaging observations of both the hot and cool helmet streamer plasma. We conclude that TNE occurring in the largest closed loops in the corona may explain several puzzling observations of the corona, such as the ubiquitous blue shifts observed at the edges of active regions. We also discuss the implications of our results for the solar wind.

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D2.2-0014-18 SEARCH FOR PREDICTED PERIODIC FLOWS IN LOOPS UNDERGOING THERMAL NON-EQUILIBRIUM

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Long-period intensity pulsations have been recently detected in coronal loops with EUV images of both SoHO/EIT (Auchère et al., 2014) and SDO/AIA (Froment et al., 2015). These pulsations have been interpreted as resulting from thermal non-equilibrium (TNE), thus providing a signature of a highly-stratified and quasi-constant heating at the loops footpoints (Froment et al., 2017; Auchère et al., 2016). Depending on the adequacy between the geometry of the loop and the characteristics of the heating, this can result in either complete (at chromospheric temperatures) or incomplete (> 1 MK) condensation and evaporation cycles, that are responsible for the observed intensity pulsations. Using 1D hydrodynamic simulations, Froment et al. (2017) were able to reproduce the observed pulsations, with incomplete condensation for the active region studied in their previous paper. The simulations also predict periodic plasma flows along the loops footpoints, with velocities up to 40 km/s.

We try to detect these flows by using time series of spatially resolved spectra from the EUV spectrometer Hinode/EIS. We systematically search for EIS datasets that correspond to the observation of pulsation events among the 3000+ that were detected in AIA data, between 2010 and 2016. For the 9 datasets that are found, we derive series of Doppler velocity maps, which allows us to track the evolution of the plasma velocity in the loop over several pulsation periods. We then compare these data to the results of previous simulations and observations. However the expected pulsations in velocity cannot be identified in any of the datasets that we analysed. We demonstrate that line of sight ambiguities, combined with low signal to noise ratio or lack of time cadence, can explain this non-detection.

D2.2-0015-18 EVOLUTION OF MAGNETIC-TOPOLOGY DURING ERUPTION OF A LABORATORY ARCHED MAGNETIZED PLASMA

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The solar atmosphere is carpeted with arched magnetic structures that confine plasma and store energy over a broad range of spatio-temporal scales. Solar eruptive events (e.g., coronal mass ejections and flares) are triggered when these structures become unstable by a variety of fundamental processes (e.g., force-imbalance, magnetic-reconnection, current-driven instabilities). Contemporary research on these topics is at the forefront of solar and heliospheric physics due to its relevance to space weather. After briefly reviewing the progress made in this area and highlighting the importance of laboratory experiments, new results from the UCLA

experiment on arched magnetized plasmas (plasma β 10−3, Lundquist number = 102-105,

plasma radius/ion-gyroradius 20, B 1000 Gauss at footpoints) will be presented. The arched magnetized plasma was created using a lanthanum hexaboride (LaB6) plasma source and it evolved in an ambient magnetoplasma produced by another source. The experiment runs continuously with a 0.5 Hz repetition rate and produces tens of thousands of nearly identical eruptions within a day. This unique feature provides flexibility in recording the plasma parameters with a good-resolution in three-dimensions. During the time-evolution of the arched magnetoplasma, multiple-frames were captured using a fast-CCD camera and correlated with the magnetic-topology recorded using a three-axis magnetic-loop probe. The relative magnitudes of the parameters of the arched and ambient magnetoplasma were varied to simulate conditions relevant to arched magnetized plasmas on the Sun. This laboratory research provides important details of physical processes that occur before and after eruption of arched magnetized plasma structures (e.g., spontaneous excitation of Alfven waves and kink-mode oscillations, ejection of large scale flux ropes).

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D2.2-0016-18 EXPERIMENTAL INVESTIGATION OF COAXIAL-GUN-FORMED PLASMAS INJECTED INTO A BACKGROUND TRANSVERSE MAGNETIC FIELD OR PLASMA

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Injection of coaxial-gun-formed plasma jets (open B-field) and plasma spheromak/bubbles (closed B-field) into a background transverse vacuum magnetic field or into a background magnetized plasma has been studied in the helicon-cathode (HelCat) linear plasma device at the University of New Mexico.[1] These situations may have bearing on astrophysical settings (e.g. astrophysical jet stability, coronal mass ejections, etc.) and fusion plasmas (e.g. plasma injection for tokamak fueling, ELM pacing, or disruption mitigation). The magnetic Reynolds number of the gun plasma is 100, so that magnetic advection dominates over magnetic diffusion. The gun plasma ram pressure, ρjetV 2 >B2/2μ0, the background magnetic pressure, so jet 0

that the jet or bubble can easily penetrate the background B-field, B0. When the gun axial B-field is weak compared to the gun azimuthal field, a current-driven jet is formed with a global helical magnetic configuration. Applying the transverse background magnetic field, it is observed the emergent kink stabilization of the jet due to the formation of a sheared flow in the jet above the threshold 0.1kVA.[2] We conclude that the tension force arising from increasing curvature of the background magnetic field induces the measured sheared flow gradient, resulting in the emergent kink stabilization.[3] In the case of injected bubbles, spheromak-like plasma formation is verified. However, launching into a transverse background magnetic field led to the observation of finger-like structures on the side with a stronger magnetic field null between the spheromak and background field. The finger-like structures are consistent with magneto-Rayleigh-Taylor instability. Jets or spheromaks launched into a background, low-β magnetized plasma show similar behavior as above, respectively, in both cases.

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D2.2-0017-18 OBSERVATIONS OF A SHEAR-FLOW INSTABILITY DRIVEN BY DYNAMIC PROMINENCE MOTIONS

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Prominences are incredibly dynamic across the whole range of their observable spatial scales, with observations revealing gravity-driven fluid instabilities, waves, and turbulence. With all these complex motions, it would be expected that instabilities driven by shear in the fluid motions contained in the prominence body would develop. However, evidence of these have been lacking. Here we present the discovery in a prominence, using observations from the Interface Region Imaging Spectrograph (IRIS), of a shear flow instability, a mode of the Kelvin-Helmholtz instability that makes streams of fluid develop serpentine patterns, driven by transonic motions in the prominence body. This finding presents a new mechanism through which we can create turbulence from the flows observed in quiescent prominences. The observation of this instability in a prominence highlights their great value as a laboratory for understanding the complex interplay between magnetic fields and fluid flows that play a crucial role in a vast range of astrophysical systems.

D2.2-0018-18 THREE-DIMENSIONAL VELOCITY MEASUREMENTS IN SOLAR PROMINENCE BUBBLES AND COMBINED KELVIN-HELMHOLTZ/ RAYLEIGH-TAYLOR INSTABILITY

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We present measurements of flow velocities in solar prominences that display so-called "prominence bubble" events. Prominence bubbles are large-scale buoyant intrusions into prominences that rise from below and penetrate into the overlying plasma. They are believed to be due to magnetic flux emergence below prominences and can trigger Rayleigh-Taylor and KelvinHelmholtz instability flows as they interact with the overlying prominence. Prominence bubbles frequently result in the formation of plumes that rise into, or entirely through, the overlying prominence. This presents a mechanism for increasing magnetic flux and helicity in the associated coronal magnetic flux tubes, which are key for their eventual loss of equilibrium and eruptions as coronal mass ejections (CMEs).

In this presentation, Hinode/Solar Optical Telescope (SOT) and Interface Region Imaging Spectrograph (IRIS) observations are analyzed to infer three-dimensional flow vectors in the "boundary layer" above several prominence bubble events. IRIS Doppler velocity measurements indicate flow speeds of 50–100 km/sec perpendicular to the sky plane, consistent with flow speeds inferred from combined Kelvin-Helmholtz/Rayleigh-Taylor instability analysis using typical quiescent prominence density and magnetic flux density values. With these typical values, flow speeds and magnetic flux densities within the bubbles can be inferred to be on the order of 100 km/sec and 10 Gauss, respectively. We discuss the implications of these novel results, and in particular, the potential for strong shear flows at the bubble boundary to trigger Kelvin-Helmholtz instability waves that develop into large-scale Rayleigh-Taylor instability plumes.

D2.2-0019-18 WHAT BRAKES CORONAL RAIN?

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Coronal rain blobs usually fall toward the solar surface with a smaller than free-fall acceleration. After conducting numerical simulations with different setups, we conclude that once a dense blob forms and starts to fall along a coronal loop, a pressure gradient is established along the loop such that higher (smaller) pressure can be found below (above) the blob. This pressure gradient produces an upward force that partially counteracts gravity and leads to the observed non-free-fall dynamics.

D2.2-0020-18 EXCITATION AND EVOLUTION OF TRANSVERSE LOOP OSCILLATIONS BY CORONAL RAIN

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Coronal rain is composed of cool dense blobs that form in solar coronal loops and are a manifestation of catastrophic cooling linked to thermal instability. The nature and excitation of oscillations associated with coronal rain is not well understood. We present an overview of observations of coronal rain oscillations seen in data from IRIS, SOT/Hinode and AIA/SDO as well as ground-based observatories. We follow this with detailed analytical and numerical MHD modelling to elucidate the excitation mechanism and evolution of wave characteristics in rain. We will discuss the possibility for rain blobs to excite transverse oscillations due to gravitational or inertial forces as well as acoustic oscillations due to a piston effect. In particular, we shall highlight the first evidence of the excitation of vertically polarised transverse loop oscillations triggered by a catastrophic cooling at the loop top and consistent with inertial excitation due to two thirds of the loop mass comprising of cool rain mass. The seismological capability of the oscillation is exploited to deduce the relative rain mass. It is shown to be consistent with the evolution of the oscillation period showing the loop losing a third of its mass due to falling coronal rain in a 10-15 minute time period.

D2.2-0021-18 NUMERICAL SIMULATIONS OF CORONAL LOOP HEATING BY TRANSVERSE WAVES

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The problem of heating of coronal loops by transverse magnetohydrodynamic waves is addressed. Recently, it has been shown that the plasma mixing effect due to the Kelvin-Helmholtz instability occurring at the loop boundaries contributes significantly to the temperature distribution inside a loop. Using the MPI-AMRVAC code, we perform three-dimensional numerical simulations of the behaviour of transverse magnetohydrodynamic waves driven at the loop footpoint to understand the efficiency of that mechanism for coronal loop heating. We consider different driver frequencies and polarisations, and analyse their effect on the heating of gravitationally stratified loops. We compare our results with the previous ones to reveal the effects of mentioned physical factors on heating of coronal loops by transverse waves.

D2.2-0022-18 TRANSVERSE OSCILLATIONS IN CORONAL RAIN

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Coronal rains are the plasma condensations which fall, with velocity less than free fall, to chromosphere along the loop like paths. They are usually associated with active region loops. They consists of cool and dense plasma that appear in the solar atmosphere in a period of few minutes. They are believed to be formed in coronal loops because of thermal instability. We report the transverse oscillations in coronal rain as observed by Interface Region Imaging Spectrograph (IRIS). Such oscillations are also reported before using SST in H-alpha. We find the evidence of both standing and propagating waves. These oscillations are found to be decayless. Using IRIS, we investigate different properties of coronal rain at transition region. We perform seismology to estimate magnetic fields and Alfven speed in such structures. These oscillations are also seen in AIA 304 extreme ultraviolet images. Thus combining IRIS and AIA we investigate the properties of coronal rain at different heights in the solar atmosphere. In addition to this, we also perform the spectroscopic analysis at different phases of the evolution of the coronal rain.

D2.2-0023-18 A STATISTICAL STUDY OF FILAMENT OSCILLATIONS ASSOCIATED WITH FLARES/CMES

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Filament oscillation is gathering attention these years. Through filament seismology, it is becoming a promising way to probe coronal magnetic field in a simpler way without lowering much accuracy. In certain cases, filaments are seen oscillating before CMEs and/or flares. That means filament oscillation is a possible precursor of these two phenomena. To verify such an assumption, we take out a statistical research over the SDO/AIA filament eruption catalog. We focus on those oscillations followed by flares/CMEs. What we concern are the triggers of the oscillations and their connection with the following eruptions. For each main trigger, we will pick out a case in the catalog for a more detailed study. We are interested in the relation between the oscillations and the following flares, as well as the time interval between filament eruption and flare onset. The latter would be a useful parameter for space weather forecast.

D2.2-0024-18 SIMULTANEOUS TRANSVERSE AND LONGITUDINAL OSCILLATIONS IN A QUIESCENT PROMINENCE TRIGGERED BY A CORONAL JET

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In this paper, we report our multiwavelength observations of the simultaneous transverse and longitudinal oscillations in a quiescent prominence. The prominence was observed by the GONG and by SDO/AIA on 2015 June 29. A C2.4 flare took place in NOAA active region 12373, which was associated with a pair of short ribbons and a remote ribbon. During the impulsive phase of the flare, a coronal jet spurted out of the primary flare site and propagated in the northwest direction at an apparent speed of 224 km/s. Part of the jet stopped near the remote ribbon. The remaining part continued moving forward before stopping to the east of prominence. Once the jet encountered the prominence, it pushed the prominence to oscillate periodically. The transverse oscillation of the eastern part (EP) of prominence can be divided into two phases. In phase I, the initial amplitude, velocity, period, and damping timescale are 4.5 Mm, 20 km/s, 25 minutes, and 7.5 hr, respectively. The oscillation lasted for two cycles. In phase II, the initial amplitude increases to 11.3 Mm while the initial velocity halves to 10 km/s. The period increases by a factor of 3.5. With a damping timescale of 4.4 hr, the oscillation lasted for about three cycles. The western part (WP) of prominence also experienced transverse oscillation. The initial amplitude is only 2 Mm and the velocity is less than 10 km/s. The period (27 minutes) is slightly longer than that of EP in phase I. The oscillation lasted for about four cycles with the shortest damping timescale (1.7 hr). To the east of prominence, a handful of horizontal threads experienced longitudinal oscillation. The initial amplitude, velocity, period, and damping timescale are 52 Mm, 50 km/s, 99 minutes, and 2.5 hr, respectively. To our knowledge, this is the first report of simultaneous transverse and longitudinal prominence oscillations triggered by a coronal jet.

D2.2-0025-18 HIGH RESOLUTION OBSERVATIONS OF PROMINENCE ROTATION BY HINODE AND IRIS

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Fine structures of prominences, especially threads, and their dynamics provide physical information about the magnetic configuration and property in the corona. Here we report two events of prominence rotation observed by the Hinode and IRIS satellites. In the first event, we found transverse motions of brightening threads at speeds up to 55 km/s seen in the plane of the sky. Such motions appeared as sinusoidal space-time trajectories with a typical period of 390 s, which is consistent with plane-of-sky projections of rotational motions. At least 15 episodes of such motions occurred in two days, none associated with any eruption. For these episodes, the plane-of-sky speed is linearly correlated with the vertical travel distance, suggestive of a constant angular speed. In the second event, spectral data taken by IRIS showed strong blueshifts in the top portion of the prominence with a speed of 30-40 km/s, while redshifts of similar speeds were detected at the bottom. Line width of the bright threads were significantly larger than those of stationary threads. These behaviors indicate rotations of helical prominence threads. We interpreted the activations as evidence of unwinding motions caused by magnetic reconnection between twisted prominence fields and ambient coronal fields.

D2.2-0026-18 PROMINENCE/TORNADO PLASMA PARAMETERS

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We present a comparison of the plasma physical parameters in prominences and tornadoes using IRIS data and ground based polarimetry measurements obtained with THEMIS. Mg II lines give a good diagnostics of the temperature and optical thickness of the structures. The Stokes parameters from the He D3 line allow to distinguish the behaviour of the magnetic field in typical prominences and atypical prominences (e.g. bubbles, eruptive prominence).

We concentrate on the Dopplershifts in a tornado observed in transition region lines and in Halpha. Our results support the existence of oscillations in tornadoes but not rotation. A reconstruction of the 3D geometry of a helical prominence obtained by following the trajectory of kernels yields surprising results. The loops are shown to be quasi-horizontal structures with no curvature. We conclude that it is important to take into account the 3D structure of the prominence to study the dynamics of the prominence plasma.

D2.2-0027-18 TWO SOLAR TORNADOES OBSERVED WITH THE INTERFACE REGION IMAGING SPECTROGRAPH

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The barbs or legs of some prominences show an apparent motion of rotation, which are often termed solar tornadoes. It is under debate whether the apparent motion is a real rotating motion, or caused by oscillations or counter-streaming flows. We present analysis results from spectroscopic observations of two tornadoes by the Interface Region Imaging Spectrograph. Each tornado was observed for more than 2.5 hours. Doppler velocities are derived through a single Gaussian fit to the Mg ii k 2796Å and Si iv 1393Å line profiles. We find coherent and stable red and blue shifts adjacent to each other across the tornado axes, which appears to favor the interpretation of these tornadoes as rotating cool plasmas with temperatures of 104K105K. This interpretation is further supported by simultaneous observations of the Atmospheric Imaging Assembly on board the Solar Dynamics Observatory, which reveal periodic motions of dark structures in the tornadoes. Our results demonstrate that spectroscopic observations can provide key information to disentangle different physical processes in solar prominences.

D2.2-0028-18 IRIS OBSERVATIONS AND MODELING OF MGII FLARE LOOPS

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Solar chromospheric flares are often associated with cool loops which are rooted in the ribbons. These loops extend into coronal altitudes and usually are modelled as prominence-like structures illuminated from the solar disk. The loops exhibit large down-flows (coronal rain) and they evolve in time in accordance with the characteristic cooling times of the loop plasmas. Cool loops are visible in various spectral lines formed at chromospheric temperatures. We exploit novel observations of such loops in MgII h and k lines obtained by the IRIS satellite, analyse selected observations where the cool loops are well visible and study their temporal evolution. Our spectroscopic diagnostics is based on 2D non-LTE modelling of MgII lines in flare loops taking into account the flows along the loops. From these models we determine various plasma parameters and the rates of radiation cooling. These results allow us to better understand the structure, dynamics and evolution of cool flare loops.

D2.2-0029-18 MASS FLOWS WITHIN A SOLAR PROMINENCE OBSERVED BY THE NEW VACUUM SOLAR TELESCOPE

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The material of solar prominences is often observed in a state of flowing. These information about mass flows (MF) is important and useful for us to understand the internal structures and dynamics of prominences. By using the New Vacuum Solar Telescope, we have carefully studied the MFs in a solar prominence, and found that there are two types of MF existing in the middle and leg of the prominence, respectively. The plasma mainly flowed back and forth in the middle of the prominence, while in its legs the plasma mainly dropped to the photosphere. The observation indicates that a prominence may has a piecewise structure, which results in the different behaviors between the middle and legs of the prominence. According to this explanation, a magnetic distribution of the prominence can be estimated from the observed MFs. Besides, it also suggests that these MFs may have a significant influence on the magnetic structure of the prominence.

D2.2-0030-18 DISAMBIGUATED MAGNETIC FIELD MEASUREMENTS IN A QUIESCENT PROMINENCE

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The magnetic field vector was measured in a prominence by interpretation of the Hanle effect, following the method described in Bommier, V., Leroy, J.L., and Sahal-Bréchot, S., 1981, A&A, 100, 231, but with the difference that the measurements were spatially resolved in the prominence body, because the prominence was observed with the French THEMIS telescope (Izaña, Tenerife, Canarias). The prominence was observed on two following days, and the measurement ambiguity was resolved by selecting the closest pair in the ambiguous solutions, whose symmetry changes along the days due to solar rotation. The method successfully worked. The observed line was He I D3. The polarisation was integrated along the line profile for accuracy purposes, and the two line components were not resolved. The magnetic field was then assumed to be horizontal, as shown by Athay et al. (1983, Solar Phys. 89, 3). The magnetic field strength and the α angle between the field vector and the prominence long axis were unambiguously obtained for nearly each pixe 0.5e−4G/km (increasing with height) is found above h = 34M m, in excellent agreement with Leroy et al.(1983 0.6e−4G/km (decreasing with height), contrarily to the model. In this region, the α angle is also found decreasing with height, but in a quicker manner and with more scattered values. The prominence is found of Inverse Polarity at all heights.

D2.2-0031-18 SCOOPING UP A PROMINENCE: EMBEDDING A FILAMENT IN A CME

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We report on thermodynamically consistent magnetohydrodynamic simulations from chromosphere to corona, where an erupting flux rope gets formed by photospheric converging motions. Our model shows how chromospheric material can get levitated into the flux rope and form a filament. The flux rope-filament system transits from quasi-equilibrium stages to an accelerated eruption, and this transition coincides with a changeover in the reconnection occurring in the current sheet underneath the flux rope. A slow Sweet-Parker stage transforms to an unsteady bursty reconnection regime with multiple islands. The largest of these islands are seen to merge with the chromospheric fields below to produce flare arcade loops. Our simulation unifies a variety of processes, from small-scale reconnection structures up to full-scale embedded filaments in a coronal mass ejection.

D2.2-0032-18 FILAMENT DISINTEGRATION IN RELATION TO QUASI-SEPARATRIX LAYERS

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The disintegration of solar filaments via mass drainage is frequently observed during a variety of dynamic phenomena, ranging from tornado-like activities, failed eruptions, to partial eruptions. It is generally considered that the draining of dense filament material is directed by both gravity and magnetic field, yet what causes the draining remains elusive. To shed new light into this question, we compared the impact sites of the draining mass with the footprints of large-scale quasi-separatrix layers in a partial eruption, and found a reasonable match between them. Hence we conclude that it is the interactions of the filament field with the overlying QSLs that result in the splitting and disintegration of the filament.

D2.2-0033-18 PLASMA PHYSICAL PARAMETERS OF A PROMINENCE EMBEDDED IN THE CORE OF A CORONAL MASS EJECTION

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We determine the plasma physical parameters of an erupting prominence embedded in the core of a CME, combininging visible light coronagraphic images from SOHO/LASCO with UV spectra acquired by SOHO/UVCS. Strong UV emissions were detected in the hydrogen Lyman α and Lyman β lines and C III line. Visible light and UV intensities have been used to estimate the projected thickness and velocity of the prominence, together with the effective plasma temperature, microturbolent velocity, and column density. These parameters have been used to constrain 1D NLTE modeling of the erupting plasma, taking into account the effects of large flow velocities (Doppler dimming). Roughly one-half of considered points in the prominence body show a non-negligible Lyman α optical thickness. Comparison between the calculated and the measured intensities of the two Lyman lines was also used to derive the geometrical filling factor. Results show that the erupting prominence plasma is relatively hot, with a low electron density, a wide range of effective thicknesses, a rather narrow range of radial flow velocities, and a microturbulence of about 25 km/s. This analysis provides a basis for future diagnostics of prominences using the METIS coronagraph on board the Solar Orbiter mission.

D2.2-0034-18 EVIDENCE OF COOL PROMINENCE MATERIAL EMBEDDED IN CMES FROM POLARIZATION MEASUREMENTS

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In white-light coronagraph images, cool prominence material is sometimes observed as bright substructures or plasmoids in coronal mass ejections (CMEs). Based on observations of a CME with the SECCHI/STEREO coronagraphs on 31 August 2007, Mierla et al. (2011) have shown that the emission from such bright patches is characterized by very low polarization and was due to H-alpha radiation from cool prominence material. We have examined several polarization images of CMEs obtained with the LASCO-C2 coronagraph with its orange filter. This filter is approximately centered on the HeI D3 line. This low excitation line emission is superior to the H-alpha emission of HI because its FIP is much higher. In several cases, we observe very low-polarization components embedded in CMEs characterized by a much larger polarization resulting from the Thomson scattering. They most likely present evidence of cool prominence material carried by the CMEs.

D2.2-0035-18 AN ANALYSIS OF SIMULTANEOUS OBSERVATIONS OF A CME-ASSOCIATED ERUPTIVE PROMINENCE WITH IRIS, AIA/SDO, EUVI/STEREO AND KCOR

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We present the simultaneous observations of a CME-associated eruptive prominence which have been made by the Interface Region Imaging Spectrograph (IRIS), Atmospheric Imaging Assembly (AIA) of SDO, EUVI of STEREO and the ground-based K-COR coronagraph. IRIS observations started on 2014 May 28 at 11:25 UT, lasted for about 4.5 hours. With the aim of deriving the velocity vector, we first combined an optical flow method on the AIA 304 observations to compute the POS velocities in the prominence and a Doppler technique with the IRIS observations to compute the LOS velocities. Then we characterized the Mg h and k profiles (time and space-dependent) and compared with the signatures of various (1000) prominence models through NLTE radiative transfer computations (I.A.S. PROM7 code). We paid much attention to the exact incident radiation in various lines and continua. The model parameters include pressure, temperature, height, thickness, radial and turbulence velocities. Having selected the best (fitting) models, we were able to derive the total (hydrogen) density and compute the mass flows. We also used the STEREO observations to derive the 3D geometry of the prominence and K-COR to derive the density later on in the process of eruption. Applying this method to more prominences observed by IRIS could help to reduce the large range of thermodynamic parameters in eruptive prominences and to improve their MHD modeling.

D2.2-0036-18 INTERACTION BETWEEN COOL MATERIAL FROM SUN-GRAZING COMETS AND THE LOW CORONA

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Sun-grazing comets dive into altitudes lower than 1 solar radius from the chromosphere. Cool materials of temperature lower than 103K explode from the comet into the 106 K corona. These materials undergone various stages of rapid chemical reactions in scales of seconds to minutes. Such reactions Structures in such images of various wavelengths indicate strong variation in ambient conditions of the corona. We combine three numerical models: low corona model, particle transportation model, and cometary plasma interaction model into one framework to model the interaction of Sun-grazing comets in the low corona. In our framework, cometary vapor are ionized via multiple channels, and then detained by the coronal magnetic field. In seconds, these ions are further ionized into their highest charge state, which is revealed by certain emission lines. Constrained by coronal graphs and cometary interaction images, we apply our framework to trace back to the local condition of the ambient corona, and its spatial/time variation. Our frame work is able to resolve structures of sub-million meters to tens of million meters. Once trained by multiple stages of the comet's journey in the low corona, this framework can identify the fine spatial variations in plasma density and magnetic field intensity, which may be visible to future close-up observations.

D2.2-0037-18 MAGNETIC DIAGNOSTICS OF CORONAL RAIN USING THE DKIST

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The routine production of coronal rain in the outer solar atmosphere provides one of the finest probes we have of the coronal plasma environment and its apparent structuring. Despite the range of phenomena discovered with imaging observations, the magnetic environment hosting and marshaling rain production remains poorly constrained by observations. With the dawn of the DKIST and its advanced suite of five facility instruments, this is primed to change. The large DKIST aperture (4 meter) provides a collecting area capable of combining rapid exposure imaging diagnostics and spectroscopic observations of coronal rain with meaningful spectropolarimetric observations, which to date have been rarely achieved for coronal rain. The brightness of coronal rain in key chromospheric diagnostics (as compared to hot infrared coronal lines) offers a very significant photon advantage for conducting "cool" coronal magnetometry. This talk will discuss the building blocks for an observational framework to study coronal rain at DKIST, including how to coordinate VBI imaging, VISP spectropolarimetry, VTF 2D spectro-imaging, and DL-NIRSP IFU-based spectropolarimetry. This discussion will be guided by recent observations of neutral helium production within coronal rain that allow us to much better predict DKIST capabilities for coronal rain polarimetry. In addition, automated analysis techniques based on the Rolling Hough Transform have been developed that assist with these techniques. Coronal rain is a critical use case for early science at DKIST when it becomes operational in 2020.

D2.2-0038-18 PERSPECTIVE OF DIAGNOSING COOL MATERIALS WITH THE LYMANALPHA SOLAR TELESCOPE

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The Lyman-alpha Solar Telescope (LST) is one of the three payloads proposed for the Advanced Space-based Solar Observatory (ASO-S) mission, which has already been approved by the Chinese Academy of Sciences (CAS). The LST payload consists of three instruments and is aiming at observing the Sun from disk center up to 2.5 solar radii in both the Lyman-alpha line and white-light with high tempo-spatial resolution. The LST payload selects the Lyman-alpha line as one of its observation wavebands due to the unique advantages of the line in observing the Sun: as the most intensive line in Ultraviolet (UV) solar spectrum, its larger relative brightness with respect to the visible waveband in the corona leads to less stringent requirement for the stray light suppression and make it suitable to detect faint features. Meanwhile, the wide temperature coverage of the line allows us to access both lowand high-temperature features on the Sun, such as prominences (filaments), jets, loops, coronal holes, coronal mass ejections (CMEs), flares, etc. In this talk, I will review solar observations in this line done by various satellites and sounding rockets, such as OSO, TRACE, SOHO, IRIS, VAULT, etc. Meanwhile, I will outline the perspectives of the Lyman-alpha line in future solar observations with the ASO-S mission

D2.2-0039-18 CHEMICAL FRACTIONATION IN SOLAR PROMINENCES

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The First Ionization Potential (FIP) fractionation of elemental abundances in the solar atmosphere and solar wind is a known process which appears to vary depending on the magnetic field property and the dynamic nature of the environment. It is generally identified by an increase of the low FIP elements (with FIP energy below 10 eV) compared to the high FIP elements (with respect to the photospheric values). For instance, the low FIP element abundance is enhanced within active regions by about a factor of 3-4, with respect to photospheric values. A similar property is measured in the slow solar wind. This is one of the reasons why the FIP fractionation is used as a proxy for identifying the solar wind source regions on the Sun, a topic of particular relevance for the upcoming Solar Orbiter mission. Cool, low-state ionized plasma and its composition have been measured in-situ within interplanetary Coronal Mass Ejections (ICMEs) in only a few cases. This cool plasma has been associated to remnants of erupting prominences. However, this association is not confirmed, because the measurement of the composition within prominence plasma is very difficult and poorly known. The scope of this paper is to provide a reliable measurement of elements composition and FIP fractionation in a prominence using the available SOHO/SUMER dataset of the prominence atlas presented in Parenti et. al 2005. Our investigation will consider ions formed in the prominence-corona transition region, taking into account possible density and opacity effects in the formation of the spectral lines.

D2.2-0040-18 RECONNECTION MICROJETS IN THE SOLAR CORONA

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Coronal rain is one of the highest resolution tracers of the coronal magnetic field. In this work the dynamics of a prominence/coronal rain complex are analysed based on spectroscopic and imaging observations with IRIS, Hinode/SOT and SDO/AIA. The loop-like magnetic field arcade hosting the rain is observed to slowly expand in height. Prior and especially during this movement, several (100) small (1 arcsec) and short (<20 sec) bursts of plasma perpendicular to the loop arcade are captured in the Si IV and Mg II lines. The line profiles are broad and asymmetric with long tails above 100 km/s. These microjets are accompanied with strong intensity enhancements co-spatially and along the loop in most of the AIA channels, indicating significant energy release increasing the temperature to several MK. Some events generate transverse MHD waves and the strongest events are accompanied by ejection of plasmoidlike structures. We interpret these microjets as magnetic reconnection outflows, produced by component reconnection in a strong guide field. The originally cold conditions of the rain allows, in this case, a unique high resolution glance into the reconnection dynamics in low beta plasmas, and marks the X-target in the Sun for next-generation telescopes.

D2.2-0041-18 PROPERTIES OF PROMINENCES IN 13-24 CYCLES OF ACTIVITY

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Digitization of solar prominences Kodaikanal Observatory (India) on photographic plates in the CaIIK line for the period 1907-1960 was performed. These data were supplemented by data such as daily observations of prominences Kislovodsk Observatory (1957-2017), digitization of prominence sketches by the spectrohelioscopes network (1922-1934) and prominences on synoptic charts (1887-1898, 1904-1915). Comparative analysis of the velocity drift of highlatitude prominences to the poles in activity cycles are performed. Connection between the velocity drift and the power of the activity cycle has been established. Analysis of the height prominences distribution are performed. The maximum of the heights distribution is about 30 Mm. Also there is a second maximum for a height of 60 Mm.

D2.2-0042-18 ON THE NATURE OF FUNNEL PROMINENCES

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It has been proposed that prominences are manifestations of a magneto-thermal convection process that involves ever-present dynamic descents of cool material threads and upflows of hot bubbles and plumes (Berger et al. 2011 Nature). On global scales, prominences may play an important role as the return flows of the chromosphere-corona mass cycle. A critical step in this cycle is the condensation of million-degree coronal plasma into T<10,000 K prominence material by radiative cooling instability. Direct observational evidence has been lacking for decades, a situation that has recently changed, especially with the advent of the SDO mission. We present here SDO/AIA observations of runaway cooling in coronal loops leading to condensation at magnetic dips and formation of funnel-shaped prominences (e.g., Liu et al. 2012, 2014; Berger et al. 2012 ApJL). We find that a macroscopically quiescent prominence is microscopically dynamic, involving the passage (through condensation and drainage) of a significant mass of typically 1015 gram/day (comparable to the mass of a typical CME). This picture is further supported by the theoretical development on spontaneous formation of current sheets and condensations (Low et al. 2012a, b, ApJ). Such funnel prominences, usually small in size, can constitute a new type of prominences. We suggest that similar processes could produce elementary building blocks of large-scale quiescent prominences in filament channels.

D2.2-0043-18 ARE “SOLAR TORNADOES” REALLY ROTATING?

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Solar “tornadoes” have been proposed to explain certain vertical structures in prominences that exhibit apparent rotations. Yet, it remains highly controversial whether such motions are real rotations or transverse oscillations. We present a statistical study of IRIS observations that reveal no clear evidence of systematic or coherent rotations, which would otherwise result in opposite Doppler shifts, i.e., blueshifts on the one side of the vertical structure and redshifts on the other, which were not found in our sample of “tornadoes”. In addition, we find in one particular case observed by SDO/AIA that the “tornado” disappeared upon the impact of an eruption that pushed its mass away along a primarily horizontal trajectory (presumably along magnetic field lines). This “tornado” shortly reformed with the replenishment of material from the return flow of some of the displaced mass back to its original location, at the dips of local magnetic field lines, followed by back and forth transverse oscillations around the dips. Such observations from both IRIS and AIA suggest that, at least for the cases being analyzed here, the apparent oscillatory motions of “tornadoes” are a result of longitudinal oscillations (like a pendulum) of dense and heavy prominence material about the local minimum of gravitational potential at the magnetic dips, an interpretation proposed and supported by a number of authors.

D2.2-0044-18 COOL MATERIAL IN THE HOT SOLAR CORONA AND THE CHROMOSPHERECORONA MASS CYCLE

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In the million-degree hot and tenuous solar corona, under favorable conditions, some mass can undergo a radiative cooling instability and condense into material of 100 times cooler in two distinct forms - prominences and coronal rain. Being at similar temperatures, they exhibit contrasting morphologies and behaviors: a quiescent prominence usually consists of numerous long-lasting, filamentary downflow threads, while coronal rain consists of transient mass blobs falling at comparably higher speeds along well-defined, curved paths (e.g., guided by coronal loops). We report recent imaging and spectroscopic observations from SDO/AIA and IRIS of a hybrid prominence-coronal rain complex structure that suggest different magnetic environments being responsible for such distinctions. We also present an ensemble of observations of the so-called funnel prominences that reside near the dips of magnetic funnels. Regardless of their morphological and behavioral differences, a large fraction of prominence and coronal rain material eventually falls back to the chromosphere and serves as the return flow of the socalled chromosphere-corona mass cycle (the other half of this cycle is the upward transport of heated mass from the chromosphere to the corona). We estimate the downflow mass fluxes in prominences and coronal rain, and compare them with the coronal mass budget in this cycle and with the mass loss to the solar wind and coronal mass ejections (CMEs). We will discuss the broad physical implications of these observations for fundamental questions, such as coronal heating and beyond.

D2.2-0045-18 SOLAR CORONA OBSERVATIONS IN ACTIVITY CYCLES 17-24

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The results of the work of the global observation network are considered, and a comparative analysis of the data of various coronal observatories is performed. The coronal activity index has been reconstructed for the period 1939-2016 based on the data of various observatories in Kislovodsk system. For this purpose, the corona daily intensity maps from the Sacramento Peak and Lomnicky Štit observatories according to the Solar-Geophysical Data journal have been digitized; they supplement the data of other observatories. The homogeneity and continuity of the corona observations at the Kislovodsk station, including activity cycle 24, is confirmed. Unfortunately, the only observatory at present that continues observation of the spectral corona in Fe XIV5303A and Fe XIV6374A lines is the Kislovodsk astronomical station Mountain Astronomical Station (MAS) of the Central Astronomical Observatory, Russian Academy of Sciences (Pulkovo). The data on the combined corona in 5303 A line are analyzed. It is shown that there is a high correlation of the intensity index of green corona with solar radiation measurements in the vacuum UV region. Data on the beginning of the new 25th activity cycle in the corona at high latitudes are presented.

D2.2-0046-18 PRACTICAL REALIZATION OF THE FORCE-FREE MAGNETIC FIELD MODELS

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To apply force-free magnetic field models we present and discuss properties and feathers of the following models: Miller and Turner solution, modified Miller and Turner solution, Romashets and Vandas solution, Integral model, Krittinatham and Ruffolo model. These models can be used to interpret in-situ observations of the magnetic flux rope, study Forbush decrease in magnetic clouds or investigate transport effects of solar energetic particles injected inside a coronal mass ejection.

D2.2-0047-18 CONCURRENCE OF COOL AND WARM JETS BY MAGNETIC FLUX EMERGING FROM BELOW THE SOLAR CHROMOSPHERE TO THE TRANSITION REGION

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In the solar atmosphere, jets are ubiquitous at various spatial-temporal scales. They are important for understanding the energy and mass transports in the solar atmosphere. According to recent observational studies, the high-speed network jets are likely to be intermittent but continual sources of mass and energy for the solar wind. Here, we conduct a magnetohydrodynamics simulation to investigate the mechanism of these network jets. A combination of magnetic flux emergence and horizontal advection is used to drive the magnetic reconnection in the transition region between a strong magnetic loop and a background open flux. The simulation results show that not only a fast warm jet, much similar to the network jets, is found, but also an adjacent slow cool jet, mostly like classical spicules, is launched. Differing from the fast warm jet as driven by magnetic reconnection, the slow cool jet is mainly accelerated by gradients of both thermal pressure and magnetic pressure near the outer border of the massconcentrated region compressed by the emerging loop. These results provide a new perspective on our understanding of the formation of both the slow cool jets from the solar chromosphere and the fast warm jets from the solar transition region.

SPACE PLASMAS IN THE SOLAR SYSTEM, INCLUDING PLANETARY MAGNETOSPHERES (D)

SOLAR TRANSIENTS: FROM SOLAR ORIGIN TO EARTH IMPACT AND THE OUTER HELIOSHERE (D2.3)

D2.3-0001-18 CMES AND SHOCKS EVOLUTION IN THE INTERPLANETARY SPACE. OBSERVATIONS OF CME EVOLUTION FROM THE SUN TO THE EARTH AND BEYOND

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Thanks to remote sensing instruments from space-based observatories it is possible to study in details the early propagation of solar eruptions (or Coronal Mass Ejections - CMEs). The early detection of CMEs with remote sensing instruments (e.g. EUV imagers and spectrometers, visible light coronagraphs, radio spectrometers on-board SOHO, STEREO, SDO, etc.) allows to identify the events propagating towards the Earth, and derive in advance information that are crucial for Space Weather forecasting applications. Higher up, the propagation of Interplanetary CMEs has been followed many times with Heliospheric imagers (e.g. SMEI on-board the Coriolis satellite, and HI1 - HI2 on-board the twin STEREO spacecraft), providing information on ICME drag forces, deflections, CME-CME interactions, preconditioning, and other phenomena affecting their propagation to 1 AU and beyond. These data have proven to be very useful also to derive early information on shock waves associated with major eruptions, believed to be very important accelerators of Solar Energetic Particles. Upcoming solar missions (Solar Orbiter, Parker Solar Probe, PROBA-3, etc.) will provide a new view of CMEs, hopefully helping us to answer some of the major open questions on these events.

D2.3-0002-18 CONSTRUCTING A GENERIC ICME FROM THE SUN TO EARTH FROM STATISTICAL STUDIES OF IN SITU DATA

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Interplanetary Coronal Mass Ejections (ICMEs) are detected in situ by instruments measuring the magnetic field and plasma properties of the ambient solar wind. In particular, a subset of ICMEs, referred to as Magnetic Clouds (MCs), is well defined by the presence of a rotating magnetic field, indicative of a twisted magnetic structure. Shocks, on the other hand, are also well defined in the interplanetary medium as sharp discontinuities in the plasma and magnetic properties. Both structures then allow defining the presence of a sheath region between the shock and the MC.

Over the past years, we have proposed and refined new statistical methods aiming at analyzing ICME properties, so as to assess the existence of a generic shape and a generic internal profile of ICMEs at different distances from the Sun. These methods rely on the computation from the data of the distribution of the shock normal and the flux-rope axis directions. From these analysis, we were able to constrain an analytical shape that describes best these observed distributions. Another method is a superposed epoch analysis so as to obtain typical profiles of ICME substructures at different distances from the Sun.

Next, we compare such generic features of ICMEs to numerical simulations and heliospheric images of CMEs. We will discuss the commonalities, then the discrepancies that need to be further understood between the models and the constraints given by the in situ data. This is important in completing the scenario of the evolution of solar eruptive flares, from their start in the Sun's atmosphere to their evolution in the solar wind.

D2.3-0003-18 NUMERICAL STUDY OF EROSION, HEATING, AND ACCELERATION OF THE MAGNETIC CLOUD AS IMPACTED BY FAST SHOCK

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The impact of an overtaking fast shock on a magnetic cloud (MC) is a pivotal process in CME-CME (CME: coronal mass ejection) interactions and CME-SIR (SIR: stream interaction region) interactions. MC with a strong and rotating magnetic field is usually deemed a crucial part of CMEs. To study the impact of a fast shock on an MC, we perform a multi-dimensional numerical magnetohydrodynamic simulation. Two cases are run in this study: without and with impact by fast shock. In the former case, the MC expands gradually from its initial state and drives a relatively slow magnetic reconnection with the ambient magnetic field. Analyses of forces near the core of the MC as a whole body indicates that the solar gravity is quite small compared to the Lorentz force and the pressure gradient force. In the second run, a fast shock propagates, relative to the background plasma, at a speed twice that of the perpendicular fast magnetosonic speed, catches up with and takes over the MC. Due to the penetration of the fast shock, the MC is highly compressed and heated, with the temperature growth rate enhanced by a factor of about 10 and the velocity increased to about half of the shock speed. The magnetic reconnection with ambient magnetic field is also sped up by a factor of two to four in reconnection rate as a result of the enhanced density of the current sheet, which is squeezed by the forward motion of the shocked MC.

D2.3-0004-18 MODELING THE INTERNAL STATE OF CORONAL MASS EJECTIONS (CMES) USING THEIR KINEMATICS

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Coronal Mass Ejections (CMEs) have been studied extensively for decades using remote sensing or in-situ observations. Earlier studies have estimated the internal properties of CME plasma; however such estimations were limited to a certain position or at a certain time. The evolution of internal state of CME during their continuous heliospheric propagation is not properly understood. As it is well accepted that most of the CMEs have a flux rope-like structure, in our study, we propose a self-similar flux rope model. The model is used to probe the internal state of CME in order to understand the thermodynamic process. We implement the model to a CME erupted on 12 December 2008. Using this model in conjunction with propagation and expansion speeds profile of the CME, several thermodynamic parameters and their variations with heliocentric distance is determined. Most importantly, we infer the polytropic index of the CME plasma, Lorentz force and the thermal pressure forces inside the CMEs. Based on our results, we explain the flows direction of heat and internal driver of CME expansion. We also calculate the rate of change of entropy and absorbed heat for the CMEs. The limitations of the model and approximations made in the study would also be discussed.

D2.3-0005-18 MODELING THE SOLAR WIND FROM 1 RSUN TO 1 AU

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I will present a new series of solar wind simulations of the solar wind from the surface of the Sun to 1 AU (and beyond). We used a new solar wind model, called MULTI-VP, which takes a coronal magnetic field map as input (past data or forecast) and calculates the dynamical and thermal properties of a large collection of solar wind streams the chromosphere up to about 30 Rsun in quasi-real time (while keeping a good description the plasma heating and cooling mechanisms, and taking into account the full magnetic flux-tube geometry). MULTI-VP supplies the full set of physical inner boundary conditions required to initiate the model ENLIL. The two models were used to calculate the properties of the wind flow (speed, density, temperature, magnetic field) from 1 Rsun to 1AU during Carrington rotations spanning the STEREO epoch (CRs 2055 to 2149; see https://stormsweb.irap.omp.eu/doku.php?id=windmaptable, http://www.helcatsfp7.eu/). These were calibrated against in-situ measurements of different spacecraft, white-light J-Maps and coronal/heliospheric imagery in order to provide better predictions than the classical methods. The CIR's identified in the HELCATS CIRCAT catalogue were traced back to the low corona, and their positions were verified to correlated well with the interfaces of fast and slow wind streams simulated. These solar wind simulations were performed in the scope of the HELCATS FP7 project and are included in the SIMCAT catalogue. I will discuss the predictive capabilities of this modeling stategy in terms of the arrival times, amplitudes and fine structure of fast wind streams at 1 AU. I will also address the benefits of multi-point observations and in-situ measurements and the use of synchronic magnetograms.

D2.3-0006-18 ACCELERATION AND TRANSPORT OF ENERGETIC PARTICLES IN THE HELIOSPHERE AND THEIR IMPACT ON SPACE WEATHER

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Solar Energetic Particles (SEPs) constitute an important component of space weather in terms of the radiation hazard to humans and electronic equipment, as well as the ionization of the Earth’s atmosphere. In this work, two real-time prediction tools developed in the framework of the HESPERIA HORIZON 2020 project i.e. HESPERIA UMASEP-500 and HESPERIA REleASE, providing > 500 MeV and 30-50 MeV proton predictions, respectively, will be presented. Both forecasting tools are operational under the HESPERIA server maintained at the National Observatory of Athens (http://www.hesperia.astro.noa.gr). Two main mechanisms of particle acceleration are usually employed to explain SEP events at 1 AU: (i) magnetic reconnectiondriven processes during solar flares and (ii) diffusive shock acceleration at fast Coronal Mass Ejection-driven shock waves. Despite the existence of these main sources of accelerated particles, turbulence and associated coherent structures may be responsible for heating and particle energization throughout the heliosphere. Recent observations of energetic particle enhancements in turbulent wakes of interplanetary shocks, near reconnecting current sheets and within magnetic cavities filled with magnetic islands strongly support theoretical expectations of particle energization in the presence of coherent structures in the solar wind. A new paradigm has recently emerged of particle acceleration to keV/MeV energies which occurs both far from 1 AU as well as locally in the solar wind, due to a combination of these classical mechanisms and small-scale magnetic island reconnection-related processes in magnetic cavities of various origins. Examples of such Atypical Energetic Particle Enhancements (AEPEs) in the heliosphere will be presented and discussed in this work.

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D2.3-0007-18 MODELING THE SOLAR ENERGETIC PARTICLE TRANSPORT IN THE 3D BACKGROUND SOLAR WIND: INFLUENCES OF THE COMPRESSION REGIONS

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In modeling the transport process of solar energetic particles (SEPs) in the inner heliosphere, previous simulation works often simplify the solar wind velocity as radial and constant, and treat the magnetic field as Parker spiral. In order to fully understand the effect of solar wind velocity and interplanetary magnetic field on the particles' transport process, a realistic background solar wind and magnetic field is required. In this work, we use the focused transport model to investigate the transport of SEPs in the solar wind velocity and magnetic field, which are generated by the 3D high-resolution MHD model with a six-component grid. We find that in the uncompressed solar wind, the time intensity profiles of energetic particles show similar trend in both the MHD background and the Parker magnetic field assumption. However, the simulated SEP flux displays an enhancement as much as a factor of two in the decay phase when a compression region sweeps through the local observer. Our results indicate that the magnetic focusing effect is responsible for the intensity enhancement. This suggests that the magnetic focusing effect has an important influence on the transport of SEPs. Besides, we suggest that the magnetic focusing could be more effective in large heliocentric distances rather than local magnetic focusing at 1 AU and a realistic 3D background solar wind should be included in such simulations.

D2.3-0008-18 ICME EVOLUTION AND GCR MODULATION IN THE INNERMOST HELIOSPHERE

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Using observations from MESSENGER at Mercury, in conjunction with spacecraft at 1 AU and at Mars, we investigate how interplanetary coronal mass ejections (ICMEs) evolve and modulate galactic cosmic rays (GCRs) as they propagate through the inner heliosphere. MESSENGER, the first spacecraft since the 1980s to make in-situ measurements at distances < 0.5 AU, presents a unique opportunity for observing the innermost heliosphere and allows us to make testable predictions for the upcoming Parker Solar Probe and Solar Orbiter missions. We have cataloged shock-driving ICMEs at MESSENGER between 2011 and 2015; through statistical analyses and case studies, we investigate key ICME property changes during propagation as well as changes with heliocentric distance in GCR modulation by ICMEs. We showcase specific case studies of ICMEs observed in longitudinal conjunction in the inner heliosphere to illustrate changes in ICMEs during propagation. Based on these studies, we hypothesize that: 1) ICMEs are less complex closer to the Sun, 2) ICME-driven GCR modulation is significantly stronger in the near solar environment than near 1 AU, 3) the size of Forbush decreases (Fds) diminishes

exponentially with heliocentric distance in the inner solar system, and 4) 2-step Fds are more common closer to the Sun. The results from our studies give both a direct and indirect view of how ICMEs evolve during propagation as well as a glimpse of the inner heliosphere environment about to be explored by the Parker Solar Probe and Solar Orbiter missions.

D2.3-0009-18 SHOCK LOCATION AND CME 3-D RECONSTRUCTION OF A SOLAR TYPE II RADIO BURST WITH LOFAR.

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Type II radio bursts are evidence of shocks in the solar atmosphere and inner heliosphere emitting radio waves ranging from sub-meter to kilometer lengths. These shocks may be associated with coronal mass ejections (CMEs) reaching speeds higher than the local magneto-sonic speed. Radio imaging of decameter wavelengths (20-90 MHz) is now possible with the Low Frequency Array (LOFAR), opening a new radio window to study coronal shocks which leave the inner solar corona and enter the interplanetary medium and to understand their association with CMEs. To this end we study a coronal shock associated with a CME and type II radio burst to determine the locations where the radio emission is generated and investigate the origin of the band-splitting phenomenon. The type II shock source-positions and spectra were obtained using 91 simultaneous tied-array beams of LOFAR while the CME was observed by the Large Angle and Spectrometric Coronagraph (LASCO) on board the Solar and Heliospheric Observatory (SOHO) and by the COR2A coronagraph of the SECCHI instruments onboard the Solar Terrestrial Relation Observatory (STEREO). The 3D structure was inferred using triangulation of the coronographic observations. Coronal magnetic fields were obtained from a 3-D MHD polytropic model using the photospheric fields measured by the heliospheric imager (HMI) onboard the Solar Dynamic Observatory (SDO) as lower boundary. The type II radio source of the coronal shock observed between 50 and 70 MHz was found to be located at the expanding flank of the CME, where the shock geometry is quasi-perpendicular with Bn 70. The type II radio burst showed first and second harmonic emission, the second harmonic source was cospatial with the first harmonic source to within the observational uncertainty. This suggests that radio wave propagation does not alter the apparent location of the harmonic source. The sources of the two split bands were also found to be cospatial within the observational uncertainty, in agreement with the interpretation that split bands are simultaneous radio emission from upstream and downstream of the shock front. The fast magneto-sonic Mach number derived from this interpretation was found in the range 1.3-1.5. The fast magneto-sonic Mach numbers derived from the modelling of the CME and the coronal magnetic field around the type II source were found in the range 1.4-1.6.

D2.3-0010-18 GRAD-SHAFRANOV RECONSTRUCTION OF A MAGNETIC CLOUD AND ITS EFFECT ON THE COSMIC RAY INTENSITY AT ENERGIES ABOVE 70 MEV AS OBSERVED BY LISA PATHFINDER

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The passage of an interplanetary counterpart of a Coronal Mass Ejection (ICME) was observed at L1 Lagrangian point between 2016 August 2 at 14.00 UT and August 3 at 3.00 UT. The transit of shock, sheath and magnetic cloud (MC) regions are identified and MC characteristics and topology are studied through the Grad-Shafranov reconstruction technique. Moreover, a classical Forbush decrease (FD) in the galactic cosmic ray (GCR) intensity was observed by the world-wide neutron monitor network and by instruments aboard LISA Pathfinder (PF) after 12.00 UT on 2016 August 2. In particular, the particle detector aboard LISA PF allowed for the monitoring of the GCR intensity at energies above 70 MeV n−1 with a statistical uncertainty of 1% on one-hour binned data. These variations are analyzed as well as the energy dependence of the fractional decrease of the GCR intensity at the dip of the event. Finally, the relationship between the ICME passage and the features of the observed FD are discussed in detail.

D2.3-0011-18 SIGNATURE OF FLUX ROPES BEFORE AND AFTER ERUPTIONS: ELECTRIC CURRENTS IN ACTIVE REGIONS

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Solar observations, nonlinear force-free field extrapolations relying on these observations, and three-dimensional magnetohydrodynamic (MHD) models indicate the presence of electric currents in the pre-eruption state and in the course of eruptions of solar magnetic structures which are interpreted as flux ropes (sigmoids, filaments, cavities). The MHD models are able to explain the net currents in active regions by the existence of strong magnetic shear along the polarity inversion lines, thus confirming previous observations. The models have also captured the essence of the behavior of electric currents in active regions during solar eruptions, predicting current-density increases and decreases inside flare ribbons and in the interior of expanding flux ropes, respectively. The observed photospheric current-density maps, inferred from vector magnetic field observations, exhibit whirling ribbon patterns similar to the MHD model results, which are interpreted as the signatures of flux ropes and of quasi-separatrix layers (QSLs) between the magnetic systems in active regions. We will show how observations can confirm enhancement of the total current in these QSLs during the eruptions, and how these observations can be used to investigate whether current density decrease can be seen at the footpoints of erupting flux ropes

D2.3-0012-18 INITIATION AND ACCELERATION OF CORONAL MASS EJECTIONS

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Coronal mass ejections (CMEs) are the large-scale and most energetic eruptive phenomena in our solar system and are able to seriously affect the safety of human high-tech activities in outer space. An efficient forecast of CMEs requires a clear understanding of some fundamental but elusive processes, in particular the early evolution and acceleration of CMEs. In this talk, we will first present the evolution characteristics of the pre-eruptive configurations (filaments and magnetic flux ropes) of CMEs and discuss the initiation process of CMEs. In the second part, we will focus on the acceleration process of CMEs and reveal the specific process of magnetic reconnection.

D2.3-0013-18 ERUPTIVE FLARE INITIATION AND THE CME MAGNETIC FIELD

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We recount very recent results on the correlation between photospheric characteristics of eruptive solar active regions and coronal mass ejection (CME) occurrence / characteristics. In particular, we argue that one of the most relevant parameters for CME occurrence is the non-neutralized electric currents appearing exclusively along intense, shear-ridden magnetic polarity-inversion lines (PILs) in the photosphere of eruptive active regions. These currents are simply lacking in the absence of strong PILs and shear. While the physics underlying nonneutralized currents is rich and shows far-reaching ramifications, we will focus on the injection of magnetic helicity due to non-neutralized currents in the pre-eruption phase, that will then be bodily transported via the CME. For a conductive plasma of high magnetic Reynolds number, such as that of the solar corona, we show how the fundamental helicity conservation principle can lead to estimates of, first, the CME's axial magnetic field strength and, second, the anticipated magnetic field strength of the interplanetary CME (ICME) on the verge of geospace. We discuss how this analysis can be viewed as a meaningful initial or boundary condition for more elaborate inner-heliospheric propagation models that further consider the orientation of the ICME magnetic field, thus leading to an improved understanding and prediction of ICME geoeffectiveness.

Part of this work has been supported by the EU Horizon-2020 FLARECAST project (grant agreement no. 640216).

D2.3-0014-18 WHICH FACTORS OF AN ACTIVE REGION DETERMINE WHETHER A FLARE WILL BE ERUPTIVE OR CONFINED?

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We study how the magnetic field determines whether a strong flare launched from an active region (AR) will be eruptive or confined. To this aim, we analyzed 44 flares above GOES class M5.0 that occurred during 2011–2015. We used 3D potential magnetic field models to study their location within the host AR (using the flare distance from the flux-weighted AR center, dFC) and the strength of the overlying coronal field (via decay index n). We also present a first systematic study of the orientation of the coronal magnetic field changing with height, using the orientation ϕ of the flare-relevant polarity inversion line as a measure. We analyzed all quantities with respect to the size of the underlying active-region dipole field, characterized by the distance between the flux-weighted opposite-polarity centers, dPC. We find that flares originating from the periphery of an active-region dipole field (dFC/dPC > 0.5) are predominantly eruptive. Flares originating from underneath the AR dipole field (dFC/dPC < 0.5) tend to be eruptive when they are launched from a compact AR (dPC 60 Mm) and confined when launched from an extended AR. In confined events the flare-relevant field adjusts its orientation quickly to that of the underlying dipole field with height (Δϕ 40° between the surface and the apex of the active-region dipole field), in contrast to eruptive events where it changes more slowly with height. The critical height for torus instability, hcrit = h (n = 1.5), discriminates best between confined (hcrit 40 Mm) and eruptive flares (hcrit 40 Mm). It discriminates better than Δϕ, implying that the decay of the confining field plays a stronger role than its orientation at different heights.

D2.3-0016-18 ASSESSING THE GEO-EFFECTIVENESS OF CMES: WHERE DO WE STAND AT THE END OF SOLAR CYCLE 24

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As the minimum of Cycle 24 nears, the database of CME observations from the LASCO coronagraphs will encompass two full solar cycles. This unprecedented coverage of the eruptive sun is complemented by 10+ years of stereoscopic observations from STEREO, sub-minute imaging of the EUV corona from SDO/AIA, and a plethora of high-resolution spectroscopic observations in many atmospheric layers from Hinode and IRIS. So, what have we learned from these missions about the geo-effective potential of CMEs and their sources?

In this talk, I will discuss that current status, identify some of the gaps and offer strategies for improving our understanding of geo-effective CMEs in the future.

D2.3-0017-18 SOLAR ERUPTIONS INITIATED IN SIGMOIDAL ACTIVE REGIONS

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Coronal sigmoids, generally observed in X-rays and EUV, are S-shaped active regions that have been shown to possess high probability for eruption. They present a direct evidence of the existence of flux ropes in the corona prior to the impulsive phase of eruptions. In order to gain insight into their eruptive behavior and how they get destabilized we need to know their 3D magnetic field structure. First, we review some recent observations and modeling of sigmoidal active regions as the primary hosts of solar eruptions, which can also be used as useful laboratories for studying these phenomena. Then, we concentrate on the analysis of observations and highly data-constrained non-linear force-free field (NLFFF) models over the lifetime of several sigmoidal active regions, where we have captured their magnetic field structure around the times of major flares. We present the topology analysis of a couple of sigmoidal regions pointing us to the probable sites of reconnection. A scenario for eruption is put forward by this analysis. We demonstrate the use of this topology analysis to reconcile the observed eruption features with the standard flare model. Finally, we show a glimpse of how such a NLFFF models of an erupting region can be used to initiate a CMEs in MHD simulations with an unprecedented realistic manner. Such simulations can show the effects of solar transients on the near-Earth environment and solar system space weather.

D2.3-0018-18 PROBING THE EVOLUTION OF A CORONAL CAVITY WITHIN A SOLAR CORONAL MASS EJECTION.

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On the 10 September 2017, an X-class solar flare erupted at the solar limb. The associated coronal mass ejection (CME) had the classic three part structure with a bright core surrounded by a dark cavity. This event was captured perfectly by the Hinode EUV imaging spectrometer (EIS). The EIS instrument captured spectroscopically the flaring loops, the current sheet and the cavity for the first time. In the 'standard flare model', magnetic reconnection of coronal loops occurs following the eruption of a magnetic flux rope. The flux rope is a key element of the flare process and eruption but is inherently difficult to observe. Dark cavities observed within a CME are assumed to be flux ropes. The observations we describe here, provide an insight into the characteristics of a cavity, and how the rapid injection of energy from the flare underneath forces the rapid expansion of the flux rope resulting in the eruption. Doppler shifts of over 200 km/s are measured at either end of the cavity. There is mixed temperature plasma - cool material in the centre that also has strong flows, and hot FeXXIV emission being observed. SDO Atmospheric Imaging Assembly (AIA) data shows that the cavity erupts rapidly, and is being driven by the non-thermal energy input from the flare below as measured from Fermi data.

D2.3-0019-18 WHAT CAN WE LEARN FROM CORONAL DIMMINGS ABOUT THE EARLY EVOLUTION OF EARTH-DIRECTED CMES?

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Earth-directed coronal mass ejections (CMEs) are the main drivers for severe space weather events affecting the near-Earth environment. However, they allow the least accurate measurements of their properties due to strong projection effects and especially their early evolution is not well observed with traditional coronagraphs. The most distinct phenomena associated with CMEs are coronal dimmings, i.e. localized regions of reduced emission in the extreme-ultraviolet (EUV) and soft X-rays low in the corona. They are interpreted as density depletions due to mass loss or rapid expansion of the overlying corona during the CME lift off. We extract characteristic parameters describing the dynamics, morphology, magnetic properties and the brightness evolution of coronal dimming regions in order to obtain additional information on the initiation and early evolution of Earth-directed CMEs. To this aim, we developed an automatic dimming detection algorithm (based on logarithmic base-ratio images) that allows us also to distinguish between core and secondary dimming regions.

Using this newly developed method, we extract the physical properties of 76 coronal dimming events in optimized multi-point observations and compare them with characteristic parameters describing their corresponding CMEs. The on-disk dimming evolution is studied using the high-cadence, multi-wavelengths data of SDO/AIA and the line-of-sight (LOS) magnetograms of SDO/HMI, while STEREO/EUVI, COR1 and COR2 data is used to measure the associated CME close to the limb with low projection effects.

The impulsive phase of the dimming (i.e. main expansion phase of its area) starts co-temporal with the onset of the CME and the associated flare and the overall dimming region expands around locations that are identified as core dimming regions. On average this main evacuation phase lasts for about 50 minutes. For the majority of events, the total unsigned magnetic flux involved in the dimming regions is balanced and for selected events up to 30% of this flux results from the localized core dimming regions covering only 10% of the total dimming area. The size of the total dimming region, the total unsigned magnetic flux, as well as its intensity decrease are strongly correlated with the CME mass. Events where high-cadence observations from STEREO are available show in addition also a moderate correlations between the growth rate of the dimming and the maximum speed of the CME.

D2.3-0021-18 ERUPTING SOLAR MAGNETIC FLUX ROPES AND THE BZ CHALLENGE: UNDERSTANDING DETAILS OF CME PROPAGATION IN THE INTERPLANETARY MEDIA

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Understanding the connection between magnetic topologies of a coronal mass ejection (CME) as observed closer to the Sun and in the interplanetary medium close to the Earth is vital for successful predictions of geomagnetic storms. Recent solar and magnetospheric data convincingly demonstrate that fast CME originating from near the solar disk center are the major cause of extreme space weather events. Moreover, topology and helicity of the ejected fields tends to be mainly preserved as the ejecta propagates and evolves in the interplanetary space. The interplanetary CME that is often observed near the Earth as a well organized helical structure called a magnetic cloud (MC) is the result of expansion of the original ejecta and its interaction with the heliospheric plasma and magnetic fields that may cause the ejecta to alter its shape, rotate and shed its magnetic flux. Therefore the probability of a strong geomagnetic storm to occur as well as its intensity depend on both initial properties of the erupted structure and the further interactions that the ejecta may be subjected to as it expands into the heliosphere. Detailed understanding of this interaction may shed light on the problems related to connecting solar surface phenomena to their interplanetary counterparts. In this talk I will briefly review current progress on the CME evolution in the heliosphere.

D2.3-0022-18 BZ DETERMINATIONS AND FORECASTS USING UCSD ANALYSIS TECHNIQUES

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Since the middle of the last decade, UCSD has incorporated magnetic field data in its ISEE IPS tomographic analysis. These data are extrapolated upward from the solar surface using the Current Sheet Source Surface (CSSS) model (Zhao Hoeksema, 1995) provide predictions of the interplanetary field in RTN coordinates. When extrapolated to Earth, these fields can be displayed in a variety of ways, including GSM fields in Bx, By, and Bz coordinates. The Bz GSM field component gives a fair correlation with in-situ derived fields near Earth of a few nano-Tesla variation that maximizes in spring and fall as Russell and McPherron (1973) have shown, but even more significantly its daily variation is shown to be correlated with geomagnetic Kp and Dst indices. UCSD currently operates a website that predicts these transient low-resolution GSM Bz field component variations several days in advance. More challenging to predict are large, short-lived magnetic field components that can be north-south in RTN coordinates, and whose southward GSM Bz can provide the most extreme geomagnetic effects. Here, the record for success is not as clear, but there have been some inroads to these predictions from this analysis that will be discussed.

D2.3-0023-18 THE CORONAL MAGNETIC FIELD DERIVED BY VECTOR TOMOGRAPHY FROM IR AND UV MEASUREMENTS

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One of the major problems in solar physics is to measure the coronal magnetic fields before and during the coronal transients events. Spectropolarimetric coronal observations of magnetically sensitive spectral lines provide an information about the magnetic field. However, inversion of the magnetic field from such types of measurements is not straightforward due to the nature of the line formation mechanisms and the fact that the coronal is optically thin. Because of the latter it is generally not possible to spatially resolve the coronal field over the line of sight (LOS). Tomography, i.e. observations form multiple LOSe, is required.

We applied the vector tomography technique to measurements of the Fe XIII 10747 A Hanle effect linear polarization obtained by the Coronal Multichannel Polarimeter (CoMP). The photospheric observations and divergenceless of the field were used as additional constraints in the tomographic inversion. The inversion method also requires to know the 3D distribution of the coronal electron density and temperature which have been reconstructed by scalar field tomography based on STEREO/EUVI data.

The obtained 3D coronal magnetic field has been validated by relating its structures (streamers, pseudostreamers, coronal holes) to the STEREO/EUVI images and to the global 3D coronal electron density obtained by tomography based on STEREO/COR1 data.

Also, we explore how the inclusion of circular polarization IR measurements of the coronal Zeeman effect (together with the linear polarization measurements of the Hanle effect) into the inversion will affect the quality of the magnetic field reconstruction.

D2.3-0024-18 MODELING CORONAL MASS EJECTIONS WITH EUHFORIA: A PARAMETER STUDY OF A MAGNETIZED FLUX ROPE MODEL

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Coronal Mass Ejections (CMEs) are one of the big influencers on the coronal and interplanetary dynamics. Understanding their origin and evolution from the Sun to the Earth is crucial in order to determine the impact on our Earth and society. One of the key parameters that determine the geo-effectiveness of the coronal mass ejection is its internal magnetic configuration. We present a detailed parameter study of our implemented magnetized flux rope model where we focus on changes in the input parameters and how these changes affect the characteristics of the CME at Earth and their evolution in the heliosphere.

Recently, we have implemented a magnetized flux rope model into the inner heliosphere model EUHFORIA ('EUropean Heliospheric FORecasting Information Asset'). EUHFORIA is a magnetohydrodynamical forecasting model of large-scale dynamics from 0.1 AU up to 2 AU. Coronagraph observations can be used to constrain the kinematics and morphology of the flux rope. One of the key parameters, the magnetic field, is difficult to determine directly from observations. In this work, we approach the problem by conducting a parameter study in which flux ropes with varying magnetic configurations are simulated. We have studied the effect of latitude, longitude, toroidal flux and CME speed in a previous study. Now we also focus on density, half-width and tilt of the CME and determine the sensitivity of the CME propagation to those parameters. These parameters are all closely related and will have an effect on the propagation in multiple ways. We try to disentangle the various effects.

D2.3-0026-18 THE ROLE OF EMERGING MAGNETIC FLUX IN THE INITIATION OF SOLAR ERUPTIONS

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The eruption of solar magnetic fields, generating flares and coronal mass ejections, and accelerating energetic particles, can have significant effects on the Earth's space environment. The source of these eruptions is ultimately the magnetic field which emerges from the solar interior into the solar atmosphere to energize the coronal magnetic field. We will review theoretical and observational evidence for the generation of eruptions by flux emergence. We will then report on a series of numerical experiments exploring how dynamic flux emergence into either potential or pre-energized coronal fields can lead to eruptions.

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D2.3-0027-18 SOLAR ERUPTIONS DURING MAGNETIC FLUX EMERGENCE FROM THE CONVECTION ZONE TO THE CORONA

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We present a realistic numerical model of magnetic flux emergence from the convection zone to the corona. The magnetic and velocity fields from a solar convective dynamo simulation are used as a time-dependent bottom boundary to drive the radiation magnetohydrodynamic simulations. The sophisticated treatments on the radiation and thermal conduction in the simulation allow a direct comparison between model synthesized observables and real observations. The main results are: (1) The quiet Sun corona is heated to over 1 MK by the energy flux provided by the small-scale magnetic field that is maintained by a local dynamo. (2) Emerging flux bundles create several active regions in a 200 Mm wide domain. The coronal temperature is significantly increased as active regions are forming at the photosphere. (3) Synthetic EUV images show coronal loops with various lengths and temperature. (4) More than 100 flares, with 1/3 reaching C class and above, occur in the simulation. The magnetic energy is mostly release through the work done by the Lorentz force, which is quickly thermalized by the viscosity. Moreover, the energy released during the flares and soft X-ray flux, i.e., the flare class nicely reproduce the relationship derived from observations. (5) The biggest flare reaches M2.5 and releases about 5e31 ergs magnetic energy. Plasma in cusp-shaped post-flare loops is heated to several tens MK. The flare is accompanied by the ejection of a giant flux rope that originates from highly sheared magnetic field at the polarity inversion line of a sunspot pair.

D2.3-0028-18 USING MHD SIMULATIONS FOR SPACE-WEATHER FORECASTING: WHERE DO WE STAND?

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Coronal mass ejections (CMEs) are the main driver of space-weather disturbances in the terrestrial magnetosphere. Predicting the impact of CMEs before they arrive at Earth is one of the main challenges of solar and heliospheric physics. A candidate tool for this purpose are numerical simulations. State-of-the-art MHD simulations are now capable of modeling CMEs all the way from Sun to Earth, but they are computationally still too demanding to be used for realtime modeling. At present, only a simplified model (ENLIL), which does not include the corona and simulates CMEs as velocity perturbations, is used for operational space-weather forecast. However, given the continuous increase of computing power, more sophisticated simulations may become available for this purpose in the near future, and first attempts are currently made to prepare for operational use. A specific task at hand is to evaluate the accuracy of these simulations in reproducing in-situ measurements at Earth. I this presentation, we will briefly review state-of-the-art CME simulations and discuss their predictive capabilities and limitations. As an example, we will present a recent Sun-to-Earth simulation of the well-known 14 July 2000 "Bastille-Day" event, which produced a very strong geomagnetic storm.

D2.3-0029-18 DO THE SUNSPOT UMBRA MAGNETIC FIELD CHARACTERISTICS VARY DURING FLARES AND CORONAL MASS EJECTIONS?

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We found variations in the sunspot umbra magnetic field characteristics within active regions (ARs), where eruptive events (solar flares, coronal mass ejections (CMEs)) originated. The behavior of the maximum of the module of magnetic induction Bmax, the minimum inclination of the magnetic field lines to the normal αmin and their averages values (Bmean and αmean) within umbrae were analyzed. A change of behavior of the magnetic field parameters after flare beginning is observed. Thus, for example, during 3 hours before a solar flare/eruption the min angle in umbrae of the sunspots closely located to the "feet" of an eruptive rope is increasing to a larger values (4° through 10°). Later a strong decreasing over 1 3 hours after the flare onset to small values (1°) is observed. At the same time the αmean angle varies essentially more weakly. This implies that the magnetic tube from the umbra of such sunspots after the flare onset deflects from the initial position almost as a whole, i.e. without essential transformation in the distribution of the magnetic field lines inside the tube.

D2.3-0030-18 PASSAGE OF ICMES, THEIR ASSOCIATED SHOCK STRUCTURES AND RESULTING DISTURBANCES IN THE GEO-MAGNETOSPHERE

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Coronal mass ejections (CMEs) from the Sun propagate into interplanetary space and evolve to form a large-scale structure. This structure, in many cases, when observed in near-Earth space consists of the CME ejecta and an extended shock region. Thus, while headed towards the Earth, the extended structure may hit the magnetosphere from its near-central, intermediate, or near-end location. Thus, the magnetic environment of the Earth may encounter the solar plasma and field regimes of different strength, topology, and duration in the three situations. Consequently, resulting amplitudes and nature of geomagnetic disturbances may not be similar. In this work, we analyze two geomagnetic indices (Dst and AE) and solar plasma/field parameters (plasma velocity, plasma beta, dynamic pressure, interplanetary magnetic field, its north-south component, and interplanetary electric field) in three different situations when the shock/ICME structure crosses the magnetosphere from central, intermediate, and the near-end portions of its extended structure. We find significant differences in geomagnetic and plasma/field parameters in three situations. These differences are analyzed. We study the behavior of geomagnetic disturbances in relation to simultaneous variations in different plasma/field parameters in these three situations. We study the observed differences not only during the main phase of the geomagnetic disturbances but also their recovery characteristics. Implications of these results are discussed.

D2.3-0031-18 RECENT PROGRESS IN UNDERSTANDING EARTH-AFFECTING SOLAR ERUPTIVE EVENTS

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We report on our effort of the Campaign Events Working Group of ISEST ("International Study of Earth-affecting Solar Transients"), which is one of the four elements of the SCOSTEP/VarSITI program. Our main task is to integrate theory, simulations and observations to better understand the chain of cause-effect activities from the Sun to Earth for a handful of carefully selected events. The events in our list show varied degrees of difficulty to understand the link between the solar origin and the heliospheric consequence. At one end of the spectrum, there are "textbook" events in which we can unambiguously associate the solar eruption with the interplanetary CME (ICME). At another end of the spectrum, there are "problem" events in which it is extremely difficult to find the progenitor of the ICME at 1 AU, either as a CME close to the Sun or as an eruption that is expected to leave low coronal signatures (LCSs). In this talk, using representative examples, we summarize recent progress in understanding the LCS-ICME link, and re-forecasting the shock/CME arrival time and the magnitude of the geomagnetic storm. We show how the progress has been made by coordinated analysis of new data (especially from SDO and STEREO) and advanced numerical modeling.

D2.3-0032-18 ON THE STATE OF THE ART IN PREDICTING SOLAR CORONAL MASS EJECTIONS AND THEIR PLANETARY IMPACTS

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Predicting when and how a solar coronal mass ejection will arrive at a given heliospheric location is currently a matter of large international efforts. This is of interest for many different human endeavours, such as aurora tourism, air travel, human spaceflight, scientists studying (exo)planetary atmospheric erosion, and given the possibility of a solar superstorm impacting Earth once in about 100 years, even wealth preservation. Ever more sophisticated tools are being developed, based on numerical, analytical or empirical methods, and they all rely on certain observational inputs. I will review some of the "campaign events", where several groups add different types of modeling to gain a broader picture of the involved physics. However, recently modeling efforts have emerged to cover an entire solar cycle, including on the order of 1000 CMEs.

The difficulty in forecasting a CME arrival hit or miss, its arrival time, speed and magnetic field is caused by several factors. Near the Sun, mechanisms for creating the flux rope inside the CME need to be better understood. Additionally, CMEs can be channeled out of the corona to take on a different trajectory as suggested by its source region. In interplanetary space, the shape and structure of this flux rope as it heavily expands is not well known, and interaction between CMEs and the background wind including high speed streams modulates arrival times as well as CME magnetic fields and speeds. The most important unsolved problem is the prediction of the southward interplanetary magnetic field, which should be possible given that for causing the strongest geomagnetic storms, this field component needs to be strong and steady and thus coherent.

In the near future, the missions Parker Solar Probe and Solar Orbiter may make it possible to greatly enhance our knowledge about CMEs in those key areas. But besides large-scale scientific missions, soon interplanetary space could be populated with small satellites, measuring key parameters of the solar wind at multiple locations.

D2.3-0033-18 SURPRISE GEOEFFECTIVENESS OF STEALTHY CORONAL MASS EJECTIONS FROM THE SUN TO 1 AU

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One of the underlying problems in the investigation of CME genesis and evolution is relating remotesensing observations of coronal mass ejections (CMEs) to in-situ observations of interplanetary CMEs (ICMEs). Typically, remote-sensing observations of an eruption are first observed in the low corona, followed by coronagraph observations of the global structure of the CME projected onto the plane of the sky, and then finally local, highly-quantitative measurements of an ICME are made in situ along a spacecraft trajectory. However, the dramatic change in solar activity in recent years has raised awareness of "stealth" CMEs, which are CMEs observed in coronagraph data but not in coronal images, especially in disk view. Largely identified during the deep minimum of cycle 23/24, stealth CMEs appear to be on the rise. Since solar cycle 25 brings with it the possibility of yet another low activity cycle, it is very likely that the number of stealth CMEs will remain a significant fraction of ejecta. We investigate the properties of stealth CMEs during the rise of solar cycle 24 through solar maximum, paying special attention to their proximity to coronal holes. We investigate the existence of mismatched polarity reversals in the magnetic field and electron strahl measured in situ within ICMEs associated with stealth CMEs. We discuss the plausibility of interaction with solar wind emanating from coronal holes as a key element of stealth CME eruption as evidenced by expanding coronal hole boundaries during eruption and how continued interaction with the fast solar wind emanating from these coronal holes during interplanetary transit influences the geoeffectivness of the corresponding ICMEs at 1AU.

D2.3-0034-18 ON THE CAUSES OF STEALTH INTERPLANETARY CORONAL MASS EJECTIONS

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Geomagnetic storms and other adverse space weather phenomena are known to be mostly caused by energetic eruptions from the Sun, resulting in coronal mass ejections (CMEs) as observed near the Sun, and upon arriving at the Earth, appearing as Interplanetary ICMEs (ICMEs) from in-situ solar wind plasma, magnetic field and particle observations. However, there exist one set of ICMEs that have unambiguous signatures in in-situ observations, but lack of apparent progenitor CMEs; A progenitor CME is often shown as a full halo (angular width of 360 deg) or partial halo (angular width larger than 120 deg) CME in the coronagraphs situated along the Sun-Earth line, such as LASOC onboard SOHO at the L1 point. In particular, we report a detailed study of a geoeffective stealth ICME that occurred on 2011 May 28 and whose progenitor CMEs could not be identified in LASCO images. However, fortunately, candidate progenitor CMEs were captured by the Sun-Earth-Connection-Coronal-andHeliospheric Investigation (SECCHI) onboard the Solar TErrestrial RElations Observatory (STEREO) spacecraft in the quadrature configuration, i.e., on the ecliptic orbit and nearly perpendicular to the SunEarth line. We find that there are two progenitor CMEs launching from the Sun in succession of eight hours. We apply the Graduated Cylindrical Shell (GCS) model to reconstruct the 3D geometry, propagating direction, velocity and brightness of the two CMEs. We find that the main cause of the invisibility of the first CME (CME-1) in SOHO/LASCO is due to its low mass, that is, when the CME emerges above the occulter, its brightness is as faint as the noise. The main cause of the second CME (CME-2) is due to its small size, including narrow angular width and small cross section of the magnetic flux rope. Although propagating toward the Earth, CME-2 appeared as a narrow CME, instead of halo or partial halo CME in the LASCO field of view. We also show that CME-2 propagates faster than CME-1, and they might have interacted in the interplanetary space.

D2.3-0035-18 THREE-DIMENSIONAL SHAPE RECONSTRUCTION AND PROPAGATION OF THE CME OF 22 OCTOBER 2003 FROM LASCO IMAGES

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The determination of the three-dimensional morphology and propagation of coronal mass ejections (CMEs) in coronagraphic white-light images has been a major question of coronal physics, and a challenge to the observers. The STEREO mission has so far provided the required two view points for stereoscopic reconstruction but that capability has ended with the loss of one of the S/C. Two-dimensional images as provided by the LASCO-C2 and C3 coronagraphs are generally insufficient to provide anything more than an idea of the global and internal structures of a CME. There are however favorable cases where the relatively simple morphology of a CME and the geometry of the observations allow perceiving its global shape. In those cases, forward modeling based on an a-priori shape model can be attempted, and the resulting synthetic images are compared and fitted to the observations. We present the case of the CME detected and tracked by LASCO on 22 October 2003 which is amenable to such an approach. The global shape of this CME on the images however requires the introduction of an elaborated shape model, an asymmetric plasma cloud. The images are first processed in order to remove most of the background or foreground coronal structures (essentially streamers) which are superimposed on the CME. Using the cloud model, we generate synthetic images that are fitted to the observed images. The resulting parameters allow a detailed characterization of the 3D shape and propagation of the CME.

D2.3-0036-18 THE CRITICAL CONDITIONS FOR THE ONSET OF SOLAR FLARES AND CORONAL MASS EJECTIONS

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Solar flares and coronal mass ejections (CMEs) are believed to be the explosive liberation of magnetic energy in the solar corona. However, the critical condition for their onset is not yet well understood, and thus the accurate prediction of their onset is still difficult. Which kind of instability determines the critical condition is a key question of this problem, because magnetohydrodynamic (MHD) instabilities, e.g., the kink and torus modes of instabilities, may cause the explosive energy liberation in the solar corona. Recently, Ishiguro and Kusano (2017) proposed that a new instability called double-arc instability (DAI) may work as the initial driver of solar flares and it can trigger the onset of the solar eruption by destabilizing the torus instability. In this paper, we analyze the spatiotemporal evolution of three-dimensional magnetic field structure which is reconstructed by the nonlinear force-free field (NLFFF) extrapolation technique for the solar active regions NOAA 11158 and 12673. The result suggests that the critical condition for the DAI well explains the onset of the major flares occurred in these active regions. Finally, we discuss the applicability of the critical condition to the prediction of flares and CMEs based on the statistical analysis of three hundred active regions.

D2.3-0037-18 NOAA SWPC'S OPERATIONAL GEOSPACE MODEL PERFORMANCE DURING EARTH-AFFECTING EVENTS

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The Geospace model was first transitioned into real-time operations at the NOAA Space Weather Prediction Center (SWPC) in October 2016 and has been upgraded once since going operational. The Geospace model is a part of the Space Weather Modeling Framework (SWMF) developed at the University of Michigan, and the model simulates the full time-dependent 3D Geospace environment (Earth's magnetosphere, ring current and ionosphere) and predicts global and local space weather parameters such as induced magnetic perturbations in space and on Earth's surface. The current version of the Geospace model uses three coupled components of SWMF: the BATS-R-US global magnetosphere model, the Rice Convection Model (RCM) of the inner magnetosphere, and the Ridley Ionosphere electrodynamics Model (RIM). In the operational mode, SWMF/Geospace runs continually using real-time solar wind data from a satellite at L1, either DSCOVR or ACE. We present an analysis of the overall performance of the Geospace model during the Earth-affecting events that occurred since the Geospace model went operational. We also use past large Earth-affecting events to evaluate how well the current operational version of the model would have performed during enhanced storm periods.

D2.3-0038-18 CME ACCELERATION AND EUV WAVE KINEMATICS FOR SEPTEMBER 10TH 2017 EVENT

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On September 10th 2017 a large solar eruption, accompanied by an X8.2 solar flare, from NOAA active region 12673 was observed on the Sun's western limb by the new Solar Ultraviolet Imager (SUVI) on the GOES-16 spacecraft. We present a method to identify the CME bubble shape and to determine its radial and lateral acceleration. The large field of view of SUVI allows us to study the early impulsive CME acceleration up to 2 solar radii. The CME bubble reveals a fast evolution and strong overexpansion. The radial propagation of the CME revealed a peak value of the acceleration of about 4.8 km/s2, whereas the lateral expansion reached a peak value of 8.9 km/s2. The EUV wave associated with this eruption was observed by SUVI and STEREO-A, which had a separation angle with Earth of 128°, and the common field of view of both spacecraft was 52°. SUVI images above the solar limb reveal the initiation of the EUV wave by the accelerating flanks of the CME bubble, followed by detachment and propagation of the wave with a speed of 1100 km/s. Above the limb, the wave front can be observed as high as 0.7 solar radii. The EUV wave shows a global propagation over the full SUVI disk as well as into the STEREO-A field-of-view, and can be followed up to distances of about 1727 Mm from the source region. We study the propagation and kinematics of the direct as well as the various reflected and refracted EUV wave components on the solar sphere, finding speeds in the range from 370 to 1010 km/s. Finally, we note that this EUV wave is also distinct as it reveals propagation and transmission through a polar coronal hole.

D2.3-0039-18 THE SEPTEMBER 2017 EVENTS AND THEIR IMPRINTS AT EARTH, MARS AND STEREO-A

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During the declining phase of the current solar cycle, heliospheric activity has suddenly and drastically increased starting from a simple sunspot in Active Region (AR) 2673, which transformed into a complex region with three X-class flares accompanied by several Earth-directed Coronal Mass Ejections (CME) from 4th to 6th of September.

Only a few days later, on 10th September, the same AR 2673 produced solar energetic particles (SEPs) which were registered as a ground level enhancement (GLE) at Earth and the biggest GLE on the surface of Mars as observed by the Radiation Assessment Detector (RAD) since the landing of the Curiosity rover in August 2012. Both Earth and Mars saw an impulsive and intense enhancement of the accelerated protons with energies larger than hundreds of MeV whereas STEREO-A, despite being at the back side of the event, detected gradually increasing fluxes of particles transported there across the heliospheric magnetic field. These high energy particles were mainly accelerated by the flares and shocks which were associated with three consecutive CMEs launched on 9th and 10th of September. Based on STEREO-A and SOHO coronograph images, we identified the initial three-dimensional kinematics of the three CMEs using the Graduated Cylindrical Shell (GCS) model. The first two CMEs had moderate launch speeds while the last one was extremely fast (larger than 2500 km/s at 20 solar radii). These three CMEs interacted as they propagated outwards into the heliosphere and the resulting complex interplanetary CME (ICME) together with its associated shock was highly likely related to the effective acceleration of particles at such high energies causing GLE at both Earth and Mars. The arrival of the ICME at Mars caused a very significant Forbush decrease seen by the Radiation Assessment Detector (RAD) on the surface of Mars and the arrival time is only a few hours later than that at Earth which is about 0.5 AU closer to the Sun than Mars. We investigated the interaction of three CMEs and propagation of the consequent ICME using the Drag Based Model (DBM) as well as the WSA-ENLIL plus cone model and the simulated results are compared with in-situ measurements at both Earth and Mars. The comparison shows that in order to better predict the ICME arrival and its potential space weather impact at Earth and other heliospheric locations, it is essential to 1) analyze the evolution of the ICME kinematics, especially during interactions of different CMEs and better understand the spatially and temporally varying interplanetary conditions of the heliosphere.

D2.3-0040-18 SOLAR ENERGETIC PROTON ACCESS TO THE MAGNETOSPHERE DURING THE SEPTEMBER 2017 PARTICLE EVENT

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We analyze access of energetic protons (>60 MeV) to the magnetosphere during the solar particle event of September 10, 2018. We rely primarily on measurements from the Relativistic Proton Spectrometer on board NASA's Van Allen Probes. We investigate proton access as a function of location, direction, and energy. We compare observed proton access to established geomagnetic cutoff models with the aim of assessing their utility for high altitude satellite anomaly investigations.

D2.3-0041-18 OPERATIONAL SPACE WEATHER FORECASTING AT THE UK MET OFFICE

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The Met Office Space Weather Operations Centre (MOSWOC) has been monitoring solar transients and resulting impacts on geospace and at Earth, 24/7, since its official opening in 2014. MOSWOC produces twice daily space weather forecasts, and issues real-time alerts and warnings. Forecasts issued include CME arrival times at Earth, and 4 day probabilistic predictions of solar flares, geomagnetic storms, high energy electron events and high energy proton events.

It is essential for forecasters to have access to reliable data from models which are well-supported and implemented on a robust infrastructure. To provide this, the Met Office space weather research group transitions research models to operations. Collaboration with national and international partners is key to the Met Office identifying and implementing suitable models, tools and prediction techniques to forecast solar transient impacts.

Enlil, the solar wind prediction model, is one of several models implemented operationally at the Met Office. The SWPC CME analysis tool is employed to estimate CME parameters such as origin and speed, which are used as input into Enlil. It is crucial for forecasters to understand the strengths and limitations of such models and tools in order to optimise accuracy and to communicate confidence to users. For example, using a CME analysis tool is subjective and introduces errors into predictions of CME arrival time at Earth; error in CME arrival time is

+/-9 hours.

Initial verification of space weather forecasts has been undertaken. This provides an understanding of forecaster added value and of forecast performance compared with climatology and persistence models.

This presentation will examine the operational space weather prediction techniques and models used at the Met Office. Also discussed will be accuracy of these techniques, strengths and limitations, and verification results.

D2.3-0042-18 OPERATIONAL SIMULATION OF HELIOSPHERIC SPACE WEATHER: IMPROVEMENTS OF THE WSA-ENLIL-CONE MODELING SYSTEM

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The ENLIL-based heliospheric modeling system enables faster-than real-time simulations of corotating and transient disturbances. This hybrid system does not simulate origin of coro- nal mass ejections (CMEs) but uses appearance in coronagraphs, its geometric and kinematic parameters, and launches a CME-like hydrodynamic structure into the solar wind computed using the Wang-Sheeley-Arge (WSA) coronal model. Propagation and interaction in the heliosphere is then solved by a 3-D magnetohydrodynamic (MHD) code. This modeling system is operationally used at NOAA/SWPC, NASA/CCMC, UK/MetOffice, and Korea/KSWPC. In this presentation, we introduce the recent improvements that support modeling of the evolving background solar wind, launching of CME-like transients with embedded magnetic structure, and further facilitate comparison with in-situ and remote observations. Further, we introduce the project testbed system (http://helioweather.net) that has helped us to monitor the model development, verify robustness of new model features, and evaluate the prediction accuracy. Finally, we present results of the verification and validation studies, show improvements over the currently-used version, and illustrate broader applications of the new ENLIL version to support various heliospheric missions.

D2.3-0043-18 DRAG-BASED ENSEMBLE MODEL (DBEM)

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The drag-based model (DBM) for heliospheric propagation of ICMEs is a widely used simple analytical model which can predict ICME arrival time and speed at a given heliospheric distance (Vršnak et al., 2013, SolPhys). It is based on the assumption that the heliospheric propagation of ICMEs, is solely under the influence of MHD drag, where ICME propagation is determined based on CME properties as well as the properties of the ambient solar wind. The current version of the DBM is operational as part of ESA's SSA programme (http://swe.ssa.esa.int/web/guest/graz-dbm-federated). The DBM takes into account the ICME geometry to track the whole leading edge of an ICME, it can estimate whether or not an ICME will reach the observer and calculate the transit time and impact speed. To estimate the uncertainty for a single event, Drag-Based Ensemble Model (DBEM) was developed (Dumbovic et al., 2018, ApJ) which utilizes an ensemble of the observation-based CME input and synthetic values of the ambient solar wind speed and drag parameter. Using multiple runs with different input parameters, distributions of predicted arrival times and speeds are obtained allowing to forecast the confidence in the likelihood of the ICME arrival. The DBEM was further developed to an on-line application to provide the real-time CME forecast, which is currently in a test phase, and will soon be a part of ESA-SSA Heliospheric Weather Expert Service Group (http://swe.ssa.esa.int/heliospheric-weather). We test the model and the on-line application using observations and compare the performance with other CME propagation models.

D2.3-0044-18 PREDICTING A CME ARRIVAL AS OBSERVED FROM L1 BY HELIOSPHERIC IMAGERS USING ELEVOHI

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The Lagrangian point L5 is expected to be an ideal location for a future operational space weather observatory, already indicated by The Solar TErrestrial RElations Observatory (STEREO). STEREO has improved our understanding on the interplanetary (IP) evolution of coronal mass ejections (CMEs). Especially the wide-angle heliospheric imagers (HI) facilitated the development of a variety of methods for analyzing the evolution of CMEs through IP space. In this study, we present an ensemble forecast based on 339 model runs using the HI-based CME prediction tool ELEvoHI and test if an HI observer located at L1 may be an appropriate alternative (or supplement) to an L5 HI observatory. ELEvoHI, the ELlipse Evolution model (ELEvo) based on HI observations uses the benefits of different methods and observations. It provides the possibility to adjust the CME frontal shape (angular width, ellipse aspect ratio) and the direction of motion for each CME event individually. This information can be gained from Graduated Cylindrical Shell (GCS) flux-rope fitting within coronagraph images. Using the ELlipse Conversion (ELCon) method, the observed HI elongation angle is converted into a unit of distance, which reveals the kinematics (including the initial time, distance and speed) of the event. After fitting the time-distance profile of the CME using the drag-based equation of motion, where real-time in situ solar wind speed from 1 AU is used as additional input, we obtain all input parameters needed to run a forecast using the ELEvo model and to predict arrival times and speeds at any target of interest in IP space. Here, we present a test on a slow CME event of 3 November 2010, in situ detected by the lined-up spacecraft MESSENGER and STEREO-B and remotely observed by STEREO-B/HI, i.e. it was a halo CME for

STEREO-B. These conditions simulate an Earth-directed CME observed by HI located at L1. Our study suggests that L1 may provide a sufficient vantage point for an Earth-directed CME, when observed by HI, and that ensemble modeling could be a feasible approach to use ELEvoHI operationally.

D2.3-0045-18 DEVELOPMENT OF ADAPTIVE KALMAN FILTER FOR SOLAR WIND FORECAST

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Accurate solar wind modeling is important for predicting the arrival and geomagnetic response of high-speed solar wind streams as well as for modeling the transit of coronal mass ejections in interplanetary space and their impact at Earth. Data assimilation techniques combining the strength of models and observations provide a very useful tool for accurate solar wind forecasts. We develop a method to predict the solar wind speed at Earth 1-day ahead by using coronal hole areas derived from SDO AIA images in combination with in situ solar wind plasma and field data (speed, density, and magnetic field magnitude) from ACE and Wind spacecraft. To forecast the solar wind speed, we form a multidimensional linear regression model relating the solar wind speed one day ahead with the fractional coronal hole area observed three days before the current moment, as well as proton density, magnetic field magnitude, and solar wind speed at the current moment. One of the major concerns with such data assimilation scheme is that the regression coefficients do not remain constant and are time-varying. To avoid the fitting of regression coefficients to a particular situation, that can be changed in future, we develop an adaptive Kalman filter to create a dynamic linear regression for the 1-day ahead prediction of the solar wind speed. Testing the developed forecasting technique for the period 2010-2017, we obtain a correlation coefficient between the predicted and observed solar wind speed of 0.93, with an RMS error of prediction of 33 km/s. These results demonstrate that the proposed adaptive Kalman filter method significantly improves the quality of the solar wind forecasts and can be applied for reliable real-time warnings of the space weather conditions in the near-Earth environment.

D2.3-0046-18 INTERPLANETARY SCINTILLATION OBSERVATIONS TO STUDY SOLAR WIND TRANSIENTS. A TOOL FOR SPACE WEATHER FORECASTING

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The study of solar transients and their evolution in the interplanetary medium requires the combination of different instruments. The Interplanetary Scintillation (IPS) technique is a remote sensing measurement that uses radio observations of extragalactic sources to infer solar wind properties along the line of sights. If there is a good number of radio sources around the sun detected by the radio telescope, then it is possible to infer solar wind speeds and changes in solar wind density along their lines of sight. This pixel information can help us to map the interplanetary space to infer solar wind streams and solar transients. The Mexican Array Radio Telescope (MEXART) is a plane array of 4096 dipoles dedicated to study solar wind properties applying the IPS technique. The MEXART is a transit instrument with an operation frequency of 140 MHz. The instrument is currently upgrading to digitalize its backend. This upgrade will allow us to perform daily scanning of the whole sky and to detect a few dozens of extragalactic radio sources. The MEXART is part of a global effort to combine different IPS stations located at distint longitudes under the name of Worldwide Interplanetary Scintillation Stations (WIPSS). Combining data from different WIPSS instruments in real time, potentially would allow us to track the evolution of solar wind transients in the interplanetary medium. This remote sensing of solar wind characteristics obtained from stations at different longitudes could make the IPS technique in a useful tool for space weather.

D2.3-0047-18 PREDICTION TECHNIQUES IN OPERATIONAL SPACE WEATHER FORECASTING

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The importance of forecasting space weather conditions is steadily increasing as our society is becoming more and more dependent on advanced technologies that may be affected by disturbed space weather. Operational space weather forecasting is still a difficult task that requires the real-time availability of input data and specific prediction techniques that are reviewed in this presentation, with an emphasis on solar and interplanetary weather. Key observations that are essential for operational space weather forecasting are listed. Predictions made on the base of empirical and statistical methods, as well as physical models, are described. Their validation, accuracy, and limitations are discussed in the context of operational forecasting. Several important problems in the scientific basis of predicting space weather are described, and possible ways to overcome them are discussed, including novel space-borne observations that could be available in future.

D2.3-0048-18 APPLIED ARTIFICIAL INTELLIGENCE FOR SPACE WEATHER RESEARCH

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The recent advances in Artificial Intelligence (AI) capabilities are particularly relevant to NASA Heliophysics because there is growing evidence that AI techniques can improve our ability to model, understand and predict solar activity using the petabytes of space weather data already within NASA archives. This represents a strategic opportunity, since the need to improve our understanding of space weather is not only mandated by directives such as the National Space Weather Action Plan and the Presidential Executive Order for Coordinating Efforts to Prepare the Nation for Space Weather Events, but also because space weather is a critical consideration for astronaut safety as NASA moves forward with the Space Policy Directive to leave LEO and return to the Moon.

The Frontier Development Lab (FDL) is an AI research accelerator that was established in 2016 to apply emerging AI technologies to space science challenges which are central to NASA's mission priorities. FDL is a partnership between NASA Ames Research Center and the SETI Institute, with corporate sponsors that include IBM, Intel, NVidia, Google, Lockheed, Autodesk, Xprize, Space Resources Luxembourg, as well as USC and other organizations. The goal of FDL is to apply leading edge Artificial Intelligence and Machine Learning (AI/ML) tools to space challenges that impact space exploration and development, and even humanity.

The applied AI projects for space weather that are being undertaken by the Frontier Development Lab (FDL) represent an ideal opportunity for utilization of vast amount of NASA and other data to leverage the public-private partnerships of the FDL program in a manner that is highly complementary to ongoing efforts in space weather research. In this talk I will summarize the findings from two space weather topics, "Solar flare forecasting" and "A tool for exploring variability of Solar-Terrestrial interactions" that were part of FDL 2017 summer program.

D2.3-0049-18 REAL-TIME SOLAR FLARE PREDICTION WITH DEEP NEURAL NETWORK USING VECTOR MAGNETOGRAM AND CHROMOSPHERIC BRIGHTENING

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Solar flares are the largest explosive phenomena in the Heliosphere. They affect the earth by X-ray and UV emissions, high energy particles, and magnetic storms, causing troubles of satellites and blackout in a large area. To avoid these problems, it is important to predict flares. The mechanism of solar flares is a long-standing puzzle. The energy storage and triggering processes of flares have been intensely studied. In particular, the amount of solar observation data available in the near real time has remarkably increased. However, it is still difficult to predict flares occurring in the following 24 hr. Here we focused on a new approach to predict flares using deep neural network (DNN). DNN has an advantage to deal with the huge amount of data, from which accurate empirical rules are derived. We expect that DNN models automatically predict flares in the near real-time, and that a new physics can be found from the huge amount of data.

We developed a DNN model to predict flares occurring in the following 24 hr, named Deep Flare Net (DeFN). We used observation data taken by SDO and GOES during 2010-2015:

(1) the line-of-sight and vector magnetograms by HMI/SDO, (2) the lower chromospheric and coronal brightening by 1600 and 131 A filters of AIA/SDO, and (3) the soft X-ray emission by GOES. During 2010-2015, 26 X-class, 383 M-class and 4054 C-class flares were observed on disk. First, we detected active regions from magnetogram images in 1 hr cadence. Second, we extracted features for each region, i.e., the maximum magnetic field strength, the number and the maximum length of magnetic neutral lines, the time variations of magnetic field configurations, the histories of X, M and C-class flares, the background X-ray emission, the activity in the lower chromosphere, and the histories of X-ray and 131 A emissions 1 and 2 hr before an image. Third, we applied a DNN algorithm, which consists of 8 layers, skip connections and batch normalization. We separated the database into training and testing datasets with a chronological split, i.e. in an operational setting. We evaluated the prediction result with a skill score, named the true skill statistic (TSS), and we achieved TSS=0.80 for >=M-class flares and TSS=0.63 for >=C-class flares. These are higher than those for human forecasts. Note that in usual DNN models, the prediction process is a black box. However, in the DeFN model, the features are manually selected, and it is possible to analyze which features are effective for prediction.

In this talk, we would like to introduce our DeFN model and to discuss the flare triggering mechanisms by the comparison of the extracted solar features.

D2.3-0050-18 AUTOMATED DETECTION OF SOLAR WIND HIGH-SPEED STREAMS FROM OMNI DATA AND PROPERTIES DURING CYCLES 23 AND 24

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Solar wind high-speed streams (HSSs) emanating from coronal holes are known to be responsible for geomagnetic disturbances, especially during the declining phase of the solar cycle. When the fast solar wind accumulates behind the preceding slower wind, this creates a compression region characterised by strong interplanetary magnetic field (IMF) magnitude, high solar wind density and high pressure, called corotating interaction region (CIR). Defining criteria to automatically identify such solar wind structures in long time series of data is of particular interest in order to make statistical studies of their effect on planetary environments. We present an automated HSS detection method which exclusively relies on solar wind data measured at 1 AU. The algorithm uses three criteria applied to the IMF magnitude and to the solar wind speed. This method is applied to the solar wind data gathered from 1995 to 2017, which leads to the detection of 640 HSS events from coronal holes for which the solar wind velocity exceeds 500 km/s. In addition to these, some coronal mass ejections (CMEs) are identified as HSSs by the algorithm, and these are removed by comparing with existing CME lists. Using the compiled HSS event catalogue, the statistical behaviour of several solar wind parameters (IMF magnitude, solar wind velocity, density, Akasofu epsilon parameter) and geomagnetic indices (AE and SYM-H) is studied using the superposed epoch analysis method. We discuss the characteristics of HSS events during solar cycles 23 and 24 and their different properties at 1 AU during the rising, maximum, early and late declining phases of a solar cycle.

D2.3-0051-18 PERSISTENCE IN SOLAR ACTIVITY PARAMETERS AND PREDICTION FOR SOLAR CYCLE 25TH

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The analysis of long memory processes in solar activity, space weather and other geophysical phenomena has beena major issue even after the enough available data. We have examined data of three major solar parameters namely the sunspot numbers, 10.7cm index and the Lyman alpha index for the period 1976 - 2017. We have examined the statistical test for persistence in solar activity based on the value of Hurst exponent (H) which is one of the most classical applied methods known as rescaled range analysis. The efficiency of this methodology is further improved on the basis of Hodrick Prescott filter (detrending of time series) applied on observed data for solar cycle 21st to 24th. Further, the Hurst exponent analysis has been used to investigate the persistence of above mentioned solar activity parameters. After calculation we have found H = 0.902, 0.949 and 0.965 for sunspot number, 10.7cm radio flux and Lyman alpha index respectively that supported the strong sense of persistence in time series of considered parameters. Further simplex projection analysis has been used to predict the ascension time and the maximum number of counts for 25th solar cycle. The maximum number of counts for sunspot numbers, F10.7cm index and Lyman alpha has been calculated as 102.8±24.6, 137.25±8.9 and 4.52±1.6 respectively. On basis of above findings we have predicted about the solar cycle 25th and also have forecasted that the next solar cycle will start in the year 2021 (around January) and would last up to the year 2031 (around September) with its maxima in June 2024.

D2.3-0052-18 PREPARING FOR PARKER SOLAR PROBE: SYNTHETIC WHITE-LIGHT IMAGERY AND ANALYSIS FOR THE WIDE-FIELD IMAGER (WISPR)

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The Parker Solar Probe (PSP) trajectory, approaching within 10 solar radii, will allow the white light imager, WISPR, to view the inner corona with unprecedented spatial resolution. WISPR, with a field of view extending from 13.5° to 108° elongation angle from the Sun, will image the fine-scale coronal structure with arcminute resolution. The dependency of the Thomson scattering on the imaging geometry (distance and angle from the Sun) dictates that WISPR will be very sensitive to the emission from plasma close to the spacecraft, in contrast to the situation for imaging from 1 AU. Thus, WISPR will be the first 'local' imager providing a crucial link between the large-scale corona and PSP's in-situ measurements. To prepare for this unprecedented viewing of the structures in the inner corona, we are creating synthetic white light images and animations, viewed from the PSP trajectory, using the white-light raytracing package developed at NRL (available through SolarSoft). We will present results for small flux ropes moving outward through the corona as well as fly-throughs of finely structured coronal streamers. Using the synthetic images, analysis techniques similar to traditional white light "jmaps" are used to find the "track" of a flux rope's elongation versus time. The "track" is compared with predictions using simple geometric expressions to gain information on the 3D trajectory of the flux rope. Additional analysis techniques, such as re-projections of the images, will also be discussed.

D2.3-0053-18 PROSPECTIVE OUT-OF-ECLIPTIC WHITE-LIGHT IMAGING OF CIRS AND CMES THROUGH THE CORONA AND HELIOSPHERE

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Interplanetary corotating interaction regions (CIRs) and coronal mass ejections (CMEs) can be remotely imaged in white light (WL), as demonstrated by the in-flight performance of the Coriolis/SMEI and STEREO/HI instruments. Because of the in-ecliptic locations of both the STEREO and Coriolis spacecraft, the longitudinal dimension of interplanetary CIRs and CMEs has, up to now, always been integrated in WL imagery. To synthesize the WL radiance patterns of CIRs and CMEs from an out-of-ecliptic (OOE) vantage point, we perform forward magnetohydrodynamic (MHD) modeling of the background solar wind flow at solar maximum and a halo CME at solar minimum. We assert that a panoramic OOE view in WL would be highly beneficially in revealing the morphology and kinematics of CIRs and CMEs in the hitherto unresolved longitudinal dimension, and hence for monitoring the propagation and evolution of in-ecliptic CMEs for space weather operations.

D2.3-0054-18 MODELLING AND PROTECTION FROM SOLAR FLARES THROUGH CONSTELLATION OF SATELLITES AT LAGRANGIAN POINT 1

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The Sun is the star at the center of the Solar System. It is by far the most important source of energy for life on Earth. The Sun is a boon for now but will be a bane in few million years. Till then, Solar Flares are the greatest problem that the Sun imposes on the Earth. A solar flare is a sudden flash of increased Sun's brightness. Flares are often, but not always, accompanied by a coronal mass ejection. The flare ejects clouds of electrons, ions, and atoms along with the electromagnetic waves through the Sun's corona into the outer space. It takes usually a day or two for these clouds to reach Earth. This paper presents a theoretical way to prevent blackouts on Earth caused by solar flares. A constellation of 5 satellites will be placed strategically at L1. The arms of the satellites join together and an origami protective sheet unfolds itself. The structure then forms a solar windscreen. A three-dimensional, time-dependent solar wind flow from 0 to 2 astronomical units will be simulated where the solar wind is assumed to be supersonic. Comprehensive tables and graphs will be given, which will depict the amount of time that will pass at each stage of the mission and more importantly some idea on the cost in terms of energy, as well as money, will be discussed within today's context. Even though the possibility of such a mission is probably nonexistent for this decade, it is essential to do these exercises increase the chances of human survivability. In addition, this paper hopes to establish some general guidelines for such a protective mission.

D2.3-0055-18 THE NON-FOURIER IMAGE RECONSTRUCTION METHOD FOR THE STIX INSTRUMENT.

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The STIX is an X-ray imaging spectrometer operating in the 4-150 keV range. It will be launched on board the Solar Orbiter in the beginning of 2020. The STIX is equipped with 30 pairs of grids with pixelized Caliste-SO detectors which allow for registering the Fourier components of solar flare HXR emission distribution. In our method we abandon the Fourier's approach to image reconstruction. We use only the number of counts recorded by each of detectors, and reconstruct image on the basis of the classical Maximum Likelihood method. With a knowledge of the instrument detailed geometry we are able to calculate detectors response for point source. For our purpose the point source is a 1x1 arcsec pixel on the Sun. Having calculated point source response on the grid covering entire solar disc, we can iteratively combine point responses with varying weights until the best match between reconstructed and observed detector responses is achieved. Preliminary tests revealed that the developed algorithm reproduce reliable images of simulated solar HXR sources. In particular, it is very robust for some specific configurations which are problematic for other existing algorithms.

D2.3-0056-18 DESIGN AND PRIMARY RESULT OF SOLAR X-RAY MONITOR FOR CHINA SEISMO-ELECTROMAGNETISM SATELLITE

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China Seismo-Electromagnetism Satellite(CSES) is a scientific satellite, which is used to explore the precursory information of earthquakes, space environment monitoring and geoscience. High Energy Particle Package(HEPP) is one of the eight payloads, and its main scientific objective is to measure the variation of the space high energy particles by two sub-detectors, the High-energy payload(HEPP-H), and the Low-energy payload(HEPP-L). Combining with electromagnetic and ionospheric measurement, HEPP can look for the possible relations between the flux, energy, direction or distribution of high energy particles and the electromagnetic radiation caused by earthquake. Most charged particle in the earth is captured from the high-energy particles of the solar, and the Earth space environment is strongly influenced by solar activity, HEPP include the third sub-detector, the solar X-ray monitor(HEPP-X), which is aimed to monitor the activities of solar by the X-ray generated from the interaction of high-energy particles and the Earth's space environment. In addition, by the X-ray observations, we can predict the activities of solar energetic particles in advance. In this paper, we describe the details of HEPP-X about composition, calibration and primary results on orbit.

D2.3-0057-18 LARGE-SCALE SOLAR WIND PHENOMENA: A CATALOG FOR 1976-2016.

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To obtain reliable conclusions on solar-terrestrial physics, it is very important to correctly identify large-scale phenomena of the solar wind [Yermolaev et al., 2017]. To solve these problems, we create a catalog of large-scale solar wind phenomena for the entire space era on the basis of OMNI database of in situ interplanetary measurements (see website ftp://ftp.iki.rssi.ru/pub/omni/ and paper [Yermolaev et al., 2009]) and now it includes data for 41 years (1976 - 2016). Our catalog identifies reliably 3 types of quasi-stationary streams of the solar wind (heliospheric current sheet (HCS), high speed streams from the coronal holes (HSS), and slow streams from the coronal streamers), and 5 disturbed types (compression regions before fast streams HSS (CIR), and interplanetary manifestations of coronal mass ejections (ICME) that can include magnetic clouds (MC) and Ejecta with the compression region Sheath (SHEMC and SHEEj) preceding them) as well as the interplanetary shock (IS). In particularly our analysis shows that number of disturbed types of solar wind during solar cycle 24 is lower than during previous cycles, but most average interplanetary parameters are insignificantly (within the statistical error) lower. This work was supported by Russian Science Foundation, project no. 16-12-10062.

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D2.3-0058-18 FORBUSH DECREASE MODEL FOR EXPANDING CMES (FORBMOD)

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Forbush decreases (FDs) can be used as one of the "signatures" of an ICME passage. An analytical diffusion-expansion FD model (ForbMod) was developed that is based on the widely used approach of an initially empty, closed magnetic structure (i.e. flux rope) that fills up slowly with particles by diffusion perpendicular to the magnetic field of the flux rope. In our approach the FD amplitude is not only determined by the diffusion process but also by the expansion of the flux rope. While the first process leads to a smaller amplitude the second one leads again to a larger effect. Remote CME observations and 3D reconstruction is used to constrain initial and boundary conditions. CME evolutionary properties are taken into account by incorporating the flux rope expansion. Several options of flux rope expansion are regarded as competing mechanism to diffusion, which can lead to different FD characteristics, and forward modelling is used to analyse flux rope expansion and further constrain the model. In testing the model, a number of spacecraft and planetary observation is utilised, including those by the Radiation Assessment Detector aboard the Mars Rover Curiosity. This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 745782.

D2.3-0059-18 STATISTICAL STUDY OF INTERPLANETARY SOLAR RADIO EMISSIONS

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Type II and type III radio bursts are produced by beams of suprathermal electrons accelerated at shock waves in front of coronal mass ejections, and at reconnection sites of solar flares, respectively. While these emissions originating in the solar corona are frequently measured by ground-based instruments, dedicated instruments in space are needed to observe radio sources generated in the solar wind due to the ionospheric cutoff. We performed a statistical analysis of 50 type II and 152 type III radio bursts observed by Solar TErrestrial RElations Observatory (STEREO)/Waves instruments (125 kHz – 16 MHz) between May 2007 and February 2013. We have found that type II radio bursts are preferably observed at higher frequencies, when compared to type III radio bursts in this frequency range. The flux density of type II bursts is statistically frequency independent, while the flux density of type III bursts is larger for the lower frequencies. We derived empirical relations of exponential rise and decay times of type III radio bursts. Finally, we discuss a role of solar radio emissions in space weather forecasting.

D2.3-0060-18 LOW CARBON CHARGE PLASMAS IN ICMES MEASURED BETWEEN YEAR 1998 AND 2011

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It is a statistical work investigating the cold materials in 219 ICMEs measured by both ACE and WIND satellites between year 1998 and 2011. A data combination of the ion charge distribution, the proton moments, the alpha particle moments, the magnetic field vectors, and the solar observations are applied. We use a new criterion to identify the cold material that the mean carbon ion charge in the ICME is lower than that of the 24 hours solar wind prior to the ICME by three standard deviations. The cold materials are identified in 71 ICMEs. The cold materials tend to have the speed around 400 to 500 kms-1, the duration between 2 to 6 hours, and the occurrence rate as once or twice per ICME. In all the 71 ICMEs containing the cold materials, we identify two extreme cases that one has all the mean charge of O, Mg, Si, and Fe ions lower than that in the solar wind named as type A, the other has the mean charge of these ions higher than that in the solar wind named as type B. The type A cold materials have the higher proton temperature than the ICME mean value, but the type B have the opposite trend. In all 71 ICMEs, there are 55 ICMEs related to the CMEs approaching to the earth, and 19 of them could be related to the prominence eruptions. The type B materials related to the filament indicate either a heating process appearing beyond 1.2 solar radius when the CMEs erupted, or the filaments being combination of the condensed coronal plasmas and the evaporated chromospheric plasmas. The type B cold materials not related to the filaments are similar to the slow solar wind depletion phenomenon. The nature of the type A materials is not quite clear. In type A materials, there is no heating changing the ion charge distributions under 5 solar radii, but the protons are heated.

D2.3-0061-18 A STUDY ON EFFECT OF SOLAR WIND PLASMA PARAMETERS

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Today's challenge for space weather research is to quantitatively predict the dynamics of the magnetosphere from measured solar wind and interplanetary magnetic field (IMF) conditions. Correlative studies between geomagnetic storms (GMSs) and the various interplanetary (IP) field/plasma parameters have been performed to search for the causes of geomagnetic activity and develop models for predicting the occurrence of GMSs, which are important for space weather predictions. We find a possible relation between GMSs and solar wind and IMF parameters in three different situations and also derived the linear relation for all parameters in three situations. On the basis of the present statistical study, we develop an empirical model. With the help of this model, we can predict all categories of GMSs. This model is based on the following fact: the total IMF Btotal can be used to trigger an alarm for GMSs, when sudden changes in total magnetic field Btotal occur. This is the first alarm condition for a storm's arrival. It is observed in the present study that the southward Bz component of the IMF is an important factor for describing GMSs. A result of the paper is that the magnitude of Bz is maximum neither during the initial phase (at the instant of the IP shock) nor during the main phase (at the instant of Disturbance storm time (Dst) minimum). It is seen in this study that there is a time delay between the maximum value of southward Bz and the Dst minimum, and this time delay can be used in the prediction of the intensity of a magnetic storm two-three hours before the main phase of a GMS. A linear relation has been derived between the maximum value of the southward component of Bz and the Dst, which is Dst = (0:06)+(7:65)Bz +t. Some auxiliary conditions should be fulfilled with this, for example the speed of the solar wind should, on average, be 350 km s¡1 to 750 km s¡1, plasma - should be low and, most importantly, plasma temperature should be low for intense storms. If the plasma temperature is less than 0:5 X 106 K then the Dst value will be greater than the predicted value of Dst or if temperature is greater than 0:5 X 106 K then the Dst value will be less (some nT).

D2.3-0062-18 STUDY ON QUANTITATIVE TECHNOLOGY OF MAGNETIC FIELD CHARACTERS IN SOLAR ACTIVE REGION

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In order to resolve the problem of quantitative techniques of magnetic field characters of solar active region, all SOHO Michelson Doppler Interferometer (MDI) magnetograms from 1996 to 2011 have been segmented from 45oNsim 45oS and 45oEsim 45oW, the causes that lead to projective area distortion of magnetograms have been studied, the Consine area correction factor has been established, and all segmented solar active regions area have been corrected. Quantitative index system of magnetic field characters have been established and improved, include magnetic field properties of active region and polarity separation line magnetic field properties of active region, in all, there are 18 characteristic parameters, the equations of all characters have been defined. The quantitative results have been analyzed by the PCA, and magnetic field of active region10486 erupting X17.2 flare has been qualitative analysis, the results showing: The characteristic parameters of the polarity separation line(WL*sg, WLsg, R,t,i, P hiPSL, PSL,t,i, Lsg, P himax,) can well illustrate the changes of the magnetic field structure during flare bursts. The changes of these parameters may cause magnetic field shear or magnetic field distortion, and play a leading role in the magnetic field structure during flare bursts. The characteristic parameters of the magnetic field fluxes (P hiuns, P hitot) can well illustrate the changes of the magnetic field flux in the active region during flare bursts. When these parameters change, maybe new magnetic field fluxes emerge in the active region, so they have a direct impact on the flux changes during the flare bursts. P hiPSL, and P himax are proposed in this study. 9 characteristic parameters are used together to effectively monitor the changes of the magnetic field structure and magnetic field fluxes in the active region before and after flare bursts. The research results can be directly used for flare, proton event monitoring and used to forecasting models. Enrich the means of monitoring and warning of solar activity, and improve the ability of solar activity monitoring and early warning.

D2.3-0063-18 PHOTOSPHERIC AND CHROMOSPHERIC OBSERVATIONS WITH SOLAR TELESCOPE AT HVAR OBSERVATORY

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The double solar telescope at the Hvar Observatory consists of two Carl Zeiss refractors, one with 217 mm objective diameter used for photospheric observations and the second one with 130 mm objective used for chromospheric observations. Hvar solar telescope aims to produce the high-resolution and high-cadence imaging of active regions on the Sun using a field of view of about 11 arcmin for the photosphere and 7 arcmin for the chromosphere. The modern Pulnix TM-4200GE 12-bit 4 megapixel CCD cameras recording seven frames per second together with the software that automatically selects the sharpest frames allow to study the rapid changes on the Sun in great detail. High-cadence ground-based observations are an important tool to identify and study solar flares, filaments and other solar phenomena that are associated with coronal mass ejections and their propagation to the Earth. Aiming to improve the space weather forecasts using ground-based observations, we compiled the catalogue of Hvar solar telescope observations in the solar cycle 24. In addition, expansion of this catalogue in future will be used for comparison with ALMA-SSALMON observations. This work has been supported by the Croatian Science Foundation project 6212 “Solar and Stellar Variability” (SOLSTEL).

D2.3-0064-18 OBSERVATION OF HELICITY WITH VECTOR FIELD ON PHOTOSPHERE AND SUBSURFACE

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Some observational results on current helicity and subsurface kinetic helicity will be presented. The current helicity was derived from vector magnetograms observed by Solar Magnetic Field Telescope installed at Huairou Solar Observing Station. The subsurface kinetic helicity was derived from time-distance helioseismology data-analysis pipeline of Solar Dynamics Observatory/Helioseismic and Magnetic Imager.

D2.3-0065-18 IMPULSIVE PHASE CHROMOSPHERIC FLARE EMISSION, STRUCTURE AND ENERGY BALANCE.

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Using semiempirical modelling results and the analysis of EUV flare data from the SDO spacecraft, we empirically determine the structure of the top of the chromosphere and/or base of the transition zone, during the onset and development of the impulsive phase of several solar flares. Implications of the general results are discussed, in terms of various modes of energy transport that may dominate as a function of time. These finding are contrasted with purely theoretical models, revealing needs for their improvement. In this study we have used in particular the temporal behavior of the intensity and characteristic parameters such as color temperature of the observed Lyman continuum (LyC) emission, we find that besides accelerated particles, heating by heat conduction must play an important role in defining the characteristics of the chromosphere-transition zone structure, while other mechanisms such as radiative backwarming do not play a substantial role at these atmospheric layers.

D2.3-0066-18 THE CORONAL HOLE INFLUENCE PARAMETER (CHIP) AS AN IMPORTANT PARAMETER FOR DEVELOPING THE GEOMAGNETIC STORM PREDICTION MODELS

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It is well demonstrated that fast and wide halo coronal mass ejections (CMEs) can produce geomagnetic storms. Several attempts to predict well in advance the geomagnetic storms have been carried out. Moon et al. [2005], and Kim et al. [2008, 2010] reported on an important geoeffective parameter named direction parameter (D); defined as the ratio of the shortest to the longest distance measured from the solar disk center to the CME front. Such parameter quantifies the asymmetry degree of the CME shape to indicate how much CME propagation can be directed to Earth. They also developed an empirical model for predicting geomagnetic storms; their occurrence and strength as well. Their model is based on the CME parameters such as CME speed (V), CME longitude (L), magnetic eld orientation (M), and the direction parameter (D). They showed that Dst index is best correlated with D. Here, we define another empirical model relying on the coronal hole inuence parameter (CHIP) which was introduced by Gopalswamy et al. [2009] as another CME parameter that can decide the CME propagation towards to or away from the Sun-Earth line. This is important for developing the empirical prediction models. The results show that D can be successfully replaced by the CHIP in the storm prediction model and pertain similar predicted Dst values with an accuracy 56 % for both parameters. In this paper, we also investigate the correlation between the Dst index versus CME speed, sheath speed, and ICME speed for a sample of 19 disc-center MCs and 13 disc-center non-MCs. The correlation is found to be the strongest for MCs (CC=-0.69, -0.82, and-0.84, respectively) and the smallest for non-MCs (CC=-0.20, -0.33, -0.49, respectively). We also investigate the best set of parameters which depend on CME-ICME properties and can decide the most important parameter for Dst prediction. The results show that ICME speed is better correlated with Dst than CME speed (CC=-0.77, and -0.61, respectively) but due to its short forewarning time (30 minutes), we use the CME speed in our empirical model.

D2.3-0067-18 TWO-STEP MAGNETIC RECONNECTION IN A SOLAR FLARE

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We report observations of an eruptive X2.8 flare on 2013 May 13, which shows two distinct episodes of energy release in the impulsive phase. The first episode is characterized by the eruption of a magnetic flux rope, similar to the energy-release process in most standard eruptive flares. The second episode, which is stronger than the first normal one and shows enhanced high-energy X-ray and even -ray emissions, is closely associated with magnetic reconnection of a large-scale loop in the aftermath of the eruption. The reconnection inflow of the loop leg is observed in the Solar Dynamics Observatory (SDO)/Atmospheric Imaging Assembly (AIA) 304 A passband and accelerates toward the reconnection region to speeds as high as 130 km/s. Simultaneously, the corresponding outflow jets are observed in the AIA hot passbands with speeds of 740 km/s and a mean temperature of 14 MK. RHESSI observations show a strong burst of hard X-ray (HXR) and -ray emissions with hard electron spectra of δ 3, exhibiting a soft-hard-harder behavior. A distinct altitude decrease of the HXR loop-top source coincides with the inward swing of the loop leg observed in the AIA 304 A passband, which is suggested to be related to the coronal implosion. This fast inflow of magnetic flux contained in the loop leg greatly enhances the reconnection rate and results in very efficient particle acceleration in the second-step reconnection, which also helps to achieve a second higher temperature peak up to T~30 MK.

D2.3-0068-18 OPERATIONAL FLARE FORECASTING BENCHMARKS AND INITIAL PERFORMANCE COMPARISONS

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We present here select preliminary results from a recent workshop, "Benchmarks for Operational Solar Flare Forecasts" held at the Institute for Sun-Earth Environmental Research (ISEE) in Nagoya, Japan, in late 2017. Numerous methods were tested in a head-to-head operational forecasting performance exercise. Results are quantified using standard validation metrics, with a preference for metrics based on the probabilistic forecasts (rather than categorical results which are impacted by probability thresholds). We present here a preliminary analysis of the performance impacts of general method attributes, addressing questions centered on "which approaches demonstrate improvement in operational performance, and which approaches do not?"

D2.3-0069-18 13 MILLION LIGHT CURVES, 122 MILLION PARAMETERS, AND THE CONNECTION TO CORONAL MASS EJECTIONS

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When coronal mass ejections (CMEs) depart the corona, they leave behind a transient void. Such a region evacuated of plasma is known as a coronal dimming and it contains information about the kinetics of the CME that produced it. The dimming can be so great in the extreme ultraviolet (EUV) that it reduces the overall energy output of the sun in particular emission lines, i.e., dimming is observable in spectral irradiance. This should be generally true for magnetically active stars. The Solar Dynamics Observatory (SDO) EUV Variability Experiment (EVE) data provide an excellent opportunity to search for and parameterize dimming. We focus our search on the 39 extracted emission lines data product. We search these light curves for dimming around all of the >8,500 C1 solar flares observed by the Geostationary Operational Environmental Satellite (GOES) X-ray Sensor (XRS) in the SDO era. In prior work, we have found that it is important to remove the gradual flare phase from dimming light curves in order to obtain slopes and magnitudes that are consistent with what can be obtained by spatially isolating flaring loops in spectral image data. To do this, we peak-match and subtract two different emission line light curves. In this exhaustive search and characterization of dimming, we therefore consider every permutation of the 39 emission lines as well as the "uncorrected" light curves, resulting in 1,521 light curves for every C1 solar flare. Thus, we come to a total of 13 million light curves in which to search for dimming. We parameterize each light curve in terms of magnitude, slope, and duration and correlate these with CME speed and mass. Thus, we obtain a robust relationship between irradiance coronal dimming and CME kinetics.

Here, we briefly describe the feature detection and characterization algorithms developed and applied to the 13 million EUV irradiance light curves. Machine learning techniques have been used for both this backend processing pipeline and to analyze the results. All of the code is open source python available on GitHub (https://github.com/jmason86/James-s-EVEDimming-Index-JEDI). We

then provide preliminary results on the comparison between our new catalog and the established Coordinated Data Analysis Workshops' CME Catalog.

D2.3-0070-18 NEW GLE EVENT ON SEPTEMBER 10, 2017

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New ground level enhancement (GLE) was detected by the worldwide network of neutron monitors. This is the second GLE event in the 24th solar cycle. The active "Beta-Gamma-Delta" region 2673 produced it. During September 2017 the region produced a series of strong flares (up to X class). The flare which produced the GLE was of X8.2 magnitude with coordinates S08W83 and started at 15:35 UT. GLE amplitude on neutron monitors did not exceed 6% for 5-min data reduced to the sea level, a lot of stations registered it. Fort Smith (Canada) was the first station detected the solar cosmic rays in 16:10 UT. At the nearest station Inuvik the increase began about half hour later. This is an evidence of a strong anisotropy on the first phase. We have analyzed the GLE event: energy spectra and pitch-angle distribution were derived using a methodics developed by our group. It includes calculation of asymptotic cone for each station using a modern magnetosphere model and solution of the inverse problem. This methodics was already used to calculate many GLE events. Differential energy spectra during the event are derived with a 5-min step. The spectra are not purely power-law forms, but average slope is about $\gamma = -4$. This is hard (rigid) spectrum of solar cosmic rays. The results were compared with GOES spacecraft measurements on adjacent energy range. There is an acceptable agreement.

D2.3-0071-18 CORONAL MASS EJECTIONS' KINEMATICS IN 3D USING OBSERVATIONS FROM STEREO

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We have implemented a method to track coronal mass ejections (CME) events in three dimensions by combining triangulation and tie-pointing analysis with a supervised computer vision algorithm. This novel approach does not rely on any geometric constraint, and eliminates the need for visual identification of the CME boundaries. We applied our method to CME events observed simultaneously by the twin Solar Terrestrial Relations Observatory (STEREO) COR2 coronagraph imagers from 2008 to 2011 in order to obtain their 3D kinematical characterization (i.e., the velocity vector) along with their morphological properties. Some of these events have already been analyzed using other methodologies. In these cases, a comparison of results was carried out. We found that, in spite of both the different nature of the methodologies, and the different spatial coverage of the other studies with respect to ours, the majority of the results agree. On the other had, some events exhibited discrepancies in the magnitude of the velocity vector, in the longitudinal direction of propagation, and in latitude. The discrepancies appeared mainly in those cases where quasi-simultaneous, quasi-co-located events were observed in the coronagraphs' fields of view. (G.S. gratefully acknowledges the support of NASA.)

D2.3-0072-18 EARLY DETECTION AND PROPAGATION FORECAST OF CMES FROM CORONAGRAPHIC IMAGES

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In order to forecast the arrival times of Coronal Mass Ejections (CMEs) at 1 AU for Space Weather purposes, many different pipelines and tools are actually under development by different groups. The solar physics group in Turin Observatory is currently developing new routines to derive from the analysis of remote sensing data different information needed for CME forecasting. These include the determination of ambient Parker spiral conditions, the early detection of CMEs from coronagraphic images, and their propagation in the interplanetary medium taking into account magnetic drag forces. First results on thse activities will be reviewd here.

D2.3-0073-18 TURBULENCE AND HEATING IN THE FLANK AND WAKE REGIONS OF A CORONAL MASS EJECTION

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As a coronal mass ejection (CME) passes, the flank and wake regions are typically strongly disturbed. Various instruments, including the Large Angle and Spectroscopic Coronagraph (LASCO), the Atmospheric Imaging Assembly (AIA), and the Coronal Multi-channel Polarimeter (CoMP), observed a CME close to the east limb on 26 October 2013. A hot (10 MK) rising blob was detected on the east limb, with an initial ejection flow speed of 330 km/s. The magnetic structures on both sides and in the wake of the CME were strongly distorted, showing initiation of turbulent motions with Doppler-shift oscillations enhanced from ±3 km/s to

±15 km/s and effective thermal velocities from 30 km/s to 60 km/s, according to the CoMP observations at the Fe XIII line. The CoMP Doppler-shift maps suggest that the turbulence behaved differently at various heights; it showed clear wave-like torsional oscillations at lower altitudes, which are interpreted as the anti-phase oscillation of an alternating red/blue Doppler shift across the strands at the flank. The turbulence seems to appear differently in the channels of different temperatures. Its turnover time was 1000 seconds for the Fe 171 Å channel, while it was 500 seconds for the Fe 193 Å channel. Mainly horizontal swaying rotations were observed in the Fe 171 Å channel, while more vertical vortices were seen in the Fe 193 Å channel. The differential-emission-measure profiles in the flank and wake regions have two components that evolve differently: the cool component decreased over time, evidently indicating a drop-out of cool materials due to ejection, while the hot component increased dramatically, probably because of the heating process, which is suspected to be a result of magnetic reconnection and turbulence dissipation. These results suggest a new turbulence-heating scenario of the solar corona and solar wind.

D2.3-0074-18 STUDY OF SOLAR TRANSIENTS CAUSING GMSS WITH DST -100NT DURING THE PERIOD 1999-2010

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The effect of solar features on geospheric conditions leading to geomagnetic storms(GMSs)with Dst index Dst -100nT has been investigated using interplanetary magnetic field(IMF),solar wind data(SWP) and solar geophysical data with CMEs that erupted between 1999 and 2010, we considered all 51 events .The study investigated the relationship coronal mass ejection (CME) and their influence on Earth's geomagnetic field, i.e. storms and sub storms .The study is performed mainly considering intense geomagnetic storms that occurred during Solar Cycle 23 and ascending phase of 24 Solar Cycle. It has been analysed and estimated by cross correlation method that there is a delay of 17 to 96 hours in happening GMSs on the Earth after the happening of the CME on the sun. Keywords: Coronal mass ejections; Solar Wind; Interplanetary Magnetic Field; Geomagnetic Storms.

D2.3-0075-18 COMPARING FEATURES OF GENERATION OF CORONAL MASS EJECTIONS WITH DIFFERENT VELOCITIES IN FIELD OF VIEW OF LASCO CORONAGRAPHS

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The question of what determines maximum velocity of a coronal mass ejection (CME) in coronagraph's field of view (FOV) is still pending. This paper compares features of generating CMEs with the smallest, intermediate and the highest velocities in LASCO C2 and C3 FOV, as detected based on analysis of multi-wave data with high temporal and spatial resolution. From data of magnetic field vector measurements, we compared dynamics of the field parameters in umbra of active regions' spots, where CMEs with various velocities occur.

D2.3-0076-18 SPORADIC MICROWAVE RADIATION ASSOCIATED WITH THE FORMATION AND INITIAL EXPANSION OF CMES, AS A TOOL FOR ASSESSING THEIR POTENTIAL GEOEFFECTIVENESS

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The issues of studying of geoeffectiveness of coronal mass ejections and their influence on the parameters of the near-Earth space involve analysis of and allowance for the types of the coronal mass ejections, their interaction with the near-Earth space, and the characteristics of their geoeffective manifestations. In this work, we have studied the features of the sporadic solar microwave emission which precedes recording of the geoeffective coronal mass ejections on the basis of the broadband patrol observations of the Sun in the radio range, which cover the centimeter-, decimeter-, and meter-wave ranges in some periods of the XXIst-XXIIIrd solar-activity cycles. It has been shown that a significant number of coronal mass ejections in a two-hour interval before their recording by coronagraphs are preceded by sporadic radio emission that can be defined as radio precursors of coronal mass ejections. The following regular features of the existence of radio precursors of such coronal mass ejections whose effect on the near-Earth space is accompanied by variations in the geomagnetic indices (Kp and Dst) have been established on the basis of statistical consideration: the presence of the broadband radio emission of radio precursors of coronal ejections at least in one wavelength range, centimeter or decimeter; radio-precursor duration exceeds 10 min. It is confirmed that halo and partial halo coronal mass ejections, the most geoeffective coronal mass ejections, are preceded by radio precursors which cover the centimeterand decimeter-wave ranges and have the special features, namely, the radiation component possessing similar temporal behavior at various frequencies of the microwave range with a gradual increase and subsequent decrease in the flux, which simultaneously emerges in the entire microwave range. It is confirmed that in cases where the source of coronal mass ejections is located at the western edge of the solar disk or behind its limb, the broadband radio precursors are absent due to the radiation directivity effect, whereas geoeffective manifestations of the halo and partial halo coronal ejections are possible. In conclusion, it should be emphasized that allowance for the effects in a wide spectrum of electromagnetic waves, including the microwave radiation, in the stage of formation and initial propagation of coronal mass ejections seems a necessary step in the complex approach to considering geoeffectiveness of coronal ejections and their influence on the parameters of the near-Earth space.

D2.3-0077-18 CLUSTERS OF HIGH ENERGY PARTICLES ACCORDING TO HIGH RESOLUTION NEUTRON MONITOR DATA

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Neutron monitors Baksan (Northern Caucasus, 42 N), Apatity (67 N) and Barentsburg (arch. Spitsbergen, 78 N) have an advanced data acquisition system. The system registers each neutron monitors (NM) pulse: which tube produced the pulse and time with one microsecond accuracy. The system is used to study multiplicity events on NM. The multiplicity is characterized by the number of M pulses (neutrons). A multiplicity event is clear distinct: at an average interval between pulses is 22 ms on an NM the intervals between pulses inside an M event are 10-200 mcs and number of events M = 5-200. The multiplicity is two kinds: multiplicity into NM (M = 5-10) and in the atmosphere (M = 10-200). The second kind corresponds to coming in the atmosphere a particle with very high energy from hundreds GeV and more. After upgrading the acquisition system of the monitors are connected to the universal time with accuracy less than 1 mcs. Now three NMs are like one distributed detector. It is found a long sequence of multiplicity events (15-40 events during 20 seconds) after processing the data. An average time profile and spectrum of multiplicity sequence. Time profile shows a gap before and after the sequence with low number of multiplicity events. Frequency of such sequences is two orders more than occasional fluctuation. Further more, a part of the long sequences of multiplicity are simultaneously on two or three NMs. We consider it to be detected by the neutron monitors quick surges (or clusters) of density in the high-energy particle flux. Larmour radius of 1 TeV particle in the interplanetary magnetic field is compatible to heliosphere size. In this case large scale irregularities of the interplanetary magnetic field could produce such surges. Using a wide net of NMs and solving inversed problem one could derive large scale structure of heliosphere.

D2.3-0078-18 MULTI-POINT OBSERVATIONS OF QUASI-PERPENDICULAR INTERPLANETARY SHOCK STRUCTURES

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We study structures of quasi-perpendicular interplanetary shocks observed by the Wind and DSCOVR spacecraft at L1. The continuous high-time resolution DC-magnetometer measurements (11 vectors/s on Wind and 50 vectors/s on DSCOVR) allow identification of the shock ramp structure and magnetosonic-whistler precursor waves, typically observed at up to several Hz in the spacecraft frame. We analyze the shock structure dependence on the interplanetary shock parameters and on the spacecraft separation. We also identify Wind observed interplanetary shocks without precursors resulting from magnetic field under-sampling to determine the fraction of unresolved precursors.

D2.3-0079-18 STUDY OF HALO CORONAL MASS EJECTIONS USING THE CORSET METHOD

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Coronal Mass Ejections (CMEs) are large structures constituted of plasma and magnetic field that are expelled by the Sun into the heliosphere. CMEs pointing along the Sun-Earth line, called halo CMEs, are the main cause of geomagnetic storms. We select a set of 31 halo CMEs from April of 2001 until December of 2015. We used a computational algorithm called CORonal Segmentation Technique (CORSET) to track the CME and calculate the kinematic parameters, such as radial and lateral expansion speeds. From the results of the 31 events we obtained an empirical relation between the radial and the lateral expansion speeds, described by the expression Vrad=0.78 Vexp.

D2.3-0080-18 ASHI: AN 'ALL SKY' HELIOSPHERIC IMAGER FOR VIEWING THOMSONSCATTERED LIGHT

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We have developed, and are now making a detailed design for an All-Sky Heliospheric Imager (ASHI), to fly on future deep-space missions. ASHI's principal long-term objective is acquisition of a precision photometric map of the inner heliosphere as viewed from deep space. Photometers on the twin Helios spacecraft, the Solar Mass Ejection Imager (SMEI) on the Coriolis satellite, and the Solar-TErrestrial RElations Observatory (STEREO) twin spacecraft Heliospheric Imagers (HIs), all indicate an optimum instrument design for visible-light Thomson-scattering observations. This design views a hemisphere of sky starting a few degrees from the Sun. Two imagers can cover almost all of the whole sky. A key photometric specification for ASHI is 0.1% differential photometry: this enables the three dimensional (3-D) reconstruction of density starting from near the Sun and extending outward. SMEI analyses have demonstrated the success of this technique, and when employed by ASHI, this will provide an order of magnitude better resolution in 3-D density over time. We augment this analysis to include remotely-sensed 2-D velocity, and thus when these imagers are deployed in deep space they can provide comparisons of both imaged density and velocity to those measured in situ. We present recent progress in the instrument design, its expected performance specifications, and the possibilities for its deployment over the next few years.

D2.3-0081-18 CORONAL MASS EJECTION PROPERTIES AT EARTH'S VICINITY

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It has been now over 20 years of nearly continuous coverage of solar coronagraphs and interplanetary monitors in the near Earth space. Several studies have addressed the challenge of predicting interplanetary disturbance parameters from solar observations. Special attention has been given to the coronal mass ejections (CMEs) because they are among the main origins of geomagnetic disturbances. They change the properties of the near-earth interplanetary medium, enhancing some key parameters, such as the southward interplanetary magnetic field and the solar wind speed. These quantities are known to be related to the energy transfer from the solar wind to the Earth's magnetosphere via the magnetic reconnection process. Among the several attempts to establish correlations between CMEs and their interplanetary counterpart (ICME) properties, it was found that the average CME propagation speed to 1AU is highly correlated to the ICME peak speed (Dal Lago et al, 2004). In this work, we present an extended study of such correlation, which confirms the results found in our previous study.

D2.3-0082-18 GEOEFFECTIVENESS GENERATED BY THE SIRS AND THE GEOMETRY OF THE SI

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The stream interaction regions (SIRs) are generated in the interplanetary medium when a fast solar wind stream overtakes a slower one. The boundary between fast and slow solar wind flows is known as a stream interface (SI). If these large-scale phenomena interact with the Earth's magnetosphere, they can give rise to geomagnetic storms (GSs). In this study we analyzed the geoeffectiveness of a set of GSs that were generated by SIRs during the cycle 23-24. Their geoeffectivity is measured using magnetic indices at different latitudes: PCN (Polar Cap North) and PCS (Polar Cap South), aa (antipodal amplitude), AE (Auroral Electrojet), Kp (estimated global index) and SYM-H (symmetric disturbance component in H). We analyzed the geoeffective region within the SIRs with respect to the relative position of the SI. In addition, we present an analysis of the geoefectivity generated by the geometry of the SI.

D2.3-0083-18 ELECTROMAGNETIC INDUCTION ASSOCIATED TO SOLAR ERUPTIVE EVENTS AT LOW LATITUDE

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The sun, during its eruption, emits an intense light (solar flare) followed sometimes by the ejection of millions of tons of particles (CME) which crosses the interplanetary medium and causes variation of magnetospheric (ring current) and ionospheric (electrojet) currents. The variation of these currents causes rapid variation of the terrestrial magnetic field which induces, according to Faraday's induction law, an electric field on the surface and in the solid earth. This geoelectric field creates the induced currents, which seeps into the infrastructures, such as transformers, power grids, pipelines, telecommunication cables, etc. . and damage them. These currents have many times caused damage in high latitude regions (Hydro-Québec network) leading to an increased study of GICs in these regions (John G.Kappenman 2005, David Boteler 2014). It is only in these last decades that the effects of these currents are observed in mid-latitudes (in South African's transformers) and low latitudes

D2.3-0084-18 LONG-TERM FLUCTUATIONS OF GEOMAGNETIC FIELD AS PROGNOSTIC PARAMETER OF SOLAR FLARE ACTIVITY

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This paper is devoted to short-term forecasting of powerful solar flares. The opportunity of developing the short-term forecasting technique of geoeffective solar flares is presented in this study. The technique is based on the analysis of the long-period pulsations of the horizontal component of the geomagnetic field. It was shown that there was a period of about 30-60 minutes during the days before the proton solar flares. The analysis of individual events of the powerful solar flares (observed in 1991, 2001, 2005, 2006) and geomagnetic data allowed to develop a prognostic algorithm and short-term forecasting scheme, which is presented in this report. The verification of the proposed method of solar proton flares was carried out for 3 individual events (26.11.11, 07.03.12, 17.05.12). The method enhances the reliability and reduction of the cost of the implementation of short-term forecasting of geoeffective solar flares. The assumptions about the reason of such precursors-fluctuations appearance are made.

D2.3-0085-18 CAMPAIGN EVENT FROM SUN TO EARTH, AND CONSEQUENCES ON THE IONOSPHERE OF TUCUMáN, ARGENTINA

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The Sun-Earth coupling has significant consequences on several physical systems in the heliosphere, involving significantly different spatial-time scales. A multidisciplinary approach is necessary to understand the full chain of coupled processed. In this work, we carry out a study over the main processes associated to one space weather event, we identify the essential keys from its genesis at Sun to its impact on the terrestrial environment, in particular on the ionosphere, where we evaluate the event response by using multiple instruments, including both in situ and remote measurements. Data acquired by space probes have been used to study the solar origin of the transient, as well as its transport in the interplanetary medium. These data have been combined with the ones acquired in the "Tucumán Low Latitude Observatory for Upper Atmosphere" (26° 51' S, 65° 12' W) to study consequences on the low latitude ionosphere. The main aim of this study is to analyze disturbances in low latitude ionosphere occurred when it is forced by an interaction between solar wind and terrestrial magnetosphere under the presence of a space storm in the geospace. The event we analyze here is associated with a coronal hole, placed near the solar equator, with fast streams of plasma directed towards Earth between 3 and 5 of October, 2015. This event developed an intense geomagnetic storm on October 7th 2015 having a sudden commencement in the early hours that day. The geomagnetic storm reached a Dst index of -124 nT around 23 UTC. Preliminary results showed that, associated with this geomagnetic storm, an ionospheric storm occurred over Tucuman. We observe a negative ionospheric storm followed by a positive ionospheric storm in coincidence with the minimum value of Dst.

D2.3-0086-18 SPEED VECTOR DEFLECTION IN DISTURBED TYPES OF SOLAR WIND.

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In our recent paper [Yermolaev et al., 2015] we describe the average temporal profiles of interplanetary plasma and field parameters in large-scale solar-wind (SW) streams: corotating interaction regions (CIRs), interplanetary coronal mass ejections (ICMEs including both magnetic clouds (MCs) and Ejecta), and Sheaths as well as interplanetary shocks (ISs). Changes of longitude angle ϕ in CIRs from -2 to +2° agree with earlier observations. Besides we have for the first time analyzed the average temporal profiles of bulk velocity angles in Sheaths and ICMEs and found that the angle ϕ in ICME changes from 2 to -2° while in Sheath it changes from -2 to 2° (similar to change in CIR), i.e., the streams in CIR/Sheath and ICME deflect in the opposite side. When averaging the latitude angle ϑ on all intervals of the chosen SW type, the angle ϑ is almost constant 1°. We made selection SW events with increasing and decreasing angle ϑ and found that average temporal profiles for angle ϑ in selected events have the same "integral-like" shape as for angle ϕ. The difference in average profiles for angles ϕ and ϑ is explained by the fact that most events have increasing profiles for angle in ecliptic plane due to solar rotation while for angle in meridional plane numbers of increasing and decreasing profiles are equal. This work was supported by Russian Science Foundation, project no. 16-12-10062.

Reference.

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D2.3-0087-18 SPICE OPERATIONS AND SCIENTIFIC EXPLOITATION

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SPICE Operations and Scientific Exploitation Team Consortium

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The SPICE spectrometer will address key science goals of the Solar Orbiter mission, including science questions on the origin of CMEs, the acceleration of energetic particles, and the connectivity to the heliosphere.

The SPICE Operations and Scientific Exploitation Team Consortium was selected by ESA in 2016. Support for the operations and scientific exploitation of SPICE is shared between 4 main agencies in Europe (CNES, UKSA, the Norwegian Space Center, and DLR) and NASA in the United States. The lead funding agency is CNES, responsible for providing leadership and coordinating the collective efforts to ensure that the SPICE operations activities are conducted smoothly.

The Consortium will operate SPICE and provide operations support to the Solar Orbiter project to fulfill the mission's science objectives, including:

Planning of SPICE operations, in coordination with other Solar Orbiter instruments.

Providing ESA with a data processing pipeline for low-latency data, and operating a processing pipeline up to calibrated data products.

Maintaining the SPICE instrument, including monitoring and troubleshooting instrument health and safety.

Providing software and support to the scientific community to work with SPICE data.

We will present the tasks to be performed by the consortium, the consortium team structure and responsibilities, as well as an overview of the capabilities of the instrument and its contributions to the Solar Orbiter science goals.

D2.3-0088-18 KINEMATICS OF FAST AND SLOW CORONAL MASS EJECTIONS IN SOLAR CYCLES 23 AND 24

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Coronal mass ejections (CMEs) are the large eruptions of plasma and magnetic field from the solar atmosphere in to the heliosphere. They are the drivers of space weather. We have performed a statistical study of the kinematics of slow and fast CMEs in solar cycles 23 and 24. We have investigated the distribution of the width of slow and fast CMEs using Coordinated Data Analysis Workshops (CDAW) and Computer Aided CME Tracking (CACTus) catalogs. We find that the width distribution of slow and fast CMEs follow different power laws. We study the width distribution of CMEs by isolating the limb CMEs extracted from CDAW catalog and found that results are similar to non limb CMEs. We also study the variation of occurrences of CMEs with solar cycles 23 and 24 using CDAW and CACTus catalogs. We note that while the occurrence rate of fast CMEs follow the sunspot numbers, slow CMEs do not follow this trend, at least in cycle 23. We also find that solar cycle 24 produces more slow and poor CMEs which may be due to the weak polar field of sun and heliospheric field in solar cycle 24.

D2.4-0001-18 SOLAR INFLUENCE ON REGIONAL CLIMATE: WHAT IS THE CURRENT STATUS?

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Solar radiation is the primary energy source of the Earth's climate system. It is furthermore firmly established that fluctuations of the solar irradiance, triggered by orbital changes or variations in solar activity, constitute an important driver of climate variability. Beyond the basic consideration of global energy balance and associated changes in the averaged surface temperature, there have been increasing evidences of links between solar variations and regional climate variability at multiple timescales (quasi-decadal, centennial, .). Signatures have for instance been detected in the equatorial Pacific or at high latitudes of both Hemispheres. While the regional solar signals are consistently detected in observational datasets of several kinds (e.g. meteorological reanalysis, historical climate and paleoclimate reconstructions, .), they are not univocally supported by climate model simulations constrained by realistic observed forcings as revealed by the recent analysis of the solar signal in historical simulations of the Coupled Model Intercomparison Project Phase 5 (CMIP5). I will present an overview of recent observational and modeling studies that explored solar influence on climate and describe the mechanisms that are proposed to explain the transfer of the solar signal, i.e. from fluctuations of the solar irradiance and geomagnetic activity to the surface response. These mechanisms involve complex interactions within the atmosphere-ocean coupled system. I will then stress the main scientific issues and discuss ongoing work and future research directions which may help to improve our understanding of solar influences on regional climate.

D2.4-0002-18 UNUSUAL POLAR CONDITIONS OF THE SUN DURING SOLAR CYCLE 24 AND ITS IPLICATIONS FOR CYCLE 25

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Polar field strength in one solar cycle is known to indicate the strength (e.g., Sunspot number) and phase of the next cycle. In particular the polar field strength (or its proxies such as the polar coronal hole area and microwave polar brightness) during the minimum phase of a given cycle seem to be well correlated with the maximum sunspot number of the next cycle. Polar prominence eruptions and coronal mass ejections have also been found to be indicators of low polar field; their cessation signals the time of polarity reversal. While these indicators are present in the current cycle, significant differences are found regarding the phase lag between the two hemispheres and the duration of polar eruptions. We use data from the Nobeyama Radioheliograph, the Solar Dynamics Observatory, SOLIS, and Wilcox Solar Observatory to highlight these differences. We find that the north polar region of the Sun has near-zero field strength for more than three years. This is unusually long and caused by surges of both polarities heading toward the north pole that prevent the buildup of the polar field. This seems to be due to anti-Hale active regions that appeared around the 2012 peak sunspot activity in the northern hemisphere. The unusual condition is consistent with (i) the continued high-latitude prominence eruption, (ii) the extended period of high tilt angle of the heliospheric current sheet, the weak microwave polar brightness, and (iv) the lack of north polar coronal hole. On the other hand, the south polar field has started building up and the coronal hole has appeared in early 2015 because of large active regions of the correct tilt in the southern hemisphere during the 2014 peak of sunspot activity. The extended period of near-zero field in the north polar region should result in very weak and delayed sunspot activity in the northern hemisphere in cycle 25. On the other hand the south polar field has already increased significantly, suggesting that the activity in the southern hemisphere should start early; the amplitude will depend on how the south polar fields will evolve in the declining phase of cycle 24.

D2.4-0003-18 LONG-TERM EVOLUTION OF SOLAR WIND ELEMENTAL AND CHARGE STATE COMPOSITION

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Before the 1990s observations of heavy elements in the solar wind (A > 4) were limited to a small number of brief periods with favorable conditions. This has changed with the launch of the Ulysses mission in October 1990 and the ACE mission in August 1997, whose SWICS sister instruments are providing us with composition data covering all charge states of C, N, O, Ne, N, Mg, Si, S, and Fe. The nearly uninterrupted data sets combined now cover almost three full decades: Ulysses was operating until June 2009 and ACE continues to operate until today, although with some limitations of SWICS since August 2011. We will present an overview of these unique data sets and the interpretation of the elemental and charge state composition therein.

D2.4-0004-18 STRUCTURE OF THE PHOTOSPHERIC MAGNETIC FIELD DURING SECTOR CROSSINGS OF THE HELIOSPHERIC MAGNETIC FIELD

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The photospheric magnetic field is the source of the coronal and heliospheric magnetic fields (HMF), but their mutual correspondence is non-trivial and depends on the phase of the solar cycle. The photospheric field during the HMF sector crossings observed at 1 AU has been found to contain enhanced field intensities and definite polarity ordering, forming regions called Hale boundaries. Here we separately study the structure of the photospheric field during the HMF sector crossings during Solar Cycles 21-24 for the four phases of each solar cycle. We use a refined version of Svalgaard's list of major HMF sector crossings, mapped to the Sun using the solar wind speed observed at Earth, and the daily level-3 magnetograms of the photospheric field measured at the Wilcox Solar Observatory in 1976-2016. We find that the structure of the photospheric field corresponding to the HMF sector crossings and the existence and properties of the corresponding Hale bipolar regions varies significantly with solar cycle, solar cycle phase, and hemisphere. The Hale boundaries in more than half of the ascending, maximum, and declining phases are clear and statistically significant. The clearest Hale boundaries are found during the (+,) HMF crossings in the northern hemisphere of odd Cycles 21 and 23, but less systematical during the (+,) crossings in the southern hemisphere of even Cycles 22 and 24. No similar difference between odd and even cycles is found for the (,+) crossings. This shows that the northern hemisphere has a more organized Hale pattern overall. The photospheric field distribution also depicts a larger area for the field of the northern hemisphere during the declining and minimum phases, in a good agreement with the bashful ballerina phenomenon.

Getachew, T., I. Virtanen, and K. Mursula, Structure of the photospheric magnetic field during sector crossings of the heliospheric magnetic field, Solar Physics, 292, 174, 2017.

D2.4-0005-18 THE SUNSPOT NUMBER REVISION AND RECALIBRATION: AN ONGOING EFFORT

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We will present the effort that has been undertaken by the solar community to achieve the revision of the Sunspot Numbers (Sunspot and Group numbers). The well-known Sunspot Number, for example, had never been revised extensively since its creation by Rudolf Wolf in 1849.

We will focus on the different methods that are applied and envisioned for future versions of the two series.

Some corrections rely entirely on base sunspot data, using original and newly recovered historical sunspot records. A critical data selection was applied for the 17th and 18th century and an updated database is now available.

Over the 19th century, the k scaling coefficients of individual observers were recomputed using statistical methodologies developed recently, like the "backbone" method resting on a chain of long-duration observers. After identifying major changes in the observing methods, two major inhomogeneities were corrected in 1884 in the Group Number (40% upward drift) and in 1947 in the Sunspot Number (17% overestimate).

New methods like the Active Day Fraction method (Usoskin, 2016) were applied to combine different observers and compared with other available methods.

For the most recent 50 years, a full re-computation of the group and sunspot numbers was done, using all original data from the 270 stations archived by the World Data Center - SILSO in Brussels.

The new Sunspot Number series definitely exclude a progressive rise in average solar activity between the Maunder Minimum and an exceptional Grand Maximum in the late 20th century. Residual differences between the Group and Sunspot Numbers over the past 250 years confirm that they reflect different properties of the solar cycle.

We conclude on the implications for solar cycle and Earth climate studies and on important new conventions adopted for the new series.

D2.4-0006-18 ON FORECASTING SEASONAL-TO-DECADAL-TO-MILLENNIAL TIME-SCALE SOLAR MAGNETIC ACTIVITY

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Powerful space weather events caused by solar magnetic activity pose serious risks to human health, safety, economic activity and national security. Currently it is impossible to forecast the solar eruptions that can cause these terrestrial events until they are seen on the Sun, hence leaving only a few days to mitigate their hazardous impact on our technological society. After describing the current status of decadal-scale solar activity predictions, based on all plausible methods, I will demonstrate how we can predict the recently observed "seasons" in space weather, which occur in the form of a quasi-periodic, activity burst, followed by a quiet period, with a periodicity of 6-18 months. Successful predictions of these seasonal variations in solar magnetic activity would build a much firmer ground for decadal and longer time-scale forecasts. I will close by discussing the prospects and issues with both short and long-range forecasts.

D2.4-0007-18 CENTURY-LONG, MULTI-WAVELENGTH SOLAR DATABASE FROM KODAIKANAL SOLAR OBSERVATORY

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The Kodaikanal observatory has been obtaining solar images since 1904 in broad band white light, narrow band Ca-K 393.37 nm and H 656.3 nm wavelengths. Many of these observations are still continuing. The historical data which were on photographic plates has been digitized. The calibration of the Ca-K, white light and H images have been completed. The digitized data are available through an online portal. Cross calibration between different data sources as collected from observatory across the globe is underway. Some new results from this multiwavelength database will be presented.

D2.4-0008-18 CURRENT EFFORTS TO PRESERVE MT. WILSON HISTORICAL OBSERVATIONS

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Mount Wilson Observatory (MWO) located in the San Gabriel Mountains near Pasadena, California, has been taking solar observations since the early 1900s. The earliest of which include the nearly unbroken record of daily sunspot activity from 1917 through the present day. Full disk spectroheliograms in Ca K spectral line were taken from 1915 through 1985. Starting from the 1950s synoptic magnetograms were also taken utilizing the full disk longitudinal magnetograph at MWO. However, working with historical long-term dataset presents unique challenges. To be useful, data from hand drawings needed to be digitized. Furthermore, data server failures in the past have led to a loss of public access to parts of these historical data sets. Over the past several years we have worked to process and extract metadata from MWO sunspot drawings. Recently, a new project on the preservation of historical magnetograms has been started. These efforts have provided insight into dealing with issues presented by historical datasets. In this presentation we provide an overview of current efforts in preserving the historical (solar) datasets from MWO. We discuss some of these issues and the application of these insights with regard to the recovery and processing of early magnetogram data along with the current plans to transfer this data to the public domain.

D2.4-0009-18 SOLAR IRRADIANCE VARIABILITY ON TIME SCALES OF DECADES TO MILLENNIA

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Reconstructions of past solar irradiance changes over as long periods of time as possible are crucial to our understanding of solar influence on climate. They are only possible with the help of suitable models, based on detailed understanding of the mechanisms of the variability. With the advance of such models, also the past reconstructions are becoming more reliable. Nevertheless, the remaining uncertainties spread out when extrapolating back over long periods of time. They are further amplified by the increasingly poorer amount and quality of the available data that bear information on past solar activity. We will discuss the progress and the uncertainties of irradiance reconstructions on time scales of decades to millennia.

D2.4-0010-18 ESTIMATE OF THE SOLAR LUMINOSITY VARIABILITY FOR CYCLES 23 AND 24

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The effect of the solar activity on the solar luminosity, which is the total electromagnetic solar output, is one of the fundamental questions in solar physics. Changes of the solar luminosity can arise from changes of the energy flux in the convection zone that can also affects other solar parameters such as the surface temperature, the apparent radius and shape, and the symmetry of the radiative field itself. Additionally, understanding the latitudinal distribution of the flux density is needed to compare the solar variability and its stellar analogues. Nevertheless, our observations of the solar flux density are limited to a region near the ecliptic plane, which have provided just a raw estimate of the variability of the solar luminosity. Here we present a reconstruction of the solar flux density and solar luminosity for the solar cycle 23 and ascending phase of cycle 24. The reconstruction is based on a combination of a state-of-art solar surface magnetic flux transport model and a semi-empirical total and spectral irradiance model. The flux transport model is based on assimilation of MDI/SOHO and HMI/SDO magnetograms. The irradiance model's free parameters are estimated by minimizing the difference between the model's output and the PMOD Composite of TSI measurements. We have obtained a good agreement between the model's output and the measurements. The distribution of active regions leads to a clear low latitude brightening during the solar maximum. This brightening results from the balance of the contributions from bright (faculae and network) and dark features (sunspots) located in the solar surface, which peaks near the solar equator. As the effects of dark features are limited to a narrower region, the variability of the flux density at the poles is dominated by the evolution of faculae and network. The preliminary results indicate that the heat flux blocked by sunspots is lower than the flux leaked by bright features. Consequently, an increase of the luminosity through the cycle is observed as previously estimated based on near ecliptic measurements. This work also enables an assessment of the properties of solar variability when viewed from out of the ecliptic, i.e., such as we might be viewing other stars of solar activity level. Finally, the limitations of the model and future strategies to extend the reconstruction of the flux density and solar luminosity will be presented.

D2.4-0011-18 CYCLE 24 VARIABILITY OF THE ULTRAVIOLET SOLAR SPECTRAL IRRADIANCE WITH THE SOLAR/SOLSPEC 9 YEARS OF DATA FROM THE INTERNATIONAL SPACE STATION

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Accurate measurements of solar spectral irradiance (SSI) and its temporal variation are of primary interest to better understand solar mechanisms and the links between solar variability and Earth's atmosphere and climate. We present recent Ultra Violet (UV) SSI observations performed by the SOLAR/SOLSPEC spectrometer on board the International Space Station. SOLAR/SOLSPEC observations cover the essential of the solar cycle 24, from April 5, 2008 to February 15, 2017.We provide an evolution of the solar spectral irradiance during Cycle 24 using the SOLAR/SOLSPEC data thanks to revised engineering corrections, improved calibrations, and advanced procedures to account for thermal and aging corrections of the instrument. The SOLAR/SOLSPEC observations are compared with other measurements (SORCE/SOLSTICE, SORCE/SIM, SCIAMACHY) and models (SATIRE-S, NRLSSI).

D2.4-0012-18 MAGNETIC FLUX DENSITY IN THE HELIOSPHERE THROUGH FOUR SOLAR CYCLES

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The variations of the heliospheric open magnetic flux with location and time is studied using long-term datasets obtained from magnetometers onboard space probes, including near-earth, off-ecliptic and close to Sun observations. Although the determination of the heliospheric magnetic field seems straightforward from source surface magnetic maps, we argue that deviations from the simple radial, ballistic solar wind propagation should be taken into account for specific reasons. These are the effect of fluctuations of the magnetic field, the compression of the plasma at fast-slow solar wind interfaces, and the non-radial solar wind propagation close to the Sun due to high magnetic pressure. Our study recovers a long time scale, up to four solar cycles when possible, which allows us to identify features recurrent with solar rotations and their variations with solar cycles. It is shown, that long lasting recurrent magnetic sector patterns are present as well as recurrent enhanced magnetic field flux densities. However, the rotation periods tend to be different, as the latter rotates with the equatorial rotation period of the Sun, while the sector patterns has slower recurrent periods. We discuss the consequence of the different rotation period, which cause topological constraints in some cases. Our longterm statistical study of the heliosperic open magnetic flux density may contribute to a better understanding of the global magnetic cycle of the Sun

D2.4-0013-18 RESPONSE OF THE ELECTRON SLOT REGION TO SPACE WEATHER CONDITIONS

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Enhancements of electrons in the slot region attracts a special interest for planning and operations of space missions due to detrimental effects posed to spacecrafts by energetic particles. The aim of this study is to analyse variability of the radiation environment in the slot region during the period from 1998 to 2008, which covers a vide variety of space weather conditions. Dynamics of electrons with energies >0.6 MeV, >1.5 MeV, and >3 MeV were analysed based on HEO-3 highly elliptical orbit data. The data are provided online by the Aerospace Corporation at http://virbo.org/HEO.

All the cases of electron flux increase in the slot location were analysed together with interplanetary and magnetosphere characteristics associated with these events. Probability of occurrence of a "slot event" and its magnitude were defined for different levels of geomagnetic activity, such as DST index and the hourly range of the magnetic field at high latitudes (Canada), and solar wind parameters.

Long-term variability of electron flux in the slot region related to space weather conditions was studied by analysing of annual statistical distributions of electron flux during the solar cycle (1998 - 2008). While the median values of electron fluxes do not change significantly between years, the annual mean as well as standard deviation can vary dramatically, i.e. increasing 100 times for the mean and 3000 times for the standard deviation from geomagnetically more quiet to more active years. The shape of distribution function changes as well, from almost symmetric distribution around the mean value to long-tailed distributions in active years.

D2.4-0014-18 THE STORY OF THE GRAND MODERN MAXIMUM: EVOLUTION OF SOLAR MAGNETIC FIELDS DURING THE 20TH CENTURY

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The 20th century marks a period of exceptionally high solar activity, now termed the Grand Modern Maximum. Sunspot activity increased from a low level at the beginning of the century to a maximum during the solar cycle 19, then settled to a slightly lower level during cycle 20-23, and reduced to a significantly lower level during the ongoing cycle 24. Solar coronal holes are sources of high-speed solar wind streams, which cause persistent geomagnetic activity especially at high latitudes. One can estimate seasonal solar wind speeds at 1 AU for the last 100 years using high-latitude geomagnetic measurements, and thereby obtain information on the long-term evolution of the most important structures of the solar large-scale magnetic field, in particular on persistent coronal holes. The centennial evolution of solar wind speed at 1 AU is different for equinoxes and solstices, reflecting differences in the evolution of polar coronal hole extensions and isolated low-latitude coronal holes. Equinoctial solar wind speeds had their centennial maximum in 1952, during the declining phase of solar cycle 18, verifying that polar coronal holes had exceptionally persistent extensions just before the peak of the Grand Modern Maximum of solar activity. This verifies the solar dynamo model for the most active period of solar activity. On the other hand, solstice speeds due to large low-latitude coronal holes had their centennial maximum during the declining phase of solar cycle 23. A similar configuration of seasonal speeds (coronal holes) as in cycle 23 was not found earlier, not even during the less active cycles of early 20th century. Therefore, the exceptional occurrence of persistent, isolated low-latitude coronal holes in cycle 23 is not related to the low level of sunspot activity but to the demise of the Grand Modern Maximum. Based on these findings we can reconstruct the main features of the solar magnetic field and the overall coronal structure during the last 100 years.

D2.4-0015-18 ORIGIN AND RECOVERY FROM GRAND SOLAR MINIMA IN A TIME DELAY DYNAMO MODEL WITH MAGNETIC NOISE AS AN ADDITIONAL POLOIDAL SOURCE

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We explore a reduced Babcock-Leighton (BL) dynamo model based on delay differential equations using numerical bifurcation analysis. This model reveals hysteresis, seen in the recent mean-field dynamo model and the direct numerical simulations of turbulent dynamos. The BL model with 'magnetic noise' as an additional weak-source of the poloidal field recovers the solar cycle every time from grand minima, which BL source alone cannot do. The noise-incorporated model exhibits a bimodal distribution of toroidal field energy confirming two modes of solar activity. It also shows intermittency and reproduces phase space collapse, an experimental signature of the Maunder Minimum. The occurrence statistics of grand minima in our model agree reasonably well with the observed statistics in the reconstructed sunspot number. Finally, we demonstrate that the level of magnetic noise controls the duration of grand minima and even has a handle over its waiting period, suggesting a triggering effect of grand minima by the noise and thus shutting down the global dynamo. Therefore, we conclude that the 'magnetic noise' due to small-scale turbulent dynamo action (or other sources) plays a vital role even in Babcock-Leighton dynamo models and thus should be given a serious concern to understand the space climate.

D2.4-0016-18 EXTREME SOLAR PARTICLE EVENTS: HISTORICAL PROSPECTIVE

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The era of space-borne or ground-based observations of solar energetic particle events (SPEs) covers several decades, respectively. About 70 strong energetic events (ground-level enhancements, GLEs) have been recorded by ground-based instrumentations, the greatest being GLE No.5 on 23-Feb-1956. However, the statistic is still insufficient to conclude whether the Sun can produce stronger events, how much stronger and what the expected rate of their occurrence can be. Of special importance is the question of the worst-case scenario. In order to answer these questions, one has to exploit data on much longer time scales, covering millennia and millions of years, which can be done only using proxy data of cosmogenic radionuclides. Here we present an brief overview of the present state of the art in the study of extreme SEP events and an assessment of the worst case scenario for the SEP fluence in the vicinity of Earth.

D2.4-0017-18 PRECISION MEASUREMENT OF THE MONTHLY PROTON AND HELIUM FLUXES IN COSMIC RAYS WITH THE ALPHA MAGNETIC SPECTROMETER ON THE ISS

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The precision measurements of the monthly proton and helium cosmic ray fluxes for the period from May 2011 to May 2017 with Alpha Magnetic Spectrometer on the International Space Station are presented. This period covers the ascending phase of solar cycle 24 together with the reversal of the Sun's magnetic field polarity through the minimum. The detailed variations with time of the proton and helium fluxes are shown up to rigidities of 60 GV. The time dependence of the proton to helium flux ratio is also presented.

D2.4-0018-18 AN EMPIRICAL MODIFICATION OF THE FORCE FIELD APPROACH TO DESCRIBE THE MODULATION OF GALACTIC COSMIC RAYS CLOSE TO EARTH IN A BROAD RANGE OF RIGIDITIES

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On their way through the heliosphere, galactic cosmic rays (GCRs) are modulated by various effects before they can be detected at Earth. This process can be described by the Parker equation, which calculates the phase space distribution of GCRs depending on the main modulation processes: convection, drifts, diffusion, and adiabatic energy changes. A first-order approximation of this equation is the force field approach, reducing it to a one-parameter dependency, the solar modulation potential ϕ. Utilizing this approach, it is possible to reconstruct ϕ from ground-based and spacecraft measurements. However, it has been shown previously that ϕ depends not only on the local interstellar spectrum (LIS) but also on the energy range of interest. We have investigated this energy dependence further, using published proton intensity spectra obtained by PAMELA and heavier nuclei measurements from IMP-8 and ACE/CRIS. Our results show severe limitations at lower energies including a strong dependence on the solar magnetic epoch. Based on these findings, we will outline a new tool to describe GCR proton spectra in the energy range from a few hundred MeV to tens of GeV over the last solar cycles. In order to show the importance of our modification, we calculate the global production rates of the cosmogenic radionuclide 10Be which is a proxy for the solar activity ranging back thousands of years.

D2.4-0019-18 VARIATION OF THE PSD SLOPES OF COSMIC RAYS IN 1953-2016

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The flux of cosmic rays observed at the Earth is modulated by the Sun and the heliosphere. Modulation of the galactic cosmic rays (GCR) is mostly caused by scattering on the inhomogeneities of the heliospheric magnetic field (HMF). Sporadic solar events like coronal mass ejections and merged interaction regions affect the HMF and scatter GCR. Turbulent variations are another source of inhomogeneities of the, causing scattering at different scales. The variability of the cosmic ray flux as measured ground-based neutron monitors (NMs) can serve as a probe for heliospheric turbulence and its scaling. Turbulent phenomena are often characterized by a power-law type power spectral density (PSD) of the measured variable. Using

1-hour resolution data from the global NM network in 1953–2016, we have studied the powerlaw slope in the frequency range between 5.56 10−6 and 2.14 10−6 Hz, corresponding to time scales of 50 and 130 hours. The mean power-law slope was found to be 1.81 0.02. We have studied the temporal variation of this power-law slope and found that the slope values differ for different solar cycles and different cycle phases, with steeper slopes observed usually during the ascending and maximum phases, and less steep slopes during the declining and minimum phases. This implies that the scaling of HMF turbulence varies in the course of the solar cycle, reflecting different physical processes affecting GCR modulation.

D2.4-0020-18 CHARACTERISTICS OF HIGH INTENSITY LONG DURATION CONTINUOUS AURORAL ACTIVITIES (HILDCAAS) AND ESTIMATION OF AKASOFU PARAMETERS ALONG WITH ITS CORRECTION.

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High Intensity Long Duration Continuous AE Activities (HILDCAAs) are form of geomagnetic disturbances caused by intermittent magnetic reconnection. By definition of HILDCAAs, which are intense auroral activity characterized by peak AE intensity greater than 1000nT at least for 2 days and within this period the value of AE never drops below 200nT for more than 2 h at a time. In our work, we study the characteristics of HILDCAA events based on auroral electrojet index and component of interplanetary magnetic field (Bz) using continuous wavelet transform and discrete wavelet transform. We also estimate the Akasofu parameters and its corrections during HILDCAAs. We found that during HILDCAAs, there is high fluctuation in IMF-Bz with corresponding peak of AE index. The CWT analysis shows highest intensity power areas from 50 to 300 minutes for both AE and Bz during the HILDCAAs. In DWT analysis, we used higher level of decomposition to identity the common singularities present on AE and Bz. Moreover, we found that different HILDCAA events have different geoeffectiveness based on their interplanetary cause and the amount of the average energy transferred to the magnetospheric/ionospheric system. We also found that second correction in Akasofu parameter gives nearly thrice the amount of energy predicted by Akasofu parameter without correction. This indicates that the solar wind magnetosphere energy coupling efficiency during the main phase of the storm is larger than in the HILDCAA interval.

D2.4-0021-18 SOLAR CYCLE VARIATIONS OF OCCURRENCE OF SOUTHWARD COMPONENT OF INTERPLANETARY MAGNETIC FIELD OBSERVED NEAR 1 AU

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Occurrence of southward component of IMF in the GSE system in different IMF sector polarities separately has been studied for the period from 1967 to 2016 covering solar cycles 20 to 24 using satellite data. A systematic helio-latitudinal dependence and sunspot cycle variations were observed for the period of study. The phase of the annual variations of the occurrence of the southward component of IMF in the GSE system near the Earth reverses with the reversal of the polarity of large-scale solar polar magnetic field during the above sunspot cycles. The sunspot cycle-dependence of different magnitude ranges of IMF Bz (GSE) near 1 AU is also studied during the period suggesting some characteristic features.

D2.4-0022-18 VLF IONOSPHERIC EMISSION MONITORED ON THE EQUATOR

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Ionospheric electromagnetic phenomena were recorded by the VLF instrument built at the Quito Astronomical Observatory (latitude 0°,12',57 " S; longitude 78°,29',56" W). The observations were made with an electric antenna in the frequency range 0 Hz - 100 kHz. The signal processing is carries out using a computer audio card, so the instrument sensitivity depends on the audio card electronic features. The software Spectrum lab is used for data processing and visualization. Characteristics of the emissions are presented based on the study of the signal phase and amplitude variations corresponding to distinct types of electromagnetic disturbances.

D2.4-0023-18 DYNAMICAL MODELS FOR SPACE WEATHER PREDICTION: A MULTIDISCIPLINARY APPROACH, COMPARATIVE ANALYSIS, AND NUMERICAL RESULTS.

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This report focuses on comparative analysis of dynamical models for space weather prediction. SRI researchers utilize a variety of models to better understand the current state of the space weather environment, as well as to predict future events. Many of these models have been developed by Space Research Institute (Ukraine), while other models have been developed by participants in the EU project "Progress" and are shared by the space weather community. This report starts with the physical basis and a brief description of the system identication approach. Following that, several examples illustrate practical issues in temporal and spatiotemporal prediction, NARMAX and bilinear modeling. This report concerns improvement and new development of models based on data driven modelling, such as BILINEAR and NARMAX The following methods and models have been proposed: (a) dynamical-information approach to NARMAX system identication; (b) combination of NARMAX model and Lyapunov dimension; (c) guaranteed prediction; (d) robust models; (e) risk assessment in safety analysis. The Guaranteed NARMAX Model (GNM) also provides predictions. Its main advantage is that it delivers an increased prediction reliability in comparison to earlier SRI models. A novel method of the probabilistic risk assessment of the inuence of the free space environment on space systems is considered. As an example the superlight-weight thermal protection system (TPS) is considered. An approach based on combination of nonlinear dynamical models and Lyapunov dimension are used to analyze measurements of the geomagnetic indexes and solar wind parameters.

D2.4-0024-18 FLEXIBILITY, VALIDITY AND SUSCEPTIBILITY OF CYLINDRICAL LANGMUIR PROBES FOR CUBESAT AND PICO-SATELLITE TO CHARACTERIZE IONOSPHERE AND THERMOSPHERE PLASMA

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Nobel Laureate Irving Langmuir pioneered the use of electrostatic probes to measure the electron temperature, number density, floating potential, and plasma potential in ionized gases (in the 1920's). Langmuir probe is comprised of an exposed conductor (e.g., wire) immersed within a plasma. The theory of interpreting the data acquired (namely the current drawn from the plasma at a sequence of different bias voltages) from Langmuir probes is well established. Druyvesteyn noted that the second derivative of the probe current with respect to the bias voltage is proportional to the electron energy distribution function. The analysis by Laframboise enabled accurate evaluation of experimental data for cylindrical and spherical probes regardless of sheath size. PEPL makes extensive use of planar and cylindrical Langmuir (single, double, and triple) probes for evaluating plasma properties in the plumes of thrusters and in near electrode regions. The small size of typical Langmuir probes coupled with their relatively simple theory of operation make them an indispensable and widely used plasma diagnostic. We can constructs custom probes sized to each experiment, commercially available systems do exist. This research paper explore the reliability, validity and susceptibility of small dimensional Langmuir Probe in CubeSat and Pico-Satellite for Ionosphere Characterizations. There is no general theory of Langmuir probes which is applicable to all measurement conditions, because it depends on the probe size and geometry, plasma density and temperature, platform velocity, and other factors. The actual design of the probe is usually determined by considering the relationship between the probe dimensions and the Debye length of the plasma. Keywords: Ionospheric Plasma, CubeSat, Langmuir Probe, Plasma Characterization

D2.4-0025-18 STATISTICAL STUDY OF PC4 MAGNETIC PULSATIONS AT LOW LATITUDES IN INDIA AND ITS DEPENDENCE ON SOLAR WIND VELOCITY AND INTERPLANETARY MAGNETIC FIELD

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Magnetic Pulsations recorded on the ground are the signatures of the integrated signals from the earth's magnetosphere. Pc4 geomagnetic pulsations are quasi-sinusoidal variations in the earth's magnetic field in the period range 45-150 seconds. The magnitude of these pulsations ranges from fraction of a nano Tesla (nT) to several nT. Although these pulsations can be observed in a number of ways, yet the application of ground-based magnetometer arrays has proven to be the most successful methods of studying the spatial structure of hydromagnetic waves in the earth's magnetosphere. The solar wind provides the energy for the earth's magnetospheric processes. The source of Pc4 magnetic pulsations can either be internal to the magnetosphere (endogenic) or external to it, transmitted through the magnetopause (exogenic). Most of the Pc4 studies undertaken in the past have been confined to middle and high latitudes.

The spatial and temporal variations observed in the Pc4 occurrence are of vital importance because these provide evidence that can be directly related to both endogenic and exogenic wave generation mechanisms. At low latitudes (L< 2), the wave energy predominates in the Pc4 band. However the spatial characteristics of these pulsations have received little attention in the past. The present study is undertaken for describing the dependence of low latitude Pc4 occurrence on the Solar Wind Velocity (VSW) and the Interplanetary Magnetic Field (IMF) over the period range 01 January to 31 December, 2005 employing an array of three low latitude recording stations at Hanley, Nagpur and Pondicherry.

Analysis of the data for the whole year 2005 provided similar patterns of Pc4 occurrence for VSW at all the three stations. Although Pc4 occurrence was reported for VSW ranging from 250 to 1000 Km/s, yet the major Pc4 events occurred for a VSW range of 300-700 Km/sec. The IMF dependence of Pc4 occurrence for the year 2005 has shown that even though at all the three stations, it spread for IMF magnitude of up to 22 nT, yet the majority of Pc4 events occurred for a narrower range of 2-10 nT. However it is important to note that at all the three stations, the peak in the occurrence of Pc4 events was observed for IMF range of 3 to 5 nT. The results suggest that the solar wind controls Pc4 occurrence through a mechanism in which Pc4 wave energy is convected through the magnetosheath and coupled to the standing oscillations of the magnetospheric field lines.

D2.4-0026-18 SPACE WEATHER SERVICES FROM INTEGRATION OF REMOTE SENSING AND IN SITU DATA FROM SEVERAL SOLAR SPACE MISSIONS

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The Heliospheric Data Centre project for Space Weather medium-term and short-term forecast combines remote sensing and in situ open-access data relative to the Sun, the Heliosphere and the Earth's magnetosphere. This is done with the novel big data technologies, to provide scientists with the possibility to design, implement and validate Space Weather algorithms on extensive datasets.

The Heliospheric Data Centre is a joint effort between ALTEC and INAF-OATo, both located in Turin, Italy. The project has two main objectives: 1. Consolidate and evolve the Heliospheric Data Centre, initially set up with the SOHO data coming from the ESA approved SOLAR (SOho Long-term ARchive) archive, in order to manage additional solar archives storing solar coronal and heliospheric data coming from ESA and NASA space programs. 2. Develop a Heliospheric Space Weather Centre to forecast the impacts of solar disturbances on the Heliosphere and the Earth's magnetosphere.

D2.4-0027-18 PHASE RELATIONSHIP BETWEEN SUNSPOT NUMBERS AND F10.7 CM SOLAR RADIO-FLUX USING CROSS-RECURRENCE PLOTS AND WAVELET-TRANSFORM

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Abstract The phase relationship between daily and monthly counts of sunspot and solar radioflux at 10.7 cm was investigated during Solar Cycle 23 and the current Cycle 24 (1 January 1996 - - 31 December 2013) to identify essential characteristics of solar cycle maximum. The nonlinear approaches such as cross-recurrence plots and advanced wavelet techniques are used to study the asynchronous behaviors of sunspot numbers with solar radio-flux. The results are in agreement with the past findings that solar activity maxima occur at least twice during a cycle: first, near the end of the increasing activity phase and then in the early beginning years of the declining phase. We also found that the odd and even numbered Solar Cycles 23 and 24 are essentially not in phase and have a phase difference of two months. The sunspot number and solar radio-flux are in phase at the significant period of 27 days, which corresponds to one solar rotation, during the maximum phase of the cycles. Keywords: Sunspot number, Solar radio-flux, Cross-recurrence plots and wavelet transform.

D2.4-0028-18 SOLAR ACTIVITY AND IRRADIANCE RECONSTRUCTION OVER THE HOLOCENE

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Direct measurements of the solar irradiance are only available since 1978. To understand the solar influence on Earth's climate, longer records and thus reconstructions of the solar variability in the past are needed. The directly observed sunspot number allows going back to 1610 A.D, although with progressively increasing uncertainty. To assess solar variability at earlier times, one has to rely on indirect proxies of solar activity, such as concentrations of cosmogenic isotopes 10Be and 14C in terrestrial archives. They are produced mostly in the upper atmosphere by impinging galactic cosmic rays (GCRs). The flux of GCRs is modulated by both the heliospheric magnetic field and the geomagnetic field. Therefore, the isotope signals retrieved from various sites around the globe show a very high degree of similarity, reflecting changes in the solar activity. Still, short-and mid-term deviations can be observed due to various systematic effects, such as different geochemical production, atmospheric distribution processes and local climatic conditions. To account for these differences, we have constructed a state-of-the-art consistent multi-isotope composite from one global 14C and six regional 10Be data sets. This composite is then used to reconstruct decadal values of the total and spectral solar irradiance over the Holocene with the semi-empirical SATIRE-M model, while the quasi-11 year solar cycle has been simulated statistically.

D2.4-0029-18 MAGNETIC FIELD EXPERIMENT AT L1 POINT ONBOARD ADITYA-L1 MISSION

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The Aditya-L1 mission is first Indian solar mission scheduled to be placed in a halo orbit around the first Lagrangian point (L1) of Sun-Earth system in the year 2019. The scientific payloads onboard Aditya-L1 spacecraft includes a Fluxgate magnetometer (FGM) to measure the local magnetic field which is necessary to supplement the outcome of other scientific experiments onboard. The in-situ vector magnetic field data at L-1 is essential for better understanding of the data provided by the particle and plasma analysis experiments, on board Aditya-L1 mission. Also, the dynamics of Coronal Mass Ejections (CMEs) can be better understood with the help of in-situ magnetic field data at the L1 point region. This data will also serve as crucial input for the short lead-time space weather forecasting models.

The FGM is a dual range 3-axis magnetic sensor sits on a 6 m boom mounted on the EP-01 [Earth viewing Panel] deck and configured to deploy along the negative roll direction of the spacecraft. Two sets of such sensors are to be mountedone at the boom tip (6 m from the spacecraft) and other somewhere in between the boom tip and spacecraft. The main science goals of this instrument is to measure the magnitude and nature of interplanetary magnetic field (IMF) locally and to study the disturbed magnetic conditions and extreme solar events by detecting the CME from Sun as a transient event. The secondary science goals are to study the impact of interplanetary structures and shock solar wind interaction on geo-space environment and to detect plasma waves emanating from the solar corona at L1 point.

This paper gives the detailed scientific goals of this magnetic field experiment and brief technical details of the proposed FGM onboard Aditya-L1 spacecraft.

D2.4-0030-18 THE DECLINING PHASE OF THE SUNSPOT CYCLE 24

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We explore solar activity for the decay phase of the cycle 24 using data for geomagnetic indices aa/Ap and the solar polar magnetic field intensity for shorter time intervals; these indices do not depend on Earth's climate. The baseline of the geomagnetic indices increases monotonically from 1900 to 1986 and declines rapidly afterwards. We speculate that a cycle with a period 172y may exist in aa/Ap. If one assumes that solar wind will exhibit the same periodicity for the rest of the twenty-first century, one should expect the next uptick of the aa/Ap timeline to occur in the seventies. In the meantime, the indices Ap/aa may continue to undergo three-cyclequasi-periodicity to a value lower than in early 1900s, due to a steeper slope during the last few solar cycles compared to that of the period before 1900; it may reach the grand minimum level. Solar polar magnetic field intensity is decreasing systematically for the last three cycles (22-24) as are the sunspot numbers at the cycle peaks. Livingston and Penn (2009) note a long term weakening of maximum sunspot magnetic field since 1992. The North-South asymmetry in the polar field strength is pronounced for the decay phase of cycles 23, 24; itseems to change sign after cycle 21. These trends have great implications for solar physics and future space weather/climate.

D2.4-0031-18 EXTREME SOLAR PARTICLE EVENTS AND SPACE WEATHER BENCHMARKS

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The radiation impacts of solar energetic particles (SEPs) include electronic devices, computers, satellites, communications, power grids and astronauts. The research on the extreme historical solar particle events (SPEs) and the forecast for the future extreme SPEs is significant for the protection of modern infrastructure, civilization, economy and society stability. According to the US research plan and strategy, the benchmarks and the forecast methods and hazard mitigation for the extreme space weather are vital. The space weather benchmarks and forecast methods can be obtained by investigating the extreme SPEs. The benchmarks established using the 1859 SPE only are not complete, more research on the extreme historical SPEs should be carried out. In the comprehensive method for identifying the extreme historical SPEs, the solar proton intensity is derived from the radioactive elements 14C/10Be and NO radicals produced in the Earth's atmosphere and deposited in the rings of trees, corals and ice cores; the related auroras and geomagnetic storms are found from the historical records; the non-solar origin is excluded. This paper introduces briefly the comprehensive method, provides the detail evidence of the 775 SPE and proves it to be the strongest SPE in the past 11400 years, and presents the benchmarks of the proton spectra and radiation for the 775 and 1859 SPEs.

D2.4-0032-18 SIMULATION STUDY OF COSMIC RAY INTERACTIONS WITH EARTH MAGNETOATMOSPHERE: MEASUREMENT OF DIFFERENT PARTICLE FLUXES AT SATELLITE AND BALLOON HEIGHTS

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We calculated the primary and secondary particles and radiations at the balloon height (35 km) and satellite height (400 km) due to the interaction of the primary cosmic rays and solar energetic particles/radiations with the earth's atmosphere. We consider the solar modulation of the primary cosmic ray fluxes and the geomagnetic field distribution and used Monte Carlo simulation toolkit Geant4 for the full 3D description of the atmospheric and magnetospheric modeling surround earth. We present the component-wise flux distribution of the primary and secondary cosmic rays at the mentioned heights. We also compare the simulated results near the tropical latitude (geomagnetic latitude: 14.50° N) to the measured radiation flux using small balloon-borne low energy X-ray scintillator detector at this region.

D2.4-0033-18 MEASUREMENT OF SECONDARY COSMIC RAYS AT THE PFOTZER MAXIMUM AND ITS CORRELATION WITH SOLAR ACTIVITY NEAR THE TROPIC OF CANCER

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The galactic cosmic rays in the heliosphere is primarily modulated due to solar activity. These primary cosmic rays interact in the atmosphere to produce secondary particles and radiation which again strongly depends on the geomagnetic latitude of the earth due to variation of the geomagnetic field strength. So the secondary radiation flux in turn dictated by the solar activity for various geomagnetic latitudes. At relatively lower heights such as the balloon altitude these variations are more prominent at the higher latitudes, but in the present work we have measured the variation at a relatively lower latitude near the Tropic of Cancer. We used scintillation detectors on board meteorological rubber balloons to measure the cosmic secondary radiation flux (15-140 keV) throughout the atmosphere up to about 40 km from various locations near geomagnetic latitude of about 14.50° N in West Bengal, India. These measurements covering the solar activity transition from the solar maximum of the 24th solar cycle up to the next minimum (2012-2016) shows a strong anti-correlation between the secondary cosmic-ray intensity at the Pfotzer maximum and the solar activity, even at such low geomagnetic latitude.

D2.4-0034-18 THE EFFECTIVE ENERGY FOR NEUTRON MONITORS AND COSMOGENIC ISOTOPES-REDEFINED CONCEPT

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Cosmic ray variability is often described in terms of the modulation potential (ϕ) changes. Based on measurements of ground-based energy-integrating detectors, such as neutron monitors for the recent decades, and by cosmogenic isotopes stored in natural archives for the millennial timescale, variability of ϕ can be reconstructed. Here we defined the effective energy of an energy-integrating detector as energy at which the cosmic ray flux changeability is straightforward proportional to that of the detector's response. We calculated that the effective energy for the standard sea-level polar neutron monitor is around 11-12 GeV/nucleon, while for cosmic ray reconstruction based on cosmogenic isotopes it is around 6-7 GeV/nucleon and 5.5-6 GeV/nucleon for 14C data and 10Be, respectively. We compared results based on different models of local interstellar spectrum (LIS) of galactic cosmic rays, showing that the effective energy is determined robustly against the particular LIS model.

D2.4-0035-18 ENERGETIC PARTICLES EFFECTS ON THE GLOBAL ATMOSPHERIC ELECTRIC CIRCUIT

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Events of Energetic particles are potential candidates to affect the Global Atmospheric Electrical Circuit (GAEC). This is supported by theoretical models proposing that these events can modify the atmospheric conductivity profile above thunderstorms. If very strong events occur, they are able to change the atmospheric conductivity at low altitudes. These effects can be studied through measurements of the atmospheric electric field (AEF) in fair weather regions. In this study, we investigate the AEF daily curve departures from the standard curve during solar proton events and Forbush decrease. The superposed epoch analysis was utilized in order to enhance weak effects. AEF data corresponds to the period between January 2010 - December 2017, and were recorded at Complejo Astronomico El Leoncito (CASLEO) at 2550 masl. The results show possible ionization effects in regions of disturbed and fair weather regions, which alters the GAEC.

D2.4-0036-18 ANALYSIS OF SHORT TERM PERIODIC VARIATION IN SOLAR AND TERRESTRIAL PARAMETERS USING WAVELET BASED TECHNIQUES

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Solar and terrestrial activities reveal periodic variations in large range of time scales. Analysis of periodicities in the Sun and interplanetary medium exhibits various aspects of solar and terrestrial Physics. Periodicities in solar and terrestrial parameters are classified into short, mid and long-term types on the basis of period length. Short term periodicities are attributed to the solar rotation, evolution of active regions and the outflow of solar wind. In this work wavelet transform and global wavelet transform methods are used to identify the short term periodicities of Solar wind plasma parameters (i.e. Solar wind speed, proton density, temperature, plasma pressure), component of interplanetary magnetic field (IMF) (i.e. Bx, By and Bz) and corresponding geomagnetic indices (Dst) during the current solar cycle 24. We detect the short term periodicities of 14 and 27 days with the 90% confidence level for all parameters. These periods have different amplitude for different parameters. In case of Solar wind plasma density, Bz component of IMF and terrestrial geomagnetic indices short term periodicity of 14 day are more significant. This is probably due to fast stream from coronal holes overlaps with mass ejection from or near the active region resulting in a more or less random variation of measured Solar wind speed. It was concluded that the wavelet power spectrum and Global wavelet spectrum have identified the 27 day periodicities (with 14 day being its harmonic) in the dynamic parameter of Solar wind, interplanetary magnetic field. The amplitude of the periodicity depends on the parameter considered and each of them evolves differently.

Keywords: Solar Wind, Geomagnetic activity, wavelet transform, Short term periodicity

D2.4-0037-18 THE POSSIBLE IMPACT OF SOLAR ACTIVITY ON EXTRATROPICAL CYCLONE ACTIVITY

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The mechanism based on the global electric circuit (GEC) flowing vertically from the ionosphere to the Earth's surface could potentially provide the link between the solar modulated energetic particles and Earth's weather and climate. Cosmic ray induced atmospheric ionization modulates the vertical current density (Jz) and introduces the changes in GEC that could alter the microphysical properties of the clouds (Tinsley, 2008). Due to the complexity and scale of the GEC and its feedbacks, possible implications and importance of this mechanism are still mostly unknown. One of the possible feedbacks to GEC alteration could be the proces of storm invigoration and occurrence of extratropical cyclones. Using 6-hourly sea level pressure (SLP) fields from the ERA-Interim data, extratropical cyclones are identified by tracking their low-pressure centers. Daily timescale epochsuperpositional (composite) analysis is performed to analyze the occurrence of extratropical cyclones during the biggest Forbush decrease events in the last three solar cycles. Since autocorrelations are the common feature of geophysical data, to test the significance of results we use robust Monte Carlo significance testing. This work has been supported by the Croatian Science Foundation project 6212 "Solar and Stellar Variability" (SOLSTEL).

D2.4-0038-18 ON THE ROLE OF COSMIC-RAY INDUCED IONIZATION IN AEROSOL FORMATION AND CLIMATE: INSIGHTS FROM THE SOUTHERN HEMISPHERE

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It has been proposed that cosmic rays (CRs) can affect cloud cover, and thereby the Earth's climate, by facilitating the growth of cloud-seeding aerosols in the atmosphere through increased ionization. The ion-aerosol clear-air (IACA) mechanism, by which this could occur, suggests that larger atmospheric ion concentrations (e.g. as a result of higher CR incidence) would enhance the nucleation of condensation nuclei from condensable vapours, and that a fraction of these nuclei may grow large enough to contribute to cloud formation. Contradicting findings have emerged from different studies of correlations between CR intensities and cloudiness, and the topic remains controversial. In this study, a preliminary investigation of South African climate responses to the solar activity cycle revealed very weak correlations, and although signals of characteristic 11 and 22-year CR periods were present, they were not statistically significant. Expanding on this, the study aims to assess the relatively pristine aerosol and climate data recorded at and/or near the South African National Antarctic Expedition (SANAE) IV base over different timescales. The Forbush decrease of 16-17 July 2017 is particularly fortuitous: Having occurred during the Antarctic polar night, with no substantial precipitation of energetic particles (from e.g. the radiation belts) reported, it affords the opportunity to study the response of the aerosol nucleation process in the absence of other extraterrestrial sources of ionization and anthropogenic aerosols. The observed response of aerosol properties to the CR variations is evaluated against the IACA mechanism, and the implications for cloud formation and climate is discussed.

D2.4-0039-18 ESTIMATION OF THE IMPACT OF COSMIC-RAY PROTONS DURING GLE ON THE PROCESS OF IONIZATION OF THE EARTH'S ATMOSPHERE

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This work presents the results of calculating the passage of cosmic-ray protons (CR) with spectra corresponding to GLE events through the Earth's atmosphere using the software package RUSCOSMICS based on the GEANT4 software toolkit. Parameterization of the Earth's atmosphere model was obtained through the work of NRLMSISE-00. A standard physics lists for electromagnetic processe, a quark-gluon string model for hadrons with energies above 10 GeV, Bertini cascades for energies below 10 GeV and ENDF / B-VII.1 data for calculating neutron interactions with energies from 10-11 MeV to tens of MeV were used. As a result of modeling, the energy spectra of secondary CR were obtained as a function of altitude, as well as the ionization profiles from ground level to 80 km. The results are compared with the experimental data obtained during the launch of stratospheric balloons with Geiger counters installed on them and have good agreement.

D3.1-0001-18 MAGNETOSPHERIC MULTISCALE (MMS) AT THE MAGNETOPAUSE

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Advances in science occur when new capabilities arise, such as measurements at higher time resolution, or at smaller scales, or with improved instrumentation. The successful launch of MMS brought us improved temporal resolution, the ability to measure the gradients in three orthogonal directions, improved instrumentation, and a novel data acquisition strategy aimed at returning to Earth only the data with high science value. These data have enabled us to develop new diagnostic techniques to characterize the phenomena and magnetospheric structure encountered. We can examine the curvature of the field lines, the strength and thickness of the currents, pressure balance, the orientation of current sheets and their speeds. We find extensive streaming and counterstreaming electrons along the magnetic field. We see curved fields on scales below the proton gyroradius. We detect planar magnetopause current systems with a constant total (magnetic plus plasma) pressure during the crossings of the magnetopause. We also detect self-balancing ropes with finite dimensions that do not have constant pressure as they cross the spacecraft. Some of these are magnetic flux ropes and some of these are not. The complexities found raise questions about the nature of these features at the magnetopause.

D3.1-0002-18 ON THE ROLE OF THE RCONNECTION ELECTRIC FIELD IN THE ELECTRON DIFFUSION REGION

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The structure of the reconnection diffusion region is, to a large degree, determined by the requirement to balance both the current flow and its dissipation processes, and the forces exerted onto the current layer by the inflow magnetic pressure. These balances are critical: without resupply processes, the transport of accelerated and current-carrying particles away from the diffusion region would generate a current density depletion, which, in principle, could lead to a mismatch with the curl of the magnetic field. Similarly, without heating processes, the convection of hot plasma away from the diffusion region would generate a force imbalance with the ambient magnetic field. The fact that neither of these imbalances occur is a consequence of the reconnection electric field, which is therefore not only required to facilitate magnetic flux transport, but also to provide the energization required to maintain balance in the diffusion region. In this presentation, we will use particle-in-cell simulations to analyze these balance conditions. We will furthermore show that nongyrotropic particle dynamics plays a key role both as current dissipation mechanism, and as overall heating mechanism in the diffusion region current layer.

D3.1-0003-18 THIN CURRENT SHEET PROCESSES IN THE MAGNETOSPHERE OBSERVED BY MMS

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Near-Earth space is a most suitable place to study fundamental space plasma processes due to recent advancements in the in-situ measurements from multi-point spacecraft at high cadence. In particular, MMS, launched in March 2015, enables to investigate the energy conversion processes in thin boundary and current layers both on the dayside and nightside magnetosphere. The four point measurements by MMS with spatial separation down to electron scales resolve spatial structures and temporal evolution of the thin current sheets. In this talk, we highlight selected MMS observations of thin current sheets and localized plasma signatures observed in the magnetosheath, magnetopause, and magnetotail associated with magnetic reconnection and other current sheet instabilities. We discuss the implication of these small-scale processes to the large-scale magnetospheric dynamics.

D3.1-0004-18 NATURE'S GRAND EXPERIMENT: LINKAGE BETWEEN MAGNETOSPHERIC CONVECTION, SUBSTORMS AND THE RADIATION BELTS

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The solar minimum of 2007-2010 was unusually deep and long-lived. In the later stages of this period the electron fluxes in the radiation belts dropped to extremely low levels. The flux of relativistic electrons (>1 MeV) was significantly diminished, and at times were below instrument thresholds both for spacecraft located in geostationary orbits and also those in lowEarth orbit. This period has been described as a natural "grand experiment" allowing us to test our understanding of basic radiation belt physics and in particular the acceleration mechanisms which lead to enhancements in outer belt relativistic electron fluxes.

Here we test the hypothesis [1] that processes driven by magnetospheric convection initiate repetitive substorm onsets, which in turn triggers enhancement in whistler mode chorus that accelerates radiation belt electrons to relativistic energies. Conversely, individual substorms would not be associated with radiation belt acceleration. Contrasting observations from multiple satellites of energetic and relativistic electrons with substorm event lists, as well as chorus measurements, shows that the data are consistent with the hypothesis.

We show that repetitive substorms are associated with enhancements in the flux of energetic and relativistic electrons and enhanced whistler mode wave intensities. This is consistent with the recent RBSP case studies [2], which suggested that substorms were the trigger for chorus which lead to acceleration of radiation belt electrons to relativistic energies. However, in our study we see a two stage chorus wave power enhancement, the first starts slightly before the repetitive substorm epoch onset, suggesting that magnetospheric convection leading the chorus activity may be the trigger. This conclusion requires some care, as the second and strongest enhancement in chorus is very slightly after the onset, complicating the picture

During the 2009/2010 period the only relativistic electron flux enhancements that occurred were preceded by repeated substorm onsets, consistent with enhanced magnetospheric convection and repetitive substorms as a trigger. This work has been recently published in JGR [3].

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D3.1-0005-18 IMAGING DAYSIDE INTERACTIONS

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Understanding the nature of the solar wind-magnetosphere interaction and the causes of space weather within the Earth's magnetosphere are fundamental objectives for the Heliophysics discipline. A host of mechanisms have been proposed to govern the solar wind's interaction with the Earth's dayside magnetosphere. In situ observations at the magnetopause and in the high latitude dayside ionosphere provide ample evidence for steady and bursty, local and extended, component, antiparallel, and maximum magnetic field shear reconnection, the Kelvin-Helmholtz instability, and boundary waves driven by both intrinsic solar wind and foreshock-generated variations. In conjunction with results from numerical simulations, global observations from imagers and arrays of observatories can provide the information needed to evaluate the significance of each proposed mechanism as a function of the prevailing solar wind conditions. The amplitude, location, and extent of the magnetopause motion driven by each mechanism can serve as proxies for the solar wind mass, energy, and momentum that it transfers to the magnetosphere. The same is true for the perturbations that each mechanism drives in the dayside auroral oval. This talk outlines some of the global interaction puzzles that remain to be solved and some of the tools that can be used to address them, including global MHD and hybrid code numerical simulations, global imagers (e.g., soft X-ray, ENA, EUV, FUV, Thomson scattering), cubesat constellations for in situ measurements and tomography, and arrays of well-instrumented ground observatories.

D3.1-0006-18 THE STRUCTURE OF LOW MACH NUMBER, LOW BETA, QUASI-PERPENDICULAR COLLISIONLESS SHOCKS

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We present results from a recent study [Wilson et al., 2017] of the structure of 145 low Mach number (M 3), low beta (β 1), quasi-perpendicular interplanetary collisionless shock waves observed by the Wind spacecraft has provided strong evidence that these shocks have large amplitude whistler precursors. The common occurrence and large amplitudes of the precursors raise doubts about the standard assumption that such shocks can be classified as laminar structures. This directly contradicts standard models. In 113 of the 145 shocks (78

D3.1-0007-18 VARIABILITY OF KEV ELECTRONS IN THE EARTH'S MAGNETOSPHERE

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Our daily life depends more and more on space. The communication satellites are the best example of such dependence. There are about 1000 operational satellites at different orbits in near-Earth space. All of them pass through the Earth's magnetosphere where the radiation environment is hazardous for them and varies significantly with solar activity. The presence of rapidly-varying low energy (<200 keV) electrons causes surface charging effects on satellites, changes in the satellite potential and degradation of satellite surface materials. Understanding the physical processes responsible for the keV electron variations in the near-Earth space is, therefore, a timely and extremely pressing issue. Variations of solar wind parameters such as solar wind velocity and/or density have been clearly associated with changes in the electron fluxes of both keV and MeV energies in the inner Earth's magnetosphere. Interplanetary Magnetic Field (IMF) and Interplanetary Electric Field (IEF) variations are also geoeffective since they result in storms and substorms. The distribution of keV electrons further accelerated to MeV energies by various processes is critically important for radiation belt dynamics. The near-Earth plasma sheet (at about 10 RE, RE=6371 km) is the source region. Although, there have been several statistical studies for plasma sheet electrons, no final knowledge on the variations of source electrons with solar activity is available. The electron flux at keV energies varies significantly with geomagnetic activity. Substorms play a key role in electron dynamics but the associated electromagnetic fields are usually very complex and very difficult to model. The chain of physical processes starting with the analysis of solar wind driving of the source population in the plasma sheet, transport and acceleration of low energy electrons from the plasma sheet to geostationary orbit and further inside, including the roles of substorm-associated electromagnetic fields will be presented and discussed. Studying the keV electrons in the inner magnetosphere provides a critical link for our community to understand the dynamics of the radiation environment in geospace driven by the Sun.

D3.1-0008-18 THE INDUCED MAGNETOSPHERE OF VENUS: HIGHLIGHTS FROM VENUS EXPRESS

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When the solar wind flow carrying frozen-in interplanetary magnetic field impacts a conductive sphere, for instance Venus surrounded by its ionosphere, currents are induced in the conductive layer and the associated magnetic fields deviate the solar wind flow. A void of the solar wind called an induced magnetosphere forms. The interaction of the supersonic solar wind plasma with this obstacle results in drapping of the interplanetary magnetic field lines and the formation of domains and boundaries somewhat similar to the magnetosphere proper, despite different underlying physics. Those include a bow shock, magnetosheath, induced magnetosphere boundary (IMB, somewhat similar to the magnetopause), magnetotail, ionopause. It is the convective electric field that governs plasma dynamics in an induced magnetosphere contrary to the Earth case where it is the inductive electric field. As a consequence the Venus plasma sheet orientation is fully controlled by the interplanetary magnetic field. The convective electric field also results in asymmetries in both the magnetosheath, polar ionospheric field strength as well as in the drapping magnetic field.

Topologically, drapping magnetic field of the induced magnetosphere's tail and stretched dipole field of the terrestrial magnetospheric tail are quite different but both configurations result in anti-parallel magnetic field lines, which may reconnect. Indeed, reconnection events were observed in the Venus magnetotail.

The solar wind energy, momentum, and matter transfer constantly occur through IMB.The solar wind matter transfer through IMB results in the deposition of α-particle (helium) into the atmosphere. The energy transfer results in the planetary ion acceleration. The acceleration to energies above the escape energy results in the ion escape, which, due to high gravity at Venus, is the main escape process. The ions are accelerated by the convective electric field, electric field due to the electron pressure gradients ("polar wind"), and the Hall electric field. The total escape rate of planetary ions ((3-6)×1024 s–1 for oxygen ions) is similar to the Martian one despite higher gravity, by far more dense atmosphere, higher UV flux, and higher dynamic pressure. Is it a coincidence?

In this talk we review the physics of an induced magnetosphere with the focus to Venus and the latest relevant findings from the Venus Express mission.

D3.1-0009-18 ON THE CROSS-SCALE COUPLING FROM FLUID-SCALE KELVIN-HELMHOLTZ WAVES INTO ION AND ELECTRON SCALES AND ASSOCIATED PLASMA HEATING

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Understanding the energy transfer between different scales is a major challenge in collisionless plasmas. Kelvin-Helmholtz instability (KHI) is a universal shear flow instability taking place in many plasma systems such as magnetospheres of magnetized and non-magnetized planets, solar corona, Coronal Mass Ejectas, astrophysical accretion disks, as well as in laboratory plasmas. During recent years it has been shown that KHI can produce significant plasma transport via reconnection in the vortices as well as via secondary mechanisms such as kinetic wave activity and diffusion through thin boundaries created by the KHI. Likely sssociated with this transport, statistical studies have shown that cold-component ions are about 30-40 percent more abundant and hotter on the dawn side of the Earth's plasma sheet. In this talk we discuss the origin of the asymmetric evolution of the KHI and associated plasma heating via various physical mechanisms associated with the KHI such as kinetic plasma waves and magnetic reconnection, and by using data from ESAs Cluster mission, NASAs THEMIS and MMS missions, as well as high-resolution numerical simulations that can address the generation of unstable ion velocity distribution functions. Kelvin-Helmholtz instability and associated non-adiabatic heating mechanisms play also an important if not a dominant role in Jovian magnetospheric system.

D3.1-0010-18 MULTI-SPACECRAFT OBSERVATIONS OF WHISTLER-MODE WAVES: RECENT PROGRESS AND OUTSTANDING QUESTIONS

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Whistler mode waves exist in the Earth's magnetosphere in a variety of forms. For instance, chorus waves appear as intense, coherent bursts of electromagnetic wave power at a few tenths of the equatorial electron cyclotron frequency, located predominantly on the dawn side outside the plasmasphere and are believed to play a crucial role in accelerating electrons to relativistic energies. Plasmaspheric hiss waves on the other hand, appear as a constant frequency band of incoherent waves, typically at 0.2-2kHz within the dayside plasmasphere, and are thought to precipitate energetic electrons from the slot region. Recent multi-point measurements performed by various satellite missions (including Van Allen Probes and THEMIS) revealed structure within these individual whistler-mode waves types, and teleconnections between the two types. This talk focuses on some of the recent multi-point observations of chorus and hiss waves, their connections to each other, and the open questions that these observations raise, particularly as we being to realize that the large scale structure of these waves is understood relatively poorly.

D3.1-0011-18 RELATIVISTIC ELECTRON ACCELERATION DUE TO AN EXTREME FAST SOLAR WIND STREAM

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Coronal holes on the Sun are a source of fast solar wind flowing out into the solar system. When they encounter the Earth's magnetosphere they are associated with some of the highest relativistic electron flux enhancements in the Earth's van Allen radiation belts and a special type of plasma wave known as chorus. Here we present a statistical analysis of chorus waves and show that for an event lasting 5 days the waves are strong enough to accelerate electrons and increase the flux greater than 2 MeV by 4 orders of magnitude. The flux increases rapidly but tends towards a plateau suggesting there is a limit to the acceleration. The flux remains high for several days even after the solar wind stream has passed. The flux level depends on the wave properties but is relatively insensitive to the presence of a pre-existing radiation belt. For satellites at geostationary orbit the flux results in a charging current that exceeds the NASA recommended guidelines for triggering an electrostatic discharge by more than a factor of 2. As a result, satellites at geostationary orbit are more at risk from a fast solar wind stream lasting 5 days or more than they are from an extreme geomagnetic storm.

D3.1-0012-18 PARTICLE ACCELERATION MECHANISMS IN MAGNETOSPHERIC PLASMAS

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Fundamental questions in magnetospheric physics relating to radiation belts concern how the belts are created and evolve. Inevitably these questions involve issues of particle acceleration. Relativistic particle acceleration at both Earth and Jupiter is still not fully understood,despite extensive research efforts. Here we briefly review some recently developed particle acceleration mechanisms. Then we examine a particularly efficient particle acceleration mechanism called ultra-relativistic acceleration (URA). URA comprises electron energization due to a special form of nonlinear phase trapping by a coherent whistler-mode wave for electrons with an initial Lorentz factor that exceeds a certain critical value. Radiation belt electrons that encounter a combination of relativistic turning acceleration followed by multiple URA interactions can undergo significant energy increase. Under ideal conditions,at Earth (L = 4) several-hundredkeV electrons can be energized to several MeV within a few seconds,while at Jupiter (L = 8),several-hundred-keV electrons can be energized by tens of MeV in a few tens of seconds. URA can play a prominent role in generating the several-MeV electrons observed in Earth's outer zone and the tens-of-MeV electrons observed in Jupiter's magnetosphere. More generally, we expect URA to be an effective particle energization mechanism in cosmic plasma environments that contain a magnetic mirror geometry and sufficiently intense electromagnetic emissions.

D3.1-0013-18 ENERGETIC ELECTRON ACCELERATION AND PRECIPITATIONS ASSOCIATED WITH CHORUS WAVES; ARASE OBSERVATIONS

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The whistler mode chorus waves work dual role for the acceleration and precipitation of energetic electrons. The Arase satellite that was launched in December, 2016 has obtained comprehensive data sets for plasma/particles and fields/waves. In March and April, 2017, the Arase satellite observed several magnetic disturbances driven by CIR and subsequent coronal hole streams. During the period, the Arase satellite observed continuous chorus activities for a few days associated with the high-speed solar wind. During this period, comprehensive observations from the Arase satellite and ground-based observations are realized. EISCAT at Tromso, Norway observed strong ionization at the low altitude, indicating sub-relativistic electrons of the radiation belts precipitate into the atmosphere. During the period, the Arase satellite successfully observed intense chorus waves outside the plasmapause, indicating the resonance with chorus waves causes the pitch angle scattering of energetic electrons. Simultaneously, large flux enhancement of the outer belt electrons was observed with enhancement of chorus waves. We discuss the dual role that chorus waves play in controlling the dynamics of the radiation belts.

D3.1-0015-18 NEW OBSERVATIONS AND MODELING CLARIFYING THE ROLE OF EMIC WAVES FOR ULTRA-RELATIVISTIC ELECTRON LOSS IN THE HEART OF THE RADIATION BELTS.

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Recent observations and modeling provided significant improvements in our understanding of the energization mechanisms for the electrons in the radiation belts. However, loss processes remain poorly understood. In this study we present analysis of the evolution of electron radial profiles of fluxes, pitch angle and energy distributions. Our modeling and observational results show that different loss mechanisms are operational at different energies. Global simulations at all energies, radial distances, and pitch angles are compared to Van Allen Probes observations of electron fluxes. The VERB 3D model including various waves is capable of reproducing the dynamics of pitch angle distributions and energy spectra, demonstrating which loss mechanisms dominate at different energies. Analysis of the profiles of phase space density provides additional confirmation for our conclusions and presents a novel technique that identifies the region of intense local loss due to EMIC wave scattering. This technique allows us to identify the minimum energy affected by the EMIC loss and the location of the EMIC-induced loss. Modeling and observations clearly show that EMIC waves produce loss of 2-4 MeV in the heart of the belts but it remains unclear if they can contribute to the loss at lower energy.

D3.1-0016-18 NORMAL-MODE MAGNETOSEISMOLOGY AS A VIRTUAL INSTRUMENT FOR INVESTIGATION OF PLASMA MASS DENSITY IN THE INNER MAGNETOSPHERE

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Previous studies have demonstrated that the field line resonance (FLR) frequencies detected on closed field lines can be used to infer the plasma mass density distribution in the inner magnetosphere. This “normal-mode magnetoseismology” technique can act as a virtual instrument that turns spacecraft measurements of the magnetic and/or electric field into plasma mass density, which is a fundamental physical quantity that is difficult to measure directly but important to investigations involving the MHD timescales, reconnection rates, or instability/wave growth rates. This paper presents examples of normal-mode magnetoseismology results based on Magnetospheric Multiscale (MMS) measurements. During the October 2015 magnetic storm, MMS passed through the dayside magnetosphere once per day, and the observed FLR frequencies indicate a clear enhancement in the plasma mass density starting from the beginning of the magnetic storm. Simultaneous charge density values inferred from the upper hybrid resonance frequency measurements imply that the average ion mass also increased. On the third day in the recovery phase, MMS observed a significant enhancement in both mass density and the average ion mass in a narrow region spanning 1RE in the radial direction, indicating the existence of an oxygen torus. The O+ concentration in this oxygen torus is estimated to be as high as 40%. Multiple FLR harmonics can also be used infer the distribution of plasma mass density along the field line, and we will present examples of the results based on MMS observations.

D3.1-0017-18 MAGNETIC RECONNECTION ASSOCIATED WAVES IN TURBULENT MAGNETOSPHERIC PLASMAS

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Recent observations by the MMS spacecraft have confirmed that magnetic reconnection can occur not only at large scale boundaries, such as the magnetopause or magnetotail current sheets, but also in the turbulent magnetosheath. Secondary reconnection can also take place within reconnection jets. The high resolution MMS field, plasma and particle data allowed to identify the fluid and particle signatures of reconnection in a turbulent environment. It has been found that these signatures resemble the observed features in inflow/outflow, electronand iondiffusion regions of reconnection events at large-scale boundaries. Here we investigate the wave generation mechanisms for lower hybrid, whistler and electrostatic waves which are expected to occur in different regions of magnetic reconnection in a turbulent environment. The wave activity driven by reconnection outflow events are compared in the terrestrial magnetosheath and magnetotail. The identification of the expected fluid, kinetic and wave signatures provides efficient tools to further strengthen our ability to observe magnetic reconnection in turbulent plasmas.

D3.1-0018-18 SHEAR ALFVEN WAVES IN MULTI-ION PLASMAS

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Understanding the behavior of plasma waves in mixed-species plasmas is important for explaining many observations seen in both space and laboratory plasmas. The addition of a second ion species in a magnetized plasma introduces new cutoffs and resonances, such as the ion-ion hybrid cutoff frequency for parallel propagating shear Alfven waves [1]. Previous experiments on the Large Plasma Device (LAPD) have demonstrated the existence of a propagation gap between the ion cyclotron frequencies of the two ion species [2]. Additional experiments have been performed on the LAPD in order to better characterize the propagation of these waves for a wider range of plasma conditions. An antenna was used to launch shear Alfven waves in a mixed helium and neon plasma across a range of frequencies, and the results were documented and will be presented.

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D3.1-0019-18 ELECTROMAGNETIC FIELDS OF MAGNETOSPHERIC DISTURBANCES IN CONJUGATE IONOSPHERES: CURRENT/VOLTAGE DICHOTOMY

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A circuit analogy for the magnetosphere-Ionosphere current systems has two extremes for drivers of ionospheric currents: the “voltage generator” (ionospheric electric fields/voltages are constant while current varies) and the “current generator” (current is constant while the electric field varies). Here we indicate another aspect of magnetosphere - ionosphere interaction which should be taken into account when considering the current/voltage dichotomy. We show that oscillatory FAC interact with the ionosphere in a different way depending on forced driving or excitation of resonant field line oscillations. A quasi-DC driving corresponds to a voltage generator, when the ground magnetic response is proportional to the ionospheric Hall conductance. The excitation of resonant field line oscillations corresponds to the current generator, when the ground magnetic response practically does not depend on the ionospheric conductance. According to the suggested conception such ULF phenomena as TCV, Pc5 waves, should be considered as resonant response of the magnetospheric field lines and they correspond to current generator. Quasi-DC non-resonant disturbances such as SC correspond to voltage generator. However, there quite a few factors that obscure the determination of the current/voltage dichotomy - occurrence of the auroral oval, ionospheric ihomogeneities, shielding of higher frequency ULF waves by the E-layer.

D3.1-0020-18 NON-LINEAR LEAST SQUARE FITTING TECHNIQUE FOR THE DETERMINATION OF FIELD LINE RESONANCE FREQUENCY IN GROUND MAGNETOMETER DATA: APPLICATION TO THE REMOTE SENSING OF PLASMASPHERIC MASS DENSITY

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The accurate determination of the Field Line Resonance (FLR) frequency of a resonating geomagnetic field line is necessary for the remote monitoring of the plasmaspheric mass density during geomagnetic storms and quiet times alike. Under certain assumptions the plasmaspheric mass density at the equator is inversely proportional to the square of the FLR frequency. The most common techniques to determine the FLR frequency from ground magnetometer measurements are the amplitude ratio and phase difference techniques, both based on geomagnetic field measurements at two latitudinally separated ground stations. Previously developed automated techniques have used statistical methods to pinpoint the FLR frequency using the amplitude ratio and phase difference calculations. We now introduce a physics-based automated technique, using non-linear least square fitting of the ground magnetometer data, to reproduce the resonant wave characteristics on the ground, and from those determine the FLR frequency. One of the advantages of the new technique is the estimation of physically determined errors of the FLR frequency. These yield physically determined errors of the equatorial plasmaspheric mass density. We present analytical results of the new technique, and test it using data from the Inner-Magnetospheric Array for Geospace Science (iMAGS) ground magnetometer chain along the coast of Chile and the east coast of the United States. We compare the results with the results of previously published statistical automated techniques.

D3.1-0021-18 IMPLICATIONS OF EXTRA-NONLINEAR STRUCTURES IN AURORAL PLASMAS

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The satellite electric borne instruments recorded the signatures of solitary waves in magnetospheric plasma as bipolar, monopolar and tripolar in the Electric field (E) data. These structures be either parallel or perpendicular to the local magnetic field. The E-field bipo- lar structures moving parallel to the background magnetic field (Electrostatic Solitary Waves (ESWs)) is observed ubiquitous in different magnetospheric boundary regions. Apart from conventional bipolar E-field signatures there are signatures of offset bipolar pulses for which the distance between the bipolar peaks is much more than the characteristic width of each peak. In this regard we are intended to provide a theoretical understanding of those kinds of structures.

In our work, two electron temperature warm multi-ion plasma which is quite significant in magnetospheric studies have been analyzed by using conventional Sagdeev pseudopotential technique. Apart from conventional solitary wave solution this model support different kinds of extra nonlinear structures like Super Solitary Waves and Double Layers. Super solitary Waves are a new class of nonlinear structure which are characterized in having wiggled bipolar E-field pulses. It had been found the the ambient cooler electron concentration plays a deterministic role in initiating the transition process of a compressive ion acoustic solitary to the corresponding SSW and DL. In the transitional process of an ion acoustic solitary wave to a DL it has been observed that beyond a critical value of cooler electron the width of the solitary wave increases rapidly with the increasing amplitude. This anomalous increase in the width with the amplitude motivated us to compare our results with the satellite observations of Temerin et al [1]. It shows a good agreement. This further validates our model for its applicability to interpret the slowly moving ESWs in the auroral region.

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D3.1-0022-18 FIRST EVER FINDING OF A NOVEL STRUCTURE CALLED FOLDED DOUBLE LAYER (FDL) IN A MAGNETIZED PLASMA

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Broadband Electrostatic Noise (BEN) have been observed by satellites in various regions of the magnetosphere such as the plasma sheet boundary layer, the polar cusp, bow shock, auroral region, etc. Satellite observations of BEN revealed the signatures of the Electrostatic Solitary Waves (ESWs), which are monopolar and bipolar pulses in the electric field data. The high frequency part of the BEN is often studied by the electron acoustic solitary waves and double layers. Besides the usual monopolar and bipolar pulses, CLUSTER satellite observations also revealed more composite structures like tripolar ESWs. The interpretation for these kind of structures may further provides a key to understand the Earth's magnetosphere.

A novel structure called 'Super Solitary Waves (SSWs)' have captured the attention considerably in recent days. They are extra nonlinear solitary wave pulses with an extra wiggles in their bipolar electric field profile. Besides SSWs, there exists a unique type of solitary wave structure called as 'cusp like solitary waves', arising due to the imminent singularity in the Sagdeev pseudopotential profile. It is a unique trait for a magnetized plasma and has no counterpart for an unmagnetized case. In the vicinity of singularity like solutions, we have obtained the first ever electron acoustic SSW in a magnetized plasma. Due to its presence near the singularity, we presume that the SSW and singularity like solutions have some association in a magnetized plasma. While investigating it, we have encountered a novel structure, which shows the signatures of an SSW and a DL (Double Layer), we prefer to call this new structure as "Folded Double Layer (FDL)". This structure have a monopolar electric field with a wiggle or fold and exhibits an extra large amplitude solution.

In this present work, we are reporting the first ever finding of an electron acoustic FDL and its association with the cusp like solitary wave. We have considered a model comprising of beam and bulk electron fluids along with two ions and the plasma is magnetized. The ions are assumed to be hotter than electrons and obeying Boltzmann distribution. We have incorporated a new analytical tool to investigate these kind of structures. We intend to apply our theoretical analyses to interpret the observations and the further investigation may throw some light upon the role of FDL in Earth's magnetosphere.

D3.1-0023-18 WHISTLER MODE WAVES MODULATION OF LANGMUIR WAVES IN THE RADIATION BELTS AND DAYSIDE MAGNETOPAUSE

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Using high-resolution waveforms measured by the Van Allen Probes and Magnetospheric Multiscale satellites, we report a novel observation that occurs both in the radiation belts and the dayside magnetopause. Namely, whistler mode waves modulate electrostatic Langmuir wave bursts. In the radiation belts, the modulation of these two wave modes occur over two time scales: rising-tone time scale and chorus wave phase period time scale. At the magnetopause region, the modulation occurs on whistler mode phase period time scale, while these two wave modes can have very large amplitudes. The periodic Langmuir wave bursts are generally observed at the phase location where the whistler mode wave E|| component is oriented opposite to its propagation direction. The electron phase space density measurements show a beam at the velocity that matches the parallel phase velocity of the whistler mode waves. Based on this evidence, we conclude that the whistler mode waves accelerate the suprathermal electrons via Landau resonance, and generate a localized periodic electron beam in phase space density. Consequently, the Langmuir waves are excited locally and are modulated by the whistler mode wave phase. This microscale interaction between whistler mode waves and high frequency electrostatic waves provides a new insight into the nonlinear wave-particle interaction and the energy conversion processes occurred both in the radiation belts and in the reconnection regions.

D3.1-0024-18 KEY PROCESSES AT THE PISTON SHOCK REGION

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Identifying blast-wave shocks, which can arise during CME formation, is a much more complex problem. The difference from piston shocks is that a blast-wave shock originates from the explosions that frequently accompany CME formation, and further propagates freely without any CME piston effects. Earth's bow shock (BS) is a piston shock. Behind the bow shock front there is a flow of the modified solar wind plasma: transition layer, which also carries the modified magnetic field of solar wind. Velocity and density of plasma as well as parameters of magnetic field of this current can be estimated if the form of the bow shock front and of magnetopause are considered to be known. In this paper we assumed them to be paraboloids of rotation. In this paper we have determined potential distribution along magnetopause from the balance condition of substance coming into transition layer from the solar wind on one side and leaving through the gap between magnetosphere and the bow shock front and through magnetopause on another. To a first approximation this distribution differs from potential distribution at the BS front only in a constant multiplier. We used the established potential distribution as a boundary condition while solving the problem on potential distribution in the magnetosphere. The first solution harmonic turned out to coincide in the form with the boundary condition on magnetopause. I have constructed the full solution for electric field in the magnetosphere having limited ourselves to the first harmonic and corotation field. I have obtained necessary equations to model processes in the region of bow shock.

D3.1-0025-18 VARIABILITY OF THE MAGNETIC FIELD OF THE SUN AND EARTH

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The geomagnetic field determines the shape of the magnetosphere. The magnetosphere changes significantly during the inversion of the geomagnetic field. Solar magnetic activity affects the shape of the magnetosphere and the processes occurring in it. So modeling of solar and geomagnetic activity is very important for studying and forecasting the state of the magnetosphere on large and small scale time ranges. Using the Parker dynamo model which is based on the combined effect of differential rotation and the alpha-effect and taking into account meridional flows we simulate the inversion of the geomagnetic field and solar cyclic magnetic activity including global minima. Analysis of observational data for the Sun does not give a complete picture of the distribution of meridional fluxes as function of depth. Large-scale meridional fluxes can also exist in the liquid core of the Earth. We analyzed how many cells can be formed for meridional fluxes. The dynamo model with various forms of meridional fluxes is analyzed analytically and it is established, as in this case the generated field will look like. The relationship between meridional fluxes and differential rotation is discussed.

D3.1-0026-18 COMPARISON OF AE ELECTROJET INDICES TO SUPERDARN MEASUREMENTS OF SUNWARD LOW LATITUDE PLASMA CONVECTION VELOCITIES

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The auroral electrojet (AE) indices, a quantitative indicator of ionospheric electrojet current intensity, can depend significantly on the strength of magnetospheric convection, substorm activity, and conductivity variations. The Super Dual Auroral Radar Network (SuperDARN) provides a nearly constant global-scale monitoring of ionospheric plasma convection. By comparing the AE indices to the sunward low-latitude plasma convection velocities, a comparison of electrojet current intensity to current carrier velocity can be conducted. Such a comparison provides insight into the plasma conductivity that relates the two measurements. This paper describes some of the similarities and differences that were observed when comparing the AE indices to the sunward low latitude plasma convection velocities measured by SuperDARN.

D3.1-0027-18 STATISTICAL ANALYSIS OF IONOSPHERIC BOUNDARY WAVE PHENOMENA ON VENUS.

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In contrast to Earth, Venus does not possess an intrinsic magnetic field. Hence the interaction between solar wind and Venus is significantly different when compared to Earth. Within the induced magnetosphere and ionosphere of Venus, previous studies have shown the existence of vortex like structures. These structures may play an important role in the atmospheric evolution of Venus. Using Venus Express data, all of the photoelectron boundaries (PEBs) are determined from 2006 to 2014 and used as an identifier for the ionopause. Pulses of dropouts in the electron energy spectrometer were observed in 371 events, which suggests potential perturbations of the boundary. Minimum variance analysis of the 1Hz magnetic field data for the perturbations is conducted and used to confirm the occurrence of the boundary waves. Statistical analysis shows that they were propagating mainly in the +-Y direction in the polar north terminator region. The generation mechanisms of boundary waves and their evolution into the potential nonlinear regime are discussed and analysed.

D3.1-0028-18 STABILITY ANALYSIS OF HIGH-M POLOIDAL WAVES IN THE MAGNETOSPHERE

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High-m poloidal waves are a class of ultra-low-frequency (ULF) waves that are excited either internally in the magnetosphere or externally driven by wave sources from the magnetopause. These waves are important in exchanging energy with particles in the inner magnetosphere, but when and where these waves will occur is still difficult to predict because the physics involved has not been fully understood. Past studies have shown that the high-m poloidal waves during magnetic storms are caused by enhanced energy in the ring current. Recent studies based on NASA ST-5 data demonstrate that high-m poloidal waves can also occur frequently during magnetically quiet times, but the mechanism of wave generation is still unclear. Quiet-time poloidal waves have also been found in recent MMS observations.

In this study, we examine satellite field and particle measurements during high-m poloidal wave events to assess whether these waves can be excited by ballooning-mirror instabilities. The field-aligned eigenmode stability criterion is based on a kinetic-MHD theory for low-frequency instabilities formulated by Cheng and Qian (1994). The theory predicts that anti-symmetric ballooning-mirror modes (e.g. the second harmonic) can be unstable during magnetic storms. Ballooning modes with a dominant transverse magnetic component may occur in plasmas with very low beta and pressure anisotropy. We present both storm-time and quiet-time high-m poloidal wave events observed by MMS, Van Allen Probes, and ST-5 satellites, and examine whether the ballooning-mirror or ballooning instability conditions are met.

D3.1-0029-18 PLASMA WAVES AT THE SHOCK FRONT: MODE IDENTIFICATION.

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Data from multi-spacecraft missions such as Cluster and MMS enable the determination of the wave propagation vector based on observations alone. In this poster we investigate the plasma wave modes observed in the vicinity of a quasi-perpendiclar shock. Knowledge of the wave mode provides insight into the acceleration and energy redistribution processes occurring at the shock front. The source of free energy to drive the waves is determined and the effects of the observed waves on the observed electron distribution investigated.

D3.1-0030-18 PIC SIMULATION OF NONLINEAR UPPER HYBRID WAVES GENERATED BY AGYROTROPIC ELECTRON DISTRIBUTION NEAR THE ELECTRON DIFFUSION REGION

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Recently, MMS spacecraft observed upper-hybrid (UH) wave activities near the electron diffusion region (EDR) of dayside asymmetric reconnection. Agyrotropic electron beam and/or crescent distributions are found together and analysis of linear instability shows that agyrotropic electrons are free energy sources of UH waves. Because observed UH waves are very intense, it is believed that nonlinear phenomena, such as wave-particle and wave-wave interactions, can play important roles in EDR dynamics. We investigate nonlinear evolutions of UH wave activities using 2-D electromagnetic particle-in-cell (PIC) simulation. Our simulation shows that the nonlinear beam-plasma interaction by the agyrotropic beam leads fundamental and second harmonic of electrostatic UH modes and radio emissions. Simulation results are well explained by the sequential processes of wave-wave interactions, which account the electromagnetic radiation of the solar type-II and type-III radio burst. The electromagnetic decay of the fundamental UH mode generates the fundamental radio emission, while the electrostatic decay generates the backscattered mode propagating backward direction to the beam. The coalescence of the fundamental UH mode and the backscattered mode leads second harmonics radio emission.

D3.1-0031-18 THE SYSTEM SCIENCE DEVELOPMENT OF LOW ENERGY ELECTRON FLUX MODELS FOR GEOSTATIONARY ORBIT

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The low energy electrons within the radiation belts can interfere with satellite electronic systems through the process of surface charging. Therefore, the prediction of these low energy electrons is vital to mitigate hazards to spacecraft. At Geosynchronous Earth Orbit, the fluxes of low energy electrons, with energies up to several hundred keV, can vary widely in Magnetic Local Time (MLT). This is antithetical to higher energies, which are uniform in MLT. This study aims to develop Nonlinear AutoRegressive eXogenous (NARX) models that account for the spatial variation in MLT. This is difficult for system science techniques, since there is sparse data availability of the electron fluxes at different MLT. To solve this problem we investigated two different approaches. The first approach binned data from GOES 13 and 15 by MLT and deduced a separate NARX model for each bin using solar wind inputs then conjugated these into one spatio-temporal forecast. The second approach employed the MLT at the point of measurement as an input along with solar wind parameters to deduce one NARX model.

D3.1-0032-18 SURVEY OF ELECTROMAGNETIC SHIELDING INSPIRED FROM MAGNETO PLASMA SAIL FOR NANOSATELLITE APPLICATIONS

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Corpuscular radiation environment in space threatens space missions in terms of device losses as well as human damage and hence the loss of big amounts of money spent on satellites. In order to overcome the hazardous radiation effects, passive and active shielding methods are being used although the passive shielding is the more desirable choice due to it's the usage of the natural ability of shielding of the material implemented on satellites and cost is comparatively lower. However, the amount of particle radiation that can be stopped is limited and has the risk of generating secondary emissions inside the spacecraft, which is more dangerous compared to ambient irradiance. Hence, the active shielding is being used in big satellites to overcome higher energetic particles then the passive shielding methods and due to their ability of particle deflection, it's more desirable so as not to generate secondary particles. In this study, the electromagnetic shielding demonstration that is inspired by Magneto Plasma Sail concept design applications is investigated by experiments conducted in Laboratory of Spacecraft Environment INteraction Engineering (LaSEINE) in Kyushu Institute of Technology. In the experiments, the ion plasma behavior around the artificial magnetosphere is investigated with magnetic field measurements in the vacuum chamber. Moreover, the results are compared with the developed hybrid particle-in-cell simulation to point out the trustworthiness of the study. In the discussion, the results are compared and argued the applicability of electromagnetic shielding on nanosatellites.

D3.2-0001-18 MULTI-SCALE STRUCTURE OF WHISTLER WAVES WITHIN EARTH'S SUPERCRITICAL BOW SHOCK: MMS OBSERVATIONS

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Whistler waves are well-known to be an important part of the shock structure, and thus have garnered a considerable amount of attention in theoretical and observational studies. Despite that attention, their generation mechanisms, their role in shock internal structure, and consequences to plasma transport are not fully understood. We report the results of our analysis of whistler waves observed by the Magnetospheric Multiscale (MMS) mission within Earth's bow shock. The long duration high-time-resolution data make apparent the multi-scale structure of whistler waves within the layer. Characteristic of high-Mach number supercritical shocks, the macrostructure is composed of a pedestal, ramp, overshoot and undershoot on ion scales, and also sub-ion scale substructures. Superposed on the ramp substructures are bursts of intense, upstream directed, oblique whistlers at lower-hybrid frequencies and below, indicating those are important sites for the generation of these waves. Based on a detailed characterization of these intense whistler waves, comparisons with the ion distribution features, and dispersion analysis, our results indicate that the likely source of these intense whistlers is the modified two-stream instability (a.k.a. kinetic cross-field streaming instability) due to the relative drift between reflected ions and electrons. We also show that these intense whistlers are affecting shock structure and plasma transport in a significant way, by inducing electron anisotropies and carrying sizable currents that lead to secondary higher frequency whistler (0.1 0.5Ωce) and electrostatic instabilities, respectively. These observed features are indicative of an intricate coupling between small-scale interaction processes and the large-scale shock structure transpiring within the layer, with significant ramifications to shock structure, and also to plasma energization and thermalization processes occurring therein. Such a characterization is only made possible now, since the high-time-resolution measurements from MMS yield accurate estimates of currents, drifts and plasma moments on sub-ion scales together with accurate determinations of wave vectors, polarizations, phase velocities, and other wave characteristics.

D3.2-0002-18 EXPLORING TURBULENT ENERGY DISSIPATION AND PARTICLE ENERGIZATION IN SPACE PLASMAS: THE SCIENCE OF THE TURBULENCE HEATING OBSERVER (THOR) MISSION

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The Universe is permeated by hot, turbulent magnetized plasmas. They are found in galaxy clusters, in accretion disks, in the intergalactic and interstellar medium, as well as in the solar corona, the interplanetary medium and planetary magnetospheres. Our comprehension of the plasma Universe is largely based on measurements of electromagnetic radiation, such as light or X-rays, which originate from charged particles that are heated and accelerated as a result of energy dissipation of turbulent fluctuations. Therefore, it is of key importance to study and understand how plasma is energized by turbulence. Most of the energy dissipation occurs at kinetic scales, where plasma no longer behaves as a fluid and the properties of individual plasma species (electrons, protons and heavier ions) become important. The Turbulent Heating ObserveR (THOR) is one of the three missions which performed Phase A studies for selection as the fourth ESA M-class mission (M4). It is the first in situ spacecraft concept that is fully dedicated to study turbulence and how turbulence energizes plasma, which ties in with ESA's Cosmic Vision science. THOR's science focuses on kinetic plasma processes aiming to understand the basic plasma heating and particle acceleration mechanisms, how energy is partitioned among different plasma components and how dissipation operates in different regimes of turbulence. To reach this goal, THOR spacecraft and payload are designed to make detailed in situ measurements of the closest available dilute and turbulent magnetized plasmas the Near-Earth's space - at unprecedented temporal and spatial resolution. THOR focuses on particular regions in space: the pristine solar wind, the Earth's bow shock and interplanetary shocks, and the compressed solar wind regions downstream of shocks. These regions are selected because of their different turbulence properties and they reflect the properties of a number of distant astrophysical environments. In such way, THOR measurements can help understanding the fundamental behavior of plasma in the Universe. Here we present THOR's science as well as the results from mission and payload Phase-A studies.

D3.2-0003-18 STATISTICS OF GEOMETRICAL INVARIANTS OF MAGNETIC FIELD GRADIENT TENSOR IN TURBULENT SPACE PLASMAS

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The nature of spatio-temporal fluctuations in turbulent fluids and magnetofluid media, such as space plasmas, is very complex due to the highly non-Gaussian and strongly long-range correlated feature of these fluctuations and the role that structure formation plays in generating such fluctuations. The investigation of such turbulent fluctuations is generally done by investigating the spectral and scaling features. Here, we present a characterisation of these fluctuations by the geometric invariants of the magnetic field gradient tensor computed using measurements from multipoint satellite missions in different space regions from MHD scales down to kinetic ones. The analysis allows the identification of the different structures responsible for the observed turbulent character. Furthermore, a clear evolution of the joint-statistics of geometrical invariants with the distance from the proton inertial length scale is observed, indicating the formation of tube-like and/or sheet-like coherent structures at the smallest scales where Ohmic dissipation concentrates.

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D3.2-0004-18 OPTIMAL FIELD GRADIENTS DERIVED FROM MULTI-SPACECRAFT OBSERVATIONS

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The MMS mission offers the unique opportunity to check the quality of magnetic gradient estimates made by multi-spacecraft analysis methods. Particle detectors onboard MMS have enough energy and time resolution to provide ion and electron currents hence the electric particle current Jp. Magnetic records from the four spacecraft are used to estimate the tensor gradient of the vector magnetic field from which the magnetometer current Jm and divB are derived. Since the early 90’s when preparing the CLUSTER mission several methods have been designed for estimating gradients of vector fields which differ by their approaches and abilities meanwhile they all give the same weight to the four spacecraft. The theory based on reciprocal vectors allows a detailed analysis of errors affecting the estimated components of the tensor gradient of a vector field which demonstrates that less regular is the tetrahedron larger are the uncertainties. An alternative to this Standard Reciprocal Vectors (SRV’s) approach is the Generalized Reciprocal Vectors (GRV’s) approach which improves the estimate of the gradient when the tetrahedron is not regular. GRV’s will be introduced first, and then shown to improve the estimated divergence of B and the agreement between Jp and Jm on MMS event cases. GRV’s applied to CLUSTER data lead to an improved estimation of divB, i.e. closer to zero, meanwhile leading to new current estimates. It is expected that improving divB with CLUSTER data is an indication of improvement of the estimated current as for MMS data. It should nevertheless be mentioned that deformations of the tetrahedron are generally much smaller for MMS than for CLUSTER. This study will be completed by looking for MMS observation with more irregular tetrahedra.

D3.2-0005-18 MMS OBSERVATIONS OF RECONNECTION

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The NASA Magnetospheric Multiscale (MMS) mission uses four closely-spaced spacecraft to investigate magnetic reconnection in the boundary regions of the Earth's magnetosphere by measuring charged particles and electric and magnetic fields at the electron scale for the first time in space. MMS benefits from several well-developed plasma simulation research programs, which reached the electron scale prior to MMS, and these efforts were augmented by the MMS Theory and Modeling team and its team of Interdisciplinary Scientists. Many of the plasma-simulation predictions on reconnection were confirmed early in the mission, while other phenomena were discovered and in some cases confirmed by simulation. The prime mission was conducted in two phases, the dayside magnetopause and the magnetotail with four spacecraft in a tetrahedron formation with separations varied from 160 km down to 7 km and a lowinclination, highly elliptical orbit with apogee at 12 Earth radii on the day side and 25 Earth Radii in the tail. The general result is that reconnection is driven by electron dynamics and is to a large extent laminar. Although turbulence is commonly observed, it does not seem to drive reconnection or to dissipate the characteristic electron distributions that form the reconnection electric field and carry the out-of-plane current. Crescent-shaped agyrotropic electron distributions were predicted by simulation to occur in the electron stagnation region and were observed early in the dayside phase of the mission. The crescents, which form in the plane normal to the magnetic field are produced by meandering motions of magnetosheath electrons as they cross the current sheet into the boundary layer and oscillate between the magnetospheric and magnetosheath magnetic field directions. The perpendicular crescents were observed to evolve into field-aligned crescents, which carry electron jets, and these distributions were subsequently confirmed by plasma simulation. The reconnection electric field is generated primarily by divergence of the electron pressure tensor although electron inertia is partially responsible. While the energy conversion occurs primarily in the electron stagnation region when the out-of-plane (guide) magnetic field is small, larger guide fields lead to equally strong energy conversion near the X-line. An unexpected result is the association of intense standing oblique whistler waves with the energy conversion. 3D plasma simulation with highly increased numbers of electrons have since confirmed the existence of these waves. In the tail where reconnection is symmetric, the X-line is coincident with the electron stagnation point. MMS has observed multiple crescent signatures in this environment.

D3.2-0006-18 ELECTRON-SCALE DYNAMICS IN MAGNETIC RECONNECTION OBSERVED BY THE MMS MISSION

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Magnetic reconnection is a cross-scale process through which plasma energization and mixing occurring in the small-scale reconnection layer modify the large-scale plasma environment. In this talk, observations resolving the electron gyro-radii by the four-spacecraft mission Magnetospheric Multiscale (MMS) will be discussed to shed light on how large-scale plasma conditions influence the electron-scale physics during reconnection. As a current sheet thins and the current density intensifies, electrons are demagnetized, enabling a reconnection electric field to accelerate them and sustain the current. However, for reconnecting current sheets with only weak magnetic fields guiding the current, the signature of this acceleration on electron distribution functions depends upon upstream conditions, and presents an example for how large-scale plasma conditions are imprinted in the electron-scale dynamics. In magnetotail reconnection when the upstream electrons are sufficiently cold, the distributions exhibit discrete striations, as predicted by simulations [Bessho et al., 2014; Shuster et al., 2015]. At the magnetopause, the signature carved by the reconnection electric field is observed as a widened crescent in the distribution functions [Chen et al., 2017; Bessho et al., 2017]. The measurements not only show signatures of acceleration but also reveal the evidence for a process that limits this acceleration without the aid of collisions.

D3.2-0007-18 ION HEATING DURING MAGNETIC RECONNECTION

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Ion heating during reconnection is investigated using magnetotail observations from the MMS spacecraft, aided by comparisons with magnetopause observations and particle-in-cell simulations. In the diffusion region, the major temperature increase is due to mixing of demagnetized ions energized by the reconnection electric field and the in-plane electrostatic potential. The single population of inflowing ions is observed to be heated across the separatrix region. Such heating will be quantified, and the effect of the electric field spatial gradient and wave fluctuations will be discussed.

D3.2-0008-18 MMS TESTS THEORIES OF MAGNETIC RECONNECTION

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Before the launch of the Magnetospheric Multiscale mission (MMS), our understanding of the electron kinetic physics of magnetic reconnection was primarily determined by the predictions of theories and numerical simulations. These predictions can be broadly divided into two categories, depending on which process is responsible for the reconnection electric field in the inner, electron, diffusion region. The first category includes wave-particle interactions leading to anomalous resistivity, which scatters current-carrying electrons. The second class is based in a thermal inertial, "quasi-viscous," effect related to the transient nature of electron orbits in the electron diffusion region. Both categories have rather different predictions for the structure of the electron diffusion region. In this presentation, we present a brief review of the predictions of these two classes of theories. We will then review key MMS events with these predictions in mind, and interpret the data analysis in this context.

D3.2-0009-18 CONFRONTING RECONNECTION SIMULATIONS WITH MMS OBSERVATIONS

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The observations at the Earth's magnetopause by the MMS have produced an extraordinarily detailed view of the dynamics of reconnection. While some theoretical ideas on the structure of the electron diffusion region have been confirmed in the observations (e.g., the crescents in the electron velocity distributions and the shift in the peak of the reconnection-driven current toward the magnetosphere), there have been a number of surprises that contradict the expectations of pre-MMS theory and models. The electron diffusion region is much more turbulent than expected, even in reconnection events with weak magnetic shear and a strong ambient guide field. Measured magnetic energy dissipation rates can take on extreme values, more than two orders of magnitude greater than in pre-MMS predictions. 2D and 3D PIC simulations of specific MMS reconnection events have been instrumental in unraveling some of these MMS discoveries. 3D simulations of the Oct 16, 2015, (weak guide field) and the December 8, 2015, (strong guide field) events both exhibit strong LHDI-like turbulence peaked along the magnetopause separatrix. In the simulations the turbulence is strong enough to prevent the reconnection-driven current layer from collapsing to electron scales and controls the local Ohm's law in the electron diffusion region through anomalous viscosity and drag. Simulations suggest that the intense dissipation in the electron diffusion region revealed in the MMS data corresponds to a whistler-like standing structure that is driven by the annihilation of the self-generated Hall magnetic magnetic field BM rather than BL as in symmetric reconnection. Surprises in the physics of symmetric reconnection in the magnetotail are also being explored and will be discussed.

D3.2-0010-18 SIMULATION STUDY OF THE THE ENERGY AND MOMENTUM CONVERTED BY RECONNECTION

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From a global point of view reconnection uses magnetic energy to produce kinetic (flow and thermal) energy and momentum. Part of this energy is carried by the electromagnetic fields (Poynting flux), part by the plasma species. Intuitively speaking ,one expects that the energy carried by the ions overwhelms that carried by the electrons that overwhelms that carrie by the fields. The means of transport of the energy released have been analyzed by observational studies have been based on CLUSTER, THEMIS and MMS events (see e.g. [1,2]), via laboratory experiments [3] and simulations [4]. More recently, the momentum released by reconnection has been analyzed under different conditions to explore the possibility of practical applications [5]. All these studies were either local (specific crossings) or used artificial setups (in laboratory or simulation). We will present here a new approach based on using realistic equilibria [6]. We spawn kinetic fully PIC simulations form a global MHD model of the magnetosphere. We zoom into two reconnection regions: at the dayside and at the magnetotail and we observe the momentum and energy flows produced by reconnection, comparing the MHD description with the kinetic description.

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D3.2-0011-18 MMS MULTI-POINT ANALYSIS OF FTES: STRESS BALANCE, PLASMA ENERGIZATION, AND INSTABILITIES

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Flux Transfer Events (FTEs) are the product of magnetic reconnection at the dayside magnetopause. They may play significant roles in determining the global rate of reconnection and accelerating particles. This study investigates the magnetohydrodynamic forces inside and outside FTEs to infer the process through which these structures become force-free using Magnetospheric Multiscale (MMS) measurements. Akhavan-Tafti et al. [2017] demonstrated that FTE size at the subsolar magnetopause follows an exponential distribution. The observed non-linear distribution appears consistent with the plasmoid instability theory in which coalescence plays a significant role in generating large-scale flux ropes (e.g., Daughton et al., 2009; Fermo et al., 2010; Huang Bhattacharjee, 2010; Loureiro et al., 2007; Shibata Tanuma, 2001; Uzdensky et al., 2010). FTEs are also shown to contain regions of elevated plasma density which greatly contribute to thermal pressure gradient forces inside FTEs. It is shown that as FTEs evolve, the plasma is evacuated as the core magnetic field strengthens and the structure becomes more magnetically force-free. The neighboring ion-scale FTEs formed at the subsolar magnetopause due to multiple X-line reconnection are forced to interact, and likely coalesce. Entropy is invoked to motivate the discussion on the essential role of coalescence in reconfiguring magnetic fields and current density distributions inside FTEs facilitating their observed exponential growth. Magnetic pressure gradient and ion thermal pressure gradient are shown to be the dominant forces inside FTEs. Local electron kinematics are studied and used to compare the contributions of parallel electric field, Fermi acceleration, and betatron acceleration mechanisms to particle energization (e.g., Dahlin et al., 2014; Drake et al., 2006) Parallel acceleration mechanisms are shown to be dominant inside and, more significantly, in the outer perimeters of FTEs (i.e., 10 ion-inertial lengths from the outer boundary) in the vicinity of the reconnection site. On the other hand, betatron acceleration controls perpendicular heating inside the FTE in the presence of magnetic pressure gradients. Downstream of the reconnection

site, the 'freshly' reconnected field lines start to straighten due to the magnetic curvature force. Straightening field lines accelerate trapped electrons parallel to the local magnetic field as they shorten themselves (i.e., first-order Fermi acceleration). These acceleration mechanisms are shown to explain the observed anisotropic pitch angle distributions in the core and then at the edges of FTEs. Finally, the anisotropic plasma temperature and plasma instabilities are shown to be correlated. In particular, fire-hose instability is shown most pronounced inside FTEs, causing magnetic reconnection and associated particle acceleration to shut down, while the anisotropic plasma moments indicate the presence of the mirror-mode instability in the outer perimeters of quasi-force free FTEs [Drake et al., 2010].

D3.2-0012-18 MOTION OF THE X-LINE AT THE DAYSIDE MAGNETOPAUSE

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Magnetic reconnection at the dayside magnetopause occurs with a large density asymmetry and for a large range of magnetic shears. In these conditions, a motion of the X-line has been predicted in the direction of the electron diamagnetic drift. When this motion is superAlfvenic, reconnection should be suppressed. We analysed a large dataset of Double Star TC1 dayside magnetopause crossings, which includes reconnection and non-reconnection events, comprising several events during which TC-1 is near the X-line. With these close events we studied the motion of the X-line along the magnetopause: the X-line moves northward or southward according to the orientation of the guide-field, which is related to the interplanetary magnetic field BY component, in agreement with the diamagnetic drift. This motion of the X line could be responsible for non-stationary reconnection even when the boundary conditions are stable. The study of the close events permitted also to verify the diamagnetic suppression condition with local observations near the X-line: the local observations at the X line are very important to test the diamagnetic suppression condition, given the substantial variation of the magnetic shear along the magnetopause.

D3.2-0013-18 AN INTUITIVE TWO-FLUID PICTURE OF SPONTANEOUS COLLISIONLESS MAGNETIC RECONNECTION AND WHISTLER WAVE GENERATION INVOLVING FROZEN-IN CANONICAL VORTICITY

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An intuitive description of spontaneous 2D collisionless magnetic reconnection is presented in the framework of 3D electron-magneto-hydrodynamics (EMHD). The relevant EMHD equations reduce to the condition that the electron canonical vorticity Qe = me ue +qeB is frozen into the electron fluid motion. Therefore, just as frozen-in magnetic flux tubes can be defined in ideal magneto-hydrodynamics, frozen-in Qe flux tubes can be defined in this regime. Following the three-dimensional behavior of the Qe flux tubes in the reconnection geometry enables an intuitive, physical portrayal of the reconnection phenomenon that has been hard to perceive via examinations of 2D projections.

In particular, physical answers to three important questions are given. First, the spontaneity of magnetic reconnection is explained by the coupling between the curvature of the Qe field lines and the central current. Any small perturbation to the current sheet will bring a localized segment of a typical Qe field line towards the null point, effectively inducing a velocity shear perpendicular to the field line which initiates an instability. Second, extreme particle acceleration is explained by a combination of Qe flux tube thinning and magnetic field cancellation. As a segment of a typical Qe flux tube convects downwards with the current sheet, the tube gets stretched and thinned, effectively increasing the magnitude of Qe within. This, coupled with magnetic field cancellation, yields an exponential increase of particle fluid velocity. Third, whistler wave generation is explained by the current sheet's role as a source of electron canonical helicity. The current sheet effectively winds up a Qe flux tube, and whistler waves represent its dynamic unwinding, just as torsional Alfvèn waves do of magnetic flux tubes.

Generalizations of this description including other factors (e.g. ion motions, compressibility, anisotropic pressure) are also briefly discussed.

D3.2-0014-18 VLASIATOR: THE INTERCONNECTED WORLD OF KINETIC PHENOMENA IN THE MAGNETOSPHERE.

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Global kinetic simulations allow bridging the gap between the scales resolvable within spacecraft constellations and the distances between them.

Using the Hybrid-Vlasov simulation system Vlasiator to simulate the entire Magnetosphere on ion kinetic scales in global simulation runs has uncovered previously unknown couplings and interdependencies of seemingly unrelated magnetospheric processes:

The effects of magnetosheath mirror modes on dayside reconnection rates have been studied, and been shown to modulate the reconnection rate significantly. Further, the reconnection outflows themselves create fast-mode waves in the sheath which act back on accelerated particles, and these have measurable effects on the bowand foreshock regions. Even beyond the polar cusps, variability of dayside reconnection outflows shows influences on tail reconnection behaviour.

We present the surprising interconnections of multiple ion kinetic magnetospheric phenomena that have previously been treated in isolation, how their features can be compared and studied in spacecraft data and how further connections can be discovered in the future.

D3.2-0015-18 MMS OBSERVATIONS OF RECONNECTION AND RELEVANT SIGNATURES IN THE MAGNETOTAIL

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Near-Earth magnetotail reconnection is considered to be a major energy conversion process leading to large-scale reconfiguration of the magnetotail. An important consequence of the magnetotail reconnection is the fast plasma jet (known as bursty bulk flow), which contributes to energy transport toward inner magnetosphere. Interaction with the reconnection jets and the Earth's dipole field leads to acceleration of particles and formation of field-aligned currents. High-time resolution measurements from MMS, launched in March 2015, enables to study of the dynamics of the sub-ion/electron-scale processes in the reconnection region as well as the fronts and plasma boundaries formed between the near-Earth reconnection and flow-braking regions. In this presentation, we highlight the new observational signatures in the reconnection region, reconnection jet, and flow braking region obtained by the four MMS spacecraft.

D3.2-0016-18 MULTISCALE MAGNETOTAIL RECONNECTION

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Magnetic reconnection in the tail of Earth's magnetosphere is inherently multiscale. Even when compared to similar processes at the magnetopause and in laboratory plasmas, it involves a much wider range of scales. First of all, because of the stabilizing effect of the northward magnetic field component Bz, the tearing stability region in the magnetotail extends from micro (electron) to global scales. Second, to be unstable on the macro-scale edge of the stability region, the tail must have a region of a tailward Bz gradient. The corresponding Bz "hump" introduces a mesoscale, intermediate between the tail current sheet thickness and its length. Finally, when the hump configuration becomes unstable it results in the formation of dipolarization fronts (DFs), which introduce structures with finer scales down to the electron inertial scale. Here we present results of 3-D PIC simulations of the tail reconnection, which starts on the macro-scale edge of the tearing stability region and proceeds through an ideal MHD stage followed by the ion tearing instability when ions become unmagnetized. The distinctive features of this region of the ion demagnetization-dominated reconnection (IDMR) are spontaneous generation of bursty bulk flows and DFs that may precede the magnetic topology change; new Hall patterns, different from the classical quadrupole pattern; and new plasma dissipation regions different from the electron diffusion region and associated with DFs. The multiscale reconnection structure extends to 3D because the IDMR processes compete with kinetic ballooning/interchange instability and flapping motions of the current sheet.

D3.2-0017-18 KINETIC SIMULATIONS OF RECONNECTION OUTFLOWS AT EARTH'S DAYSIDE MAGNETOPAUSE

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Understanding the structure and dynamics of magnetic reconnection outflows at Earth's dayside magnetopause is challenging because it involves both the global evolution of the dayside magnetosphere and the local dynamics of kinetic processes. To this end we have carried out three-dimensional semi-global kinetic simulations to investigate how plasma distributions and electromagnetic fields, as well as filamentary structures, develop, evolve, and interact in the outflow regions for different plasma parameters and magnetic field shears at the magnetopause. The simulation approach consists of first using global magnetohydrodynamic (MHD) simulations to determine the large-scale stresses imposed on the dayside magnetosphere by the solar wind, and then using the results of the MHD simulations to set the initial state and evolving boundary conditions of fully kinetic implicit particle-in-cell simulations. This approach allows us to simulate large domains both in space and energy. We discuss the results of the simulations by comparing electromagnetic fields, plasma parameters, and particle velocity distribution functions observed in different regions of the simulation domain with local spacecraft observations at the dayside magnetopause.

D3.2-0018-18 UPDATE ON SMILE - A NEW MISSION TO IMAGE THE MAGNETOSPHERE

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Solar wind - Magnetosphere - Ionosphere Link Explorer (SMILE) is a novel self-standing mission jointly developed between the European Space Agency (ESA) and the Chinese Academy of Sciences (CAS). It will observe the solar wind-magnetosphere coupling via simultaneous in situ solar wind/magnetosheath plasma and magnetic field measurements, X-ray images of the magnetosheath and polar cusps, and UV images of global auroral distributions. Remote sensing of the magnetosphere with X-ray imaging is now possible thanks to the discovery of solar wind charge exchange (SWCX) taking place in the Earth's environment. The SMILE mission is currently under phase B study. The overview and recent development of SMILE will be presented.

D3.2-0019-18 MODELING OF TAIL PROCESSES: PARTICLE ACCELERATION IN DIPOLARIZATION FRONTS

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Using three-dimensional MHD simulations, we model near tail reconnection and the formation and earthward propagation of dipolarization fronts. The simulations form the basis for particle orbit studies. Using Liouville mapping of the conservation of the phase space density along trajectories, we construct particle distribution functions, spatial maps, and energy time spectrograms that compare favorably with THEMIS and MMS observations. and shed light on accleration mechanisms and sources.

D3.2-0020-18 MULTISCALE KINETIC PROCESSES ASSOCIATED WITH FAST FLOWS AND DIPOLARIZATION FRONTS

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Fast flows and associated dipolarization fronts play a crucial role in plasma, energy and magnetic field transports through the Earth's magnetotail. They also host complex particle acceleration and energy dissipation processes. Various electrostatic and electromagnetic waves have been detected during front crossings thanks to in situ measurements provided by single (Geotail, Polar) and multisatellite (ISEE, Cluster, THEMIS and MMS) missions. In particular, large amplitude electrostatic fields related to lower-hybrid drift waves at the front and intense electromagnetic whistler waves behind the front in the region of the magnetic compression were measured. Non linear electrostatic and electromagnetic coherent structures are also often observed in the vicinity of these fronts although formation mechanisms are not fully understood. In the present study, we show recent MMS data gathered in the magnetotail and discuss possible multiscale kinetic processes related to wave-particle interactions and associated with dipolarization front crossings.

D3.2-0021-18 CONTRIBUTION OF ENERGETIC AND HEAVY IONS TO THE PLASMA PRESSURE IN THE MAGNETOTAIL AND THE RING CURRENT

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Ions in the magnetospheric plasma sheet drift toward the Earth and populate the ring current. The enhanced plasma pressure in the ring current distorts the terrestrial internal magnetic field at the surface, and this disturbance strongly affects the strength of a magnetic storm. The contribution of energetic ions (> 40 keV) and/or of heavy ions to the total plasma pressure on the closed field lines is not always considered. In this study, we assess the contribution of low-energy and energetic ions of different species to the total plasma pressure for the storm observed by the Cluster mission from 27 September until 3 October 2002. We show that the contribution of energetic ions (> 40 keV) and of heavy ions to the total plasma pressure is about 14-59% in the magnetotail and about 76-97% in the ring current. This shows that it is necessary to consider heavy ions and the energetic part of the ion distribution in simulations of the terrestrial magnetosphere. We compare the derived from Cluster observations plasma pressure in the ring current for the magnetic storm event with simulations of the Space Weather Modeling Framework, which include ionospheric ion outflows from two different models. Both models produce reasonable results. The model which produces the most heavy ions agrees best with the observations. The assessment of our current capability to reproduce the ionospheremagnetosphere coupling suggests that there is still potential for refinement in the simulations.

D3.2-0022-18 THEMIS CONJUGATE ASI AND NEAR-EARTH PLASMA SHEET OBSERVATIONS OF WAVES WITH KINETIC BALLOONING-INTERCHANGE SIGNATURES

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Eight THEMIS events of plasma sheet oscillations with kinetic ballooning/interchange instability (BICI) signatures were collected in conjunction with ground all-sky imager (ASI) observations, using an adapted model for THEMIS footprints' mapping. Here we aim at showing the auroral signatures of the BICI waves, which appear to resemble a reach activity often being diffuse and patchy aurora slightly poleward of the auroral oval. We further use the adapted model to test whether the background plasma sheet shape affects the BICI waves and the auroral shapes.

D3.2-0023-18 TURBULENCE IN THE PLASMA SHEET FROM MULTIPOINT CLUSTER AND THEMIS MEASUREMENTS.

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We present a review of main properties of the turbulence in the plasma sheet including the eddy diffusion, energy transport, intermittency, and the influence of the bursty bulk flow events. These studies have been done using the CLUSTER and THEMIS satellites. It was found that the properties of the turbulence are strongly dependent on the location within the plasma sheet and less on the geomagnetic conditions. Even during quiet geomagnetic conditions plasma in the plasma sheet is strongly turbulent. The level of turbulence increases to the tail and intensifies during geomagnetic substorms, especially during the expansion phase. Study of spatial distribution of the BBFs in the inner and outer plasma sheet for quiet and disturbed geomagnetic conditions also showed that BBFs could be an inherent component of the intermittent turbulent cascade in the central plasma sheet.

D3.2-0024-18 THE ROLE OF PLASMA SHEET O+ IN FORMING THE STORM-TIME RING CURRENT

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During storm times, the particle pressure that creates the storm-time ring current in the inner magnetosphere can be dominated by O+, and the fraction contributed by O+ is higher toward the inner edge of the ring current. The storm-time ring current is predominantly formed by inward convection of the plasma sheet, and there is no evidence that an inner source of O+ makes a significant contribution. Thus the O+/H+ pressure ratio gradient must reflect a property of the plasma sheet source. The plasma sheet population gets accelerated as it convects into the inner magnetosphere, so the range of the phase space density that dominates the pressure changes. In addition, the time to reach low L-values (L 3) can be hours longer than the time to reach the outer L-values (L 5). Therefore, the higher O+/H+ pressure ratio at the inner edge of the ring current population could result from a difference in the H+ and O+ spectra in the near-earth plasma sheet source spectrum, or from time dependence in the source, with O+ enhanced in the plasma sheet early in the storm main phase. We will use MMS and Van Allen Probes data to test which of these scenarios is more important.

D3.2-0025-18 HELIOSPHERIC PLASMA SHEET (HPS) IMPINGEMENT ONTO THE MAGNETOSPHERE AS A CAUSE OF RELATIVISTIC ELECTRON DROPOUTS (REDS) VIA COHERENT EMIC WAVE SCATTERING WITH POSSIBLE CONSEQUENCES FOR ATMOSPHERIC VORTICITY

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A new scenario is presented for the cause of magnetospheric relativistic electron decreases (REDs) and potential effects in the atmosphere and on weather. High density solar wind heliospheric plasmasheet (HPS) events impinge onto the magnetosphere, compressing it along with remnant noon-sector outer-zone magnetospheric 10-100 keV protons. The betatron accelerated protons generate coherent EMIC waves through a temperature anisotropy (Tperp/Tpar > 1) instability. The waves in turn interact with relativistic electrons and cause the rapid loss of these particles to a small region of the atmosphere. A peak total energy deposition of 3 x 1020 ergs is derived for the precipitating electrons. Maximum energy deposition and creation of electron-ion pairs at 30-50 km and at < 30 km altitude are quantified. We focus attention on the relevant Wilcox et al. [1973] correlation between solar wind heliospheric current sheet (HCS) crossings and high atmospheric vorticity centers at 300 mb altitude. Other possible scenarios potentially affecting weather are discussed.

D3.2-0026-18 MULTIPOINT MEASUREMENTS OF WHISTLER MODE CHORUS IN THE RADIATION BELTS

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The Van Allen radiation belts are influenced by the presence of whistler-mode waves. Nonlinear wave packets of whistler mode chorus cause pitch-angle or energy diffusion of different energetic electron populations. This process leads to local exchange of energy between the electron populations and, subsequently, to acceleration of energetic electrons or to their precipitation into the Earth's atmosphere. We use measurements onboard two Van Allen Probes to analyze these waves during conjunctions. We also use measurements of the Arase spacecraft at close separations. We investigate correlation of the observed chorus wave packets as a function of the separation vector, while the collected multicomponent measurements allow us to determine detailed polarization and propagation characteristics as a function of time at each spatial point.

D3.2-0027-18 A CENSUS OF KINETIC ELECTRIC FIELD STRUCTURES AND WAVES IN THE INNER MAGNETOSPHERE

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Numerous observations from the Van Allen Probes mission have firmly established that kinetic electric field structures and waves abound in the terrestrial inner magnetosphere. Examples of such structures and waves include: kinetic Alfven waves, electron phase space holes, electron acoustic solitons, and nonlinear whistler-mode waves. These structures and waves can have high amplitudes (100 mV/m), strong electric fields parallel to the background magnetic field, and are ubiquitous at plasma boundaries such as injection fronts, the plasmapause, and the Earthward edge of the plasma sheet. But how important are these structures and waves for inner magnetospheric plasma dynamics? Some theoretical treatments suggest that these waves and structures can exert more influence than chorus or hiss waves for certain particle energies.

Quantifying the importance of these structures and waves is complicated by their non-unique signatures in wave power spectra. High resolution time series electric and magnetic field data is required to uniquely identify such structures and waves as well as to determine their properties (e.g. amplitude, spatial extent).

In this presentation, we describe analysis of long (> 45 min) unbroken intervals of high resolution time series fields data spanning an electron injection event and a crossing of the Earthward plasma sheet boundary. These data enable a census of kinetic electric field structures and waves, including the relative occurrence of various structure and wave types, and their 'typical' properties, determined without reliance on amplitude-triggered fields data.

The results of this census provide insight into generation of kinetic electric field structures and waves in the inner magnetosphere as well as their impact on inner magnetospheric plasma dynamics.

D3.2-0028-18 INNER MAGNETOSPHERE DYNAMICS: SIMULATIONS AND COMPARISONS WITH MULTI-SPACECRAFT OBSERVATIONS

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The largest variations in the inner magnetosphere plasma and fields occur during geomagnetic storms and are related to the intensification of the ring current, the magnetically trapped charged particles circling Earth inside of geosynchronous orbit. To investigate ring current development on a global scale, we use our RAM-SCBE model which evolves the H+, O+, and He+ ion and electron distribution functions in the dynamic inner magnetosphere. A distinct feature of RAM-SCBE is the use of self-consistently calculated electric and magnetic fields in balance with the anisotropic ring current ion and electron populations. We simulate the dynamics of the hot (10s of keV) particles injected from the magnetotail into the inner magnetosphere during storms and substorms on both macroand micro-scale. We investigate the effects from 1) non-dipolar magnetic field configuration, 2) plasma wave scattering, and plasma sheet source population considering various boundary conditions and electric field formulations. We compare our results with simultaneous plasma and field observations from the Energetic particle, Composition, and Thermal plasma (ECT) and the Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) investigations on the Van Allen Probes. The precipitating particle fluxes are compared with observations from multiple NOAA satellites. We find that the local acceleration by plasma waves of freshly injected electrons, occurring at the injection boundary, may be significant at energies as low as 50 keV and could strongly impact the ring current and radiation belt flux enhancements. The electron precipitation into the ionosphere increases significantly as well. Implications on the ionospheric conductivity and the highly coupled inner magnetosphere system are discussed.

D3.2-0029-18 AURORAL FRAGMENTATION INTO PATCHES

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We review our recent progresses on the study of auroral fragmentation into patches using ground-based all-sky imagers and magnetospheric satellites. The auroral fragmentation has been reported by Shiokawa et al. (JGR, 2010; 2014) as finger-like structures developed in the diffuse aurora with horizontal scale sizes of 5-25 km (small scale) and 40-100 km (large scale). The development of these finger-like structures divides the diffuse aurora into patches. Thus we call it as the auroral fragmentation which is a cause of the patchy auroral structures in the diffuse aurora. Hashimoto et al. (JGR, 2015) made a statistical analysis of these auroral finger-like structures and found their occurrence rates of 13% and 4 % for largeand small-scale events, respectively. They also indicated that the finger-like structures tend to occur at the beginning of the substorm recovery phase in the post-midnight and dawn sectors.

The auroral finger-like structure suggests the development of pressure-driven instability in the magnetosphere. Recently Nishi et al. (JGR, 2017) made the first conjugate measurement of the auroral finger-like structures with the THEMIS-E satellite at 8 Re in the magnetosphere. They found clear anti-phase oscillations between the magnetic and plasma pressures in the postmidnight plasma sheet. This anti-phase variation is consistent with the idea of the pressuredriven instability. On the other hand, a conjugate event with the RBSP-A satellite at 5.5 Re does not show systematic phase relationship between the magnetic and plasma pressures. We also investigate statistical features of the phase relationship using two-year THEMIS-E observations in the nightside plasma sheet and obtained a high occurrence of the anti-phase oscillations between the magnetic and plasma pressures.

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D3.2-0030-18 AURORAL OVAL MAPPING AND ELECTRONS OF THE OUTER RADIATION BELT

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We try to solve the problem of outer radiation belt formation taking into account the latest results on the auroral oval mapping to the equatorial plane. Such mapping was based on the use of pressure as a natural marker, taking into account that in magnetostatic equilibrium the plasma pressure along a magnetic field line is conserved. We compared the results of the study of plasma pressure distribution at the equatorial plane using data of THEMIS mission and at low altitudes using data of DMSP observations and showed that most part of quiet time auroral oval maps to the surrounding the Earth plasma ring. Transverse currents in the plasma ring close inside the magnetosphere forming a high latitude continuation of the ordinary ring current. We obtained pressure distribution during magnetic storms at low latitudes and at the equatorial plane. We produced the nonlinear modelling of magnetic field distortion by obtained pressure profiles in the ring current region, and showed that distortion of magnetic field by the ring current permits to explain many features of the outer radiation belt electron dropouts and acceleration.

D3.2-0031-18 WAVE ACTIVITY AT A FRONT OF HIGH-BETA EARTH'S BOW SHOCK

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Earth's bow shock in high plasma β conditions (ratio of thermal to magnetic pressure in solar wind) is relatively rare phenomenon, since mostly solar wind β is about 1. However such a plasma object may be of interest for astrophysics. For example, high β plasma fills galaxy clusters and is observable in X-ray emissions, produced by heated electrons. We survey statistics of high-β shock observations by near-Earth spacecraft since 1995. Typical solar wind conditions are relatively low wind speed, high density and low IMF. The threshold of high β value equal to 10 allows reasonable statistics about 50 crossings. Cases of β more than 20-50 are unique. About 20 Cluster project crossings are available with spacecraft separation within several hundred km and allow estimates of wavelength of dominant plasma oscillations. Two types of mostly quasiperpendicular shocks were found: (1) with dominating coherent 1-2 Hz waves and (2) with dominating irregular 0.1-0.5 Hz waves.

D3.2-0032-18 TESTING EARTH'S BOW SHOCK MODELS

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Space plasma studies of bow shock dynamics, given the fundamental transport role and impact of natural transition boundaries, have continued to attract much interest. Using the overwhelming availability of data collected by various space science missions, several empirical models have been put forward to account for the location of the Earth's bow shock. Various solar wind and IMF parameters are used to constrain the proposed models published in the literature. For each of these empirical models, the bow shock nose velocity, at the standoff distance, is computed; each of these velocities is then compared with the observed shock speed, as determined from a multipoint present study reveals to what extent the commonly-used model parameters measurement provided by the Cluster quartet and MMS spacecraft. meters are significant and determinant, and suggests that some empirical models are more accurate than others.

D3.2-0033-18 ANISOTROPIC TURBULENCE IN THE MAGNETOSHEATH BASED ON THEMIS OBSERVATIONS

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Turbulence is a complex phenomenon with driving mechanisms still not clearly understood. Such a behavior appears naturally in space plasmas, including the solar wind, also in the magnetosheath where the flow of the solar wind plasma is slowed down by the bow shock surrounding the Earth's magnetosphere. It is expected that turbulence is intermittent in the magnetosheath, but the level of intermittency somewhat differs depending on the direction of the local magnetic field. Using the wealth of data acquired from the THEMIS mission, we have recently obtained evidence for the anisotropy of intermittent turbulence in the magnetosheath (Macek et al. 2017). In particular, we have shown that for some cases of very strong shocks and very high plasma beta, which is the ratio of the thermal pressure to the pressure of the magnetic field, the fluctuations of parameters of the magnetized plasma exhibit substantial deviations from normal probability distributions, with a large kurtosis, in the directions transverse to the ambient magnetic field. On the other hand, along the local magnetic field the kurtosis is small, the plasma can be approximately described by normal distributions and is hence close to equilibrium. A similar behavior is observed in the case of the weaker shocks, provided that the thermal and magnetic pressures are comparable. However, behind the shocks of somewhat moderate strengths and plasma beta, turbulence seems to be also non-gyrotropic. Here we will present a more detailed analysis of intermittent anisotropic turbulence in the entire magnetosheath as a function of the shock characteristics, taking into consideration the Alfvén and magnetosonic Mach numbers and the plasma beta. We hope that these results could potentially be important for the development of theory of turbulence.

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D3.2-0034-18 BUILDING A HYBRID CODE FOR MODELLING PLASMA PROCESSES IN THE MAGNETOSPHERE

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Here we want to present a new hybrid code CHIEF (Code Hybrid with Inertial Electron Fluid) that we have recently implemented. It combines an existing, well tested electronmagnetohydrodynamic (EMHD) code with an existing, well tested, state-of-the-art particle in cell (PiC) code. It simulates arbitrary kinetic ion species using a semi-lagrangian approach and describes the electrons as an inertial fluid. The fluid description uses no approximations for the electron contributions other than an equation of state relating electron pressure and temperature. Effects due to electron inertia or changes in ion flow speed or density in space and time are not neglected as in many other existing hybrid codes. Electromagnetic fields are calculated in the radiation-free limit which allows time steps that are sufficiently long to study effects on ion time scales even for heavy ions. The code has been successfully tested on a large number of test problems involving linear and non-linear plasma waves as well as instabilities that are driven by non-equilibrium ion velocity distributions. The code is particularly suited for the study of collisionless shocks – especially the acceleration of heavy ions which is computationally expensive in PiC codes – as well as collisionless magnetic reconnection and kinetic turbulence on scales above the electron dissipation range.

D3.2-0035-18 MHD SIMULATION OF THE FLUX TRANSFER EVENTS ON THE DAYSIDE MAGNETOPAUSE

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Flux transfer event (FTE) is a transient phenomenon occurring on the magnetopause caused by magnetic reconnection. By running the global MHD simulation code under different interplanetary magnetic field clock angles, we compared the FTEs in these simulation cases. It is revealed that the large scale characteristics of FTEs have apparent distinctions for different IMF clock angles. Further investigation shows that these distinctions are closely related to the dayside reconnections under different solar wind conditions.

D3.2-0036-18 USING CLUSTER OBSERVATIONS IN THE CUSP TO ESTIMATE X-RAY EMISSIONS FOR THE SMILE MISSION

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Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) is a novel self-standing mission, being designed in collaboration between ESA and the Chinese Academy of Science. Its objective is to observe solar wind-magnetosphere coupling via simultaneous in situ solar wind/magnetosheath plasma and magnetic field measurements, soft X-Ray images of the magnetosheath and polar cusps, and UV images of global auroral distributions. The observations of the cusps and magnetosheath with the X-ray imager are possible thanks to the relatively recent discovery of solar wind charge exchange (SWCX) X-ray emissions, first at comets and subsequently in the vicinity of the Earth's magnetosphere. To prepare for the mission, we must determine the expected morphology, motion, and in situ properties of the plasma (density, velocity, temperature) within the cusp and its associated structures (e.g., diamagnetic cavities). We have selected a series of Cluster cusp crossings that define these properties and can therefore be used to estimate X-ray emissions across the width of the cusp for different IMF orientations. We will show that the peak soft X-ray emissions occur near the centre of the cusp where ion densities maximize. We then show that the integral lines of sight emissions through the cusp are a factor of 2.4 times larger for IMF-Bz northward than for IMF-Bz southward. The mid-altitude cusp is a factor of 7 brighter than the exterior cusp. We will compare these observations with an MHD model.

D3.2-0037-18 ON THE MAGNETOSPHERIC DYNAMICS: A NONLINEAR MULTI-SCALE APPROACH

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The Earth's magnetospheric dynamics in response to changes of the solar wind (SW) and interplanetary magnetic field (IMF) conditions during magnetic storms and substorms is the result of both externally driven and internal processes that can be investigated via a set of geomagnetic indices (AE, AU, AL, AO, Dst, Sym-H). As a consequence of the solar wind-magnetosphere interaction, these indices display both regular and irregular variations/fluctuations on a very wide interval of timescales, ranging from a few tens of minutes up to two hundreds minutes, which are connected to the direct-driven and loading-unloading processes. All these features have been interpreted as evidences of a far-from-equilibrium nonlinear dynamics near a critical state. An important consequence of this nonlinear and near-critical-state dynamics of the Earth's magnetosphere is that there is not a one-to-one correspondence between the SW/IMF condition changes and those of the magnetospheric current systems as monitored by geomagnetic indices. In other words, the dynamics of the magnetospheric currents and of the overall magnetosphere, although triggered by the variation of the interplanetary conditions, is strongly affected by the internal conditions. This is exactly what has been understood since the early works on the nonlinear and pseudochaotic dynamics of the Earth's magnetosphere.

In this work, we present a detailed study of the timescale coupling between solar wind changes and the magnetospheric response in the course of two geomagnetic storms occurred in 2013 and 2015. To investigate the range of the coupled timescales we use the Empirical Mode Decomposition (EMD), which is particularly suitable for the analysis of nonlinear and nonstationary time series, and the Delayed Mutual Information (DMI), which is capable of providing a measure of the total linear and nonlinear correlation. Our findings support the common idea that the Earth's magnetosphere response consists of both directly driven and internal processes, where the internal processes instead of being driven have to be considered more reasonably to be triggered by external solar wind changes. Furthermore, there is a clear separation of timescales between the internal processes and the directly driven one, being the characteristic separation timescale of the order of 100-200 min.

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D3.2-0038-18 SINGLE-SPACECRAFT METHOD FOR DETERMINING WAVEVECTOR K

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A practical method is presented for determining the wavevector of a low frequency plasma wave using measurements from only a single-spacecraft. The method is described in detail in Ref.

and successful implementation using MMS spacecraft data is reported in Ref. [2].

The wavevector obtained by this method can then be used to remove the space-time ambiguity produced by frequency Doppler shift associated with spacecraft motion.

The method involves applying the Wiener-Khinchin theorem to cross-correlations of the current and magnetic field oscillations and to auto-correlations of the magnetic field oscillations. The method requires that each wave frequency component map to a unique wavevector, a situation presumed true in many spacecraft measurement situations and also implicitly required by multispacecraft methods.

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D3.2-0039-18 PARTICLE AND FIELD DYNAMICS IN DIFFERENT SCALE OF MAGNETIC HOLES AND PEAKS

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Different scale of magnetic structures (e.g. magnetic holes and peaks) are investigated in this study with the use of MMS and THEMIS spacecraft in the turbulent terrestrial magnetosheath, sheath boundary layer and the magnetotail. The plasma parameters, wave activities, geometrical characteristics, current systems and propagation features will be present, and test particle simulations are carried out to study the electron distribution functions in different cases and several new features have been revealed, implying that these magnetic structures may play some important roles in plasma instabilities, energy dissipation and energy conversion.

D3.2-0040-18 THE WEATHER IN THE INNER MAGNETOSPHERE: A CHANCE OF ELECTRON PRECIPITATION OUTSIDE OF THE PLASMASPHERE.

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One of the exciting and long outstanding questions in the field of magnetospheric physics is to understand to the point of predictability, the dynamics of the radiation belts. Until recently, much of the knowledge gained about the radiation belts came from single point measurements. Recently, there have been multiple missions which have allowed for multipoint measurements to be used to better understand the daily dynamics. In this study we will focus on the 30 keV to MeV electron population lost to the atmosphere and observed in LEO orbits. The loss of these electrons to the atmosphere is often thought to be due to specific wave -particle interactions which have specific MLT and L dependencies. Recent work has shown that the location of two of the wave types, chorus and hiss which are expected to have a large impact on these electrons, is determined in part by the boundary of the plasmasphere. Specifically, there is a null in observed wave power of either hiss or chorus right at the plasmapause. Thus, we expect that the particle populations which interact with these waves would also follow this trend.

In this presentation we will use data from the Balloon Array for Radiation belt Relativistic Electron Loss (BARREL) to infer the loss of radiation belt electrons. The BARREL mission had a total of 40 launches during two Antarctic Campaigns, with an additional 15 launches during the August turnaround seasons of 2015 and 2016 in Kiruna Sweden. We will focus on the Antarctic campaigns which took advantage of the circumpolar winds allowing for on average an array of 6 payloads aloft and distributed in L and MLT at any given time. This work will be supplemented by using LEO observations allowing for higher temporal and spatial resolution of how the radiation belt particle populations respond to the weather of the inner magnetosphere

D3.2-0042-18 NUMERICAL STUDY ON THE DOPPLER EFFECT OF THE LOW EARTH ORBIT OBSERVATIONS

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Geomagnetic ultra-low frequency (ULF) wave is one of the major energy transport mechanisms in the Earth's magnetosphere. Multi point satellite measurements have advanced our knowledge on the wave characteristics in the magnetosphere. However, in the ionosphere, spacecraft traverses different L-shells with considerably high speed, which results in the distortion of observed wave signals. We conduct three dimensional MHD wave simulations to investigate the Doppler effect of the ULF waves observed by low Earth orbit (LEO) satellites. A number of virtual spacecraft are imbedded in our model, which function as fast-moving observers in LEO. Our results show that transverse electric and magnetic field components exhibit latitude dependence in the arrival time and waveform, which is manifested when observed by fastmoving satellites. On the other hand, compressional components are insensitive to the latitude or the motion of the spacecraft. It is suggested that the Doppler effect of the LEO satellite observations can cause distinct discrepancies between ground-based and satellite measurements.

SPACE PLASMAS IN THE SOLAR SYSTEM, INCLUDING PLANETARY MAGNETOSPHERES (D)

ROLE OF NONTHERMAL DISTRIBUTIONS IN WAVE GENERATION, PARTICLE HEATING AND ACCELERATION IN SPACE PLASMAS (D3.3)

D3.3-0001-18 THE ROLE OF NON-THERMAL ELECTRON DISTRIBUTIONS IN SOLAR WIND ACCELERATION PROCESSES

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Velocity distribution functions of plasma particles measured by spacecraft in the solar wind and many other space plasmas show enhanced suprathermal tails. Such distributions can be fitted by different velocity distribution functions such as a sum of two Maxwellians with different temperatures or, better, with Kappa distributions decreasing as a power law of the velocity. The presence of nonthermal populations in space plasmas, and in particular in the solar wind, has important consequences concerning particle acceleration and plasma heating. These effects are well described by the kinetic approach using non thermal distributions. A kinetic model of the solar wind has been developed and allows us to test the effects of enhanced populations of suprathermal electrons. We also show the evolution of the suprathermal particles with the radial distance as observed by different spacecraft and how wave-particle interactions can explain the main observed features.

D3.3-0002-18 SOLITONS AND SUPERSOLITONS IN MAGNETIZED PLASMAS WITH NONTHERMAL PARTICLE DISTRIBUTIONS

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We present a brief overview of fully nonlinear, Sagdeev pseudopotential based investigations of solitons and related phenomena in magnetized fluid plasmas. We shall deal mainly with ion-acoustic structures, but also consider aspects of electron-acoustic solitons. Studies based on nonthermal velocity distributions such as the kappa and Cairns distributions will be discussed and compared. Care will be taken to point out limitations of the models, as a result of approximations underpinning the calculations. Finally, we shall draw attention to recent research that questions the existence of supersolitons in such models, because of the apparent presence of an inherent singularity in the pseudopotential.

D3.3-0003-18 SPECTROSCOPIC MEASUREMENTS OF THE ION VELOCITY DISTRIBUTION AT THE BASE OF THE FAST SOLAR WIND

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In situ measurements of the fast solar wind reveal non-thermal distributions of electrons, protons and, minor ions extending from 0.3 AU to the heliopause. The physical mechanisms responsible for these non-thermal properties and the location where these properties originate remain open questions. Here we present spectroscopic evidence, from extreme ultraviolet spectroscopy, that the velocity distribution functions (VDFs) of minor ions are already non-Gaussian at the base of the fast solar wind in a coronal hole, at altitudes of < 1.1R0. Analysis of Fe, Si, and Mg spectral lines reveal a peaked line-shape core and broad wings that can be characteristed by a kappa VDF. A kappa distribution fit gives very small kappa indices off-limb of κ 1.9 2.5, indicating either (a) ion populations far from thermal equilibrium, (b) fluid motions such as non-Gaussian turbulent fluctuations or non-uniform wave motions, or (c) some combination of both. These observations provide important empirical constraints for the source region of the fast solar wind and for the theoretical models of the different acceleration, heating, and energy deposition processes therein. To the best of our knowledge, this is the first time that the ion VDF in the fast solar wind has been probed so close to its source region. The findings are also a timely precursor to the upcoming 2018 launch of the Parker Solar Probe, which will provide the closest in situ measurements of the solar wind at approximately 0.04 AU (8.5 solar radii).

D3.3-0004-18 WAVES AND INSTABILITIES IN SPACE PLASMAS MODELLED WITH KAPPA VELOCITY DISTRIBUTIONS

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The primary advantage of the kinetic theory of waves based on the kappa velocity distribution is that it usually provides a more accurate statistical representation of collisionless space plasma environments than those based on Maxwellian types. Use of a kappa distribution model does not alter any microphysical processes, but it does change their probabilities of occurrence, which in turn affects important average quantities such as instability growth and wave damping rates. Additionally, dispersion relations can show features distinguishable from their Maxwellian counterparts, providing valuable signatures for out-of-equilibrium plasma behaviour.

A disadvantage of the approach, however, is that the mathematics arising from the use of kappa distributions is less familiar and often more complicated than that arising from the Maxwellian framework. It is perhaps because of the increased mathematical complexity that, in contrast to the Maxwellian case, the theories of wave propagation parallel and perpendicular to the magnetic field in plasmas with kappa distributions have developed separately, with no mathematically tractable theory of oblique propagation to connect them. The mathematics of each, while originating with the same linearised Vlasov-Maxwell system of equations, takes on quite a different form in each case.

This talk attempts to present a more unified approach to the problem of waves and instabilities in space plasmas modelled with kappa distributions. After briefly reviewing the traditional theoretical framework for kinetic studies of plasma waves, a modified approach that favours a more consistent treatment of the special cases of parallel and perpendicular propagation is suggested. Salient results from some of the investigations of waves and instabilities in plasmas modelled with kappa distributions carried out by the author and collaborators are discussed. Amongst others, these include studies of the whistler and EMIC instabilities driven by thermal anisotropy, as well as perpendicularly propagating electron and ion Bernstein waves. Finally, some recent results of 1D and 2D simulations of oblique waves in plasmas having a kappa distribution will be presented.

D3.3-0005-18 A MODEL FOR WEAK DOUBLE LAYERS AND COHERENT LOW-FREQUENCY ELECTROSTATIC WAVES IN THE SOLAR WIND

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A model based on ion-acoustic solitons and double layers is proposed for the weak double layers and coherent low-frequency electrostatic waves observed by Wind spacecraft in the solar wind at 1 AU. The model considers the solar wind plasma to consist of fluid hot protons, hot alpha particles streaming with respect to protons,and suprathermal electrons having kappadistribution. This plasma system supports two types of, slow and fast, ion-acoustic solitary waves. The fast ion-acoustic mode is similar to the ion-acoustic mode of proton-electron plasma, and can support only positive potential solitons. The slow ion-acoustic mode is a new mode that occurs due to the presence of alpha particles. This mode can support both positive and negative solitons and double layers. An increase of the kappaindex leads to an increase in the critical Mach number, maximum Mach number and the maximum amplitude of both slow and fast ion-acoustic solitons. The slow ion-acoustic double layer can explain the amplitudes and widths,but not shapes, of the weak double layers (WDLs) observed in the solar wind at 1 AU by Wind spacecraft.The Fourier transform of the slow ion-acoustic solitons/double layers would produce broadband low-frequency electrostatic waves having main peaks between 0.35 kHz to 1.6 kHz, with electric field in the range of E= (0.01 - 0.7) mV/m, in excellent agreement with the observed properties of the low-frequency electrostatic waves in the solar wind at 1 AU.

D3.3-0006-18 KINETIC SIMULATION OF SLOW MAGNETOSONIC WAVES AND QUASIPERIODIC UPFLOWS IN THE SOLAR CORONA

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Quasi-periodic disturbances of emission-line parameters are frequently observed in the corona. These disturbances propagate upward along the magnetic field with speeds of 100 km/s. This phenomenon has been interpreted as evidence of the propagation of slow magnetosonic waves or has been argued to be a signature of intermittent outflows superposed on the background plasmas. Here we aim to present a new "wave + flow" model to interpret these observations. In our scenario, the oscillatory motion is a slow-mode wave, and the flow is associated with a beam created by the wave-particle interaction owing to Landau resonance. With the help of a kinetic model, we simulate the propagation of slow-mode waves and the generation of beam flows. We find that weak periodic beam flows can be generated by to Landau resonance in the solar corona, and the phase with the strongest blueward asymmetry is ahead of that with the strongest blueshift by about 1/4 period. We also find that the slow wave damps to the level of 1/e after the transit time of two wave periods, owing to Landau damping and Coulomb collisions in our simulation. This damping timescale is similar to that resulting from thermal conduction in the MHD regime. The beam flow is weakened/attenuated with increasing wave period and decreasing wave amplitude since Coulomb collisions become more and more dominant over the wave action. We suggest that this "wave + flow" kinetic model provides an alternative explanation for the observed quasi-periodic propagating perturbations in various parameters in the solar corona.

D3.3-0007-18 MULTI-YEAR MEASUREMENTS OF RADIATION BELT ELECTRONS: ACCELERATION, TRANSPORT, AND LOSS

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Extended studies of Van Allen Probes data show that "source" electrons (in a typical energy range of one to a few tens of keV energy) produced by magnetospheric substorms play a crucial role in amplifying the chorus waves in the magnetosphere. It is repeatedly observed that these chorus waves then rapidly heat and accelerate the tens to hundreds of keV seed electrons that are injected by substorms into the outer Van Allen zone. Thus, we often see that geomagnetic activity driven by strong solar storms (coronal mass ejections, or CMEs) almost inexorably leads to ultra-relativistic electron production through the intermediary step of intense magnetospheric substorms. In this presentation, we report observations of some of the largest geomagnetic storms of the last several years. Distinctive events that have had significant ring current development are discussed. We focus on storms that produced dramatic effects on the relativistic and ultra-relativistic electrons measured by the Relativistic Electron-Proton Telescope (REPT) sensors on board the Van Allen Probes spacecraft. This work describes the radiation belt acceleration, transport, and loss characteristics of these intense geomagnetic events. We emphasize features seen repeatedly in the data (3-belt structures, "impenetrable" barrier properties, radial diffusion signatures) in the context of acceleration and loss mechanisms. We especially highlight solar wind forcing of the ultra-relativistic (E 5 MeV) electron populations. We present pitch angle resolved data and energy-spectral analyses for key events. The presentation also includes animated segments portraying the mission-long time variability of the outer Van Allen belt emphasizing the remarkable dynamics of the system.

D3.3-0008-18 ON FORMATION OF ELECTRON KAPPA DISTRIBUTION FUNCTIONS

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The solar wind electron distribution function is known to be composed of several components; the Maxwellian core, hot quasi isotropic halo, sometimes highly field-aligned strahl propagating in anti sunward direction, and highly energetic inverse power-law isotropic superhalo population. The highly energetic superhalo tail population is particularly well fitted with kappa distribution function. The present author developed a theory of a system of electrons and Langmuir turbulence that are in dynamical steady-state. In such a model, the kappa distribution function for the electrons emerges as a unique solution of the steady-state weak turbulence plasma kinetic equation. In view of the fact that the turbulent quasi equilibrium for Langmuir wave fluctuation and electron kappa distribution are derived in time asymptotic steady state, the question of whether finite collisionality may play a role for such a long time evolutionary state. Recently, a combined collisional and weakly turbulent collective theory is developed by the present author where collisional processes and wave turbulence is discussed within the rigorous framework. Making use of such a theory the generation process of electron kappa distribution is re-examined and it is shown that the Maxwellian core plus quasi inverse power law tail electron distribution may form at the corona base where the plasma is characterized by high collisionality. As the core-halo type of electron distribution travels outward the Langmuir turbulence process operates in order to maintain the core-halo-superhalo structure all the way to 1 AU.

D3.3-0009-18 FORMATION AND PROPERTIES OF KAPPA DISTRIBUTIONS IN THE MAGNETOSPHERE AND MAGNETOSHEATH OF THE EARTH

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Kappa functions describe particle distributions for the systems that are in stationary state but out of thermal equilibrium. The form of the kappa distribution consists of a Maxwellian core at low energies and a power law spectrum at high energies. Simultaneous determination of the parameters of kappa distributions in different space regions is important for understanding the role of different processes of particle acceleration and relaxation of kappa distribution functions to the Maxwellian ones. We study kappa distributions in different magnetospheric regions and magnetosheath, using the data of the Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission. Problems of obtaining kappa approximations are connected with different sensitivity of devices measured particle fluxes in different energy ranges and pitch angles. Another difficulty is connected with frequently observed mixtures of plasmas of different origins. It was found, that in the regions, where distribution functions are formed due to mixing of two plasma populations, they can be described using bi-kappa distributions. Such feature permits to select the contribution of every plasma population in the whole one. We show that analyzing the space distribution of k-parameter it is possible to determine the location of the region of acceleration for a specific particle population. We try to evaluate the characteristic times of distribution function relaxation by analyzing measurements during different phases of auroral substorm.

D3.3-0010-18 ROLE OF KAPPA PARTICLE DISTRIBUTIONS IN GENERATING WHISTLERMODE WAVES IN SPACE PLASMAS

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Kappa particle distributions possess a high-energy power-law tail characterized by a spectral index kappa. Here we consider the role of both the bi-kappa and kappa-loss-cone distributions in the generation of whistler-mode waves in geospace plasmas. Comparisons between the whistler-mode wave linear growth rates corresponding to the bi-kappa and bi-Maxwellian distributions depend on the thermal anisotropy A. For anisotropies less than a critical value,the bi-kappa linear growth rate (for kappa = 2) dominates the bi-Maxwellian growth rate; for anisotropies greater than the critical value the opposite applies. Similar comparisons of the linear growth rates corresponding to the kappa-loss-cone distribution depend also on the losscone index. With respect to the threshold wave amplitude for nonlinear growth,comparisons between the bi-kappa and bi-Maxwellian distributions depend on both the anisotropy A and the wave frequency. For low anisotropy,we find that threshold wave amplitudes for the bi-kappa distribution can be much less than those for the bi-Maxwellian distribution. Similar conclusions regarding the threshold wave amplitudes corresponding to the kappa-loss-cone distribution also hold. Finally,we determine wave generation regions in (A,n)-parameter space, where n is the hot(energetic) electron number density. We find that such generation regions also depend crucially on the electron thermal momentum. For instance,for lower values of the electron thermal momentum,the extent of the wave generation region corresponding to the bi-kappa distribution exceeds that for the bi-Maxwellian distribution;for higher values of the electron thermal momentum,the reverse is true. Overall,we conclude that kappa distributions can significantly enhance whistler-mode wave generation in geospace plasmas,dependent on the values of the system parameters.

D3.3-0011-18 ELECTROSTATIC SOLITARY WAVES IN THE LUNAR WAKE PLASMA

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Electrostatic waves have been observed in the lunar wake during the first flyby of the Acceleration, Reconnection, Turbulence and Electrodynamics of Moon's Interaction with Sun (ARTEMIS) mission on 13 February 2010 [1]. An alternative mechanism for the evolution of these electrostatic waves in terms of slow and fast ion-acoustic and electron-acoustic solitons is proposed. The lunar wake is modelled by a four-component plasma system comprising of hot protons, hot heavier (He++) ions, electron beam and suprathermal electrons having a kappa distribution. Three modes, viz., slow and fast ion-acoustic modes and electron-acoustic modes exist. As all three modes exists simultaneously, the electric fields associated with all three modes taken together varies in the range (0.003-17) mV m-1 which matches perfectly with the observed electric field (5-15) mV m-1. The velocities of the solitons varying in the range (30-1300) km s-1 matches with the estimated phase velocities of the order 1000 km s-1. The Fast Fourier transform (FFT) of the soliton electric fields results in broadband spectra hav- ing peak frequencies in the range of (3-1800)Hz which corresponds to (0.001-0.56) fp that matches with the observed frequencies of (0.01-0.4) fpe, fpe is the electron plasma frequency (fpe= 3237.78 Hz).The theoretical plasma model very well explains the observed electrostatic waves in the lunar wake.

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D. E. Larson, W. Baumjohann, and M. V. Goldman (2012), Kinetic instabilities in the lunar wake:ARTEMIS observations, J. Geophys. Res., 117, A03106; doi: 10.1029/2011JA017364.

D3.3-0012-18 SOLITONS, DOUBLE LAYERS AND ROGUE WAVES IN PLASMAS WITH SUPERTHERMAL CHARGED PARTICLES

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Most of the space and astrophysical plasmas contain different types of charged particles with non-Maxwellian velocity distributions (e.g., nonthermal, superthermal, Tsallis). These distributions are commonly found in the auroral region of the Earth's magnetosphere, planetary magnetosphere, solar and stellar coronas, solar wind, etc. The observations from various satellite missions have confirmed the presence of superthermal particles in space and astrophysical environments. Over the last many years, there have been a much interest in studying the different kind of properties of the electrostatic nonlinear excitations (solitons, double layers, shocks, rogue waves etc.) in a multi-component plasmas in the presence of superthermal particles. It has been analyzed that superthermal distributions are more appropriate than Maxwellian distribution for the modeling of space data. It is interesting to study the dynamics of various kinds of solitary waves, Double layers, Shocks etc. in varieties of plasma systems containing different kind of species obeying Lorentzian (kappa-type)/Tsallis distribution. Talk has been focused on the study of large amplitude solitary structures (bipolar solitary structures, double layers etc.), modulational instability and rogue waves in multi-component plasmas. The Sagdeev pseudo-potential method has been employed to setup an energy balance equation, from which we have studied the characteristics of large amplitude solitary waves under the influence of superthermality of charged particles and other plasma parameters. The critical Mach number has been determined, above which solitary structures are observed and its variation with superthermality of electrons and other parameters has also been discussed. Double layers have also been discussed. Multiple scale reductive perturbation method has been employed to derive NLS equation. From the different kind of solutions of this equation, amplitude modulation of envelope solitons and rogue waves have been studied. It has been observed that various plasma parameters significantly influence the characteristics of different kinds of nonlinear structures. These findings may be of great importance to understand the underlying physics of different phenomena occurring in space and astrophysical environments.

D3.3-0013-18 SOLAR WIND DRIVEN WHISTLER INSTABILITY IN EARTH'S CUSP REGION

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One of the fundamental questions in space plasmas still not fully understood is how the energy is transported from solar wind to the Earth's magnetosphere. In the present study, we observe electron velocity distribution (EVD) functions in the Earth's magnetosphere using the CLUSTER data. The EVD functions are observed at different times, when the CLUSTER traversing the southern cusp region on 21-10-2001, such as when the electron density is very low typical of cusp values and when it suddenly increases due to some solar wind disturbances at the magnetopause. We found that the observed EVD functions are flat top distributions and have two populations; a cold bulk magnetospheric population and a hot solar wind tenuous population. Observed EVD functions are then fitted by generalized (r,q) distribution which is the generalized form of kappa and Maxwellian distribution functions and can be reduced to kappa and Maxwellian distributions in the limiting forms r=0,q=+1 and r=0,q→, respectively [Qureshi et al., 2004; 2014]. We derive the expressions of real frequency and damping/growth rates by employing generalized (r,q) distribution function and plot them using the observed plasma parameters and fitting values of spectral indices r and q. We found that during the time of increased density these shocked solar wind electrons have the same flat top distribution consisting of one population as earlier observed by various satellites downstream the Earth's bow shock. When such hot solar wind electrons with flat top distribution enter into the Earth's magnetosphere, we obtain growth causing the Whistler waves to grow and hence responsible for the transport of energy from solar wind to the magnetosphere.

D3.3-0014-18 MULTI-SPACECRAFT OBSERVATIONS OF WHISTLER-MODE WAVE-PARTICLE INTERACTIONS: TEMPORAL OR SPATIAL STRUCTURES?

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Wave-particle interactions that generate whistler-mode chorus emissions and modify energetic electron distributions are thought of as highly localized phenomena in both space and time. We will use data from the two satellite Van Allen Probe constellation to investigate such events. Individual chorus elements have very short time durations and interaction regions that span small distances at the magnetic equator. Recent observations by the Van Allen Probes satellites imply in contrast that the interactions sometimes form relatively long-lived signatures in both electrons and waves that drift past the satellites. Fennell et al. [GRL, 2014] described an event with upper-band chorus emissions that correlated well with simultaneously measured bursts of electron flux at 30 keV in narrow ranges of pitch angle. Both satellites, separated by 0.3 hours in the morning local time sector near L 6, observed similar quasiperiodic trains of correlated flux bursts and waves. Detailed comparison of the data from the two spacecraft shows that the sequence of wave and particle pulses match almost exactly if Probe A is shifted in time by two minutes relative to Probe B. This implies that the interactions produced a set of spatial structures that drifted from one satellite to the other at a speed of 25 km/s. The result is consistent with the idea of both waves and electrons propagating and being observed at distant locations. But the high correlation of waves and electrons at near-zero delay time at both locations is surprising since the waves and electrons nominally travel at different speeds. Several additional wave-particle interaction events observed by both Van Allen Probes are analyzed to provide additional information on the spatial scale size and propagation speed of wave emissions and particle features.

D3.3-0015-18 BGK ELECTRON HOLES IN NONTHERMAL SPACE PLASMAS

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Bernstein, Greene, and Kruskal (BGK) have developed the theory for one-dimensional stationary nonlinear electrostatic waves in the Vlasov-Poisson framework of equations. Under the influence of electric potential, the theory gives localized BGK solutions characterized by a trapped population of electrons moving with the electron-hole (EH). Such structures are often detected by spacecrafts as a series of coherent bipolar electric field structures. In modeling these observed structures, most of the studies assume the space plasma in thermal equilibrium, described by the Maxwell distribution. However, several spacecraft observations reveal that the plasmas in space cannot be assumed to be in thermal equilibrium; instead, these plasmas are nonthermal and are best-modeled using generalized kappa distribution. Hence, the BGK theory for nonthermal plasma is an essential component to model EHs in space plasmas. We develop a first-ever one-dimensional model of EHs in nonthermal plasma keeping ions stationary in the electrostatic limit. We have derived the analytical expression for trapped electron density and distribution function of trapped electrons. We find a significant difference in the trapped electron density and distribution function. We find that the nonthermal plasma is more prone to trapping and as a result, the distribution function in nonthermal plasma found steeper and denser than the trapped distribution in thermal plasma. EHs formed in a nonthermal plasma are found to have a smaller size than the EHs formed in thermal plasma for same perturbation. The width and amplitude of perturbation play an important role in the development of stable EHs and deciding their characteristics. The analytical expression for width - amplitude inequality relation that decides the stability of EHs has been derived. We have observed that the parametric regime of amplitude and width of potential that supports stable BGK EH solutions in nonthermal plasma is less than that of weakly nonthermal plasma. We have applied the newly developed model to EHs observed by the FAST satellite, which operates in the auroral region where the nonthermal population dominant. bf

D3.3-0016-18 FLUID SIMULATION OF COHERENT ELECTRIC FIELD STRUCTURES IN THERMAL AND NON-THERMAL SPACE PLASMAS

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The Earth's or any other planetary magnetospheres are rich in the variety of plasma wave processes. Numerous computer simulation codes are available in the literature to model these wave processes in thermal plasmas. In most of these model simulations, the plasma is considered to be in thermal equilibrium i.e. Maxwellian distributed plasmas. However, it is now well known that the space plasmas frequently contain particle components that exhibit high or superthermal energy tails with approximate power law distributions in velocity space. Such nonthermal distributions, with overabundances of fast particles can be better fitted for superthermal velocities by kappa distributions, than by Maxwellians or one of their variants. We developed a generalized one-dimensional multi-fluid code to study the plasma wave processes in thermal and nonthermal space plasmas. In this code, different species in the plasma can be represented with either fluid or non-thermal distribution. As an application of this code, we discussed a generation mechanism of the coherent electric field structures observed in the Earth's magnetosphere.

D3.3-0017-18 COMPRESSIVE AND ALFVENIC FLUCTUATIONS IN THE SOLAR WIND

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The solar wind can be considered as a collisionless turbulent magnetized plasma. Its low collisionality suggests that the kinetic approach would be more appropriate for a description of the turbulence properties than the fluid equations. Nevertheless, observations of velocity and magnetic field variations in the mHz range revealed a qualitative consistency of their behavior with MHD wave modes. It was shown that a compressive component of these fluctuations is rather minor and pressure balanced, whereas the Alfvenic component dominates. Since these features would be scale-dependent, the present contribution analyzes variations of the solar wind velocity that are computed from the Faraday cups of the Bright Monitor of the Solar Wind on board the Spektr-R spacecraft with a time resolution of 32 ms in the frequency range of 0.001-2 Hz. These observations are complemented with the 10 Hz Wind magnetic field measurements. A preliminary survey of about 10,000 of 20-minute intervals indicates that the variations are more compressive on the smaller scales, in agreement with theoretical predictions for the kinetic wave modes.

D3.3-0018-18 PERIODIC KINETIC ALFVEN WAVES IN A PLASMA WITH TWO TEMPERATURE SUPERTHERMAL ELECTRONS

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The magnetosphere of Saturn extends up to 20 Saturn radii and can act as a very large laboratory to study nonlinear waves. Various satellite (Pioneer11, Voyager-1, Voyager2 and Cassini) observations have confirmed the presence of H+, N+, O+, OH+, H2O+ ions in Saturn's magnetosphere with number densities and temperatures varying as a function of distance from Saturn. In addition, electron populations with two distinct temperatures (cold and hot) have also been observed at different radial distances of Saturn's magnetosphere. These electrons possesses high energy tail and can be well fitted with a kappa distribution function. These different species of ions and two temperature superthermal electrons under the influence of internally generated magnetic field (B 0.21 Gauss) of Saturn can lead to various kinds of nonlinear electromagnetic wave phenomena. Motivated by these observations, we propose the formation of nonlinear periodic (cnoidal) kinetic Alfven waves in the Saturn's magnetosphere. In order to study the cnoidal kinetic Alfven waves, the modified Kortewegde Vries (mKdV) equation has been derived. To perform the parametric analysis, we have used the observed values of physical parameters from Saturn's magnetosphere, such as kappa indices, temperatures, and number densities of both the cold and hot electrons. It is observed that the variation in these parameters significantly modifies the characteristics of cnoidal kinetic Alfven waves.

D3.3-0019-18 SELF-SIMILAR PLASMA EXPANSION DYNAMICS: THE ROLE OF SECONDARY IONS AND NONTHERMAL ELECTRONS

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We present an investigation of the self similar expansion of a multi-species ion plasma into vacuum via a multi-fluid model, adopting an adiabatic equation of state for each species. Our aim is to elucidate the effect of secondary ions on a plasma expansion front, in combination with energetic electrons in the background, modeled by a kappa-type distribution function. The plasma density, velocity and electric field profiles are obtained.

Energetic (suprathermal) electrons affect the velocity of the expansion front (shape, dynamics), thus enhancing the ion acceleration mechanism.

Various special cases are considered, as regards the relative magnitude of the ion mass and/or charge state.

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D3.3-0020-18 ELECTRON BEAM DRIVEN ELECTROSTATIC WAVES IN THE LUNAR WAKE PLASMA

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Recent study of lunar wake plasma from ARTEMIS (Acceleration, Reconnection, Turbulence and Electrodynamics of Moon's Interaction with Sun) mission has revealed the presence of electrostatic waves. The lunar wake plasma is of solar wind origin. The linear analysis of electrostatic waves is carried in the lunar wake four-component unmagnetised plasma comprising of fluid protons, fluid He++, electron beam and suprathermal electrons following a kappa distribution.

Numerical analysis of the dispersion relation shows that there will be six roots corresponding to various plasma wave modes, namely, an electron acoustic mode in the positive direction (mode 1) and electron acoustic mode in the negative direction which is driven by electron beam (mode 6), fast ion acoustic mode in the positive direction (mode 2) and negative direction (mode 5) and slow ion acoustic mode in the positive direction (mode 3) and negative direction (mode 4). The electron beam mode (mode 6) and slow ion acoustic mode (mode 3) merge and forms an unstable region over certain wave number regime for normalized beam velocity of 4.3. Subsequent increase in the normalized beam velocity to 4.5 produces two unstable regions, where mode 6 merges with mode 3 in the lower wave number regime and with mode 2 in the higher wave number regime. For a beam velocity of 5.5-7.7, mode 6 merges with mode 2 only, and thereafter, merging of modes does not occur, thereby forming a stable region. The relevance of our model to explain the generation mechanism of electrostatic waves in the lunar wake will be discussed.

D3.3-0021-18 EVOLUTION OF NONLINEAR ELECTROSTATIC WAVES IN THE AURORAL ACCELERATION REGION

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Evolution of nonlinear electrostatic oscillations in a three-component magnetized plasma comprising of protons, oxygen ion beams and suprathermal electrons following -distribution has been analyzed. The nonlinear electrostatic waves are considered to be propagating at an oblique direction to the ambient magnetic field. A parametric study of the effect of initial driving electric field amplitude, wave Mach number, propagation angle, κ-index, number density and temperature of the constituent species on the evolution of nonlinear waves is carried out. The effect of these parameters on the frequency and the nature of electric field structures (sinusoidal, sawtooth or spiky) is also analyzed. The results from the model are compared with the satellite observations of spiky waveforms in the parallel electric field in the auroral acceleration region.

D3.3-0022-18 WHISTLER WAVES AT THE BOW SHOCKS VENUS AND EARTH: COMPARISON OF WAVE PROPERTIES

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When the solar wind encounters the magnetosphere of Earth and the ionosphere of Venus, a bow shock formed in the upstream of the planet where the solar wind decelerates from a superto sub-magnetosonic flow. Around the shock, there are many wave activities. In the upstream foreshock region, there is abundant wave activity generated by the shock or by the back-streaming ions and electrons from the shock. In the downstream magnetosheath region, there is also abundant wave activity either locally generated by the heated electrons or ions from the shock or transported from the shock or foreshock regions by the solar wind. Understanding these waves could improve our knowledge on the heating of electrons and ions across the shock ramp and the energy dissipation of supercritical shocks. The magnetometers of Venus Express and Magnetospheric Multiscale missions both occasionally record 128 Hz data in burst mode during their shock crossing, which allow us to analyze whistle waves around and above lower hybrid frequency. The MMS plasma measurements also could help us understand the sources of these waves. In this paper we examine and compare these waves at the bow shock of Venus and Earth.

SPACE PLASMAS IN THE SOLAR SYSTEM, INCLUDING PLANETARY MAGNETOSPHERES (D)

PLASMA TRANSPORT AND HEATING ACROSS BOUNDARY LAYERS (D3.4)

D3.4-0001-18 NEW INSIGHT INTO ENERGETIC PARTICLE ESCAPE FROM THE ENERGETIC PARTICLE DETECTOR ABOARD MMS

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Recent observations from the Energetic Particle Detector (EPD) instrument suite aboard the NASA Magnetospheric Multiscale (MMS) spacecraft show that energetic (greater than tens of keV) magnetospheric particle escape into the magnetosheath occurs commonly across the dayside. This includes a new signature that requires magnetic reconnection and the surprisingly frequent observation of magnetospheric electrons in the duskside magnetosheath. A statistical analysis of escape events identified in the 40 keV electron energy channel during the first MMS dayside season revealed strongly anisotropic pitch angle distributions indicating monohemispheric field-aligned streaming away from the magnetopause. Despite the extensive history of such research, these new observations provide a more comprehensive data set that includes unprecedented magnetic local time (MLT) coverage of the dayside equatorial magnetopause/magnetosheath. These data clearly highlight the common escape of energetic electrons along magnetic field lines concluded to have been reconnected across the magnetopause. While these streaming escape events agree with prior studies which show strong correlation with geomagnetic activity (suggesting a magnetotail source) and occur most frequently during periods of southward IMF, the high number of duskside events is unexpected and previously unobserved. Notably, the events reported here also exhibit pitch angle anisotropies indicative of streaming up to 200 keV, which could represent the magnetopause loss of >1 MeV electrons from the outer radiation belt.

D3.4-0002-18 MMS FEEPS ENERGETIC ELECTRON MICROINJECTION OBSERVATIONS DURING 2016-2017

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During MMS traversals of the midnight to dusk local time regions energetic electron data often show clusters of electron injections we call microinjections because of their short duration signatures. These microinjections of 50 to >400 keV electrons have energy dispersion signatures indicating that they gradient and curvature drifted from earlier local times. We show detailed results from some microinjections taken with burst mode data. We will also show a case where the microinjections were observed simultaneous with and superimposed upon a classic substorm electron injection profile at 10-11 Re altitude near local midnight. These data show that the energy of the electrons in the microinjections exceed those of the classic injection and were trapped with predominantly field-aligned angular distributions. Drift calculations constrained by the observed electron dispersion times indicate the electrons had drifted from near the magnetopause hours earlier in local

time. The 2016 observations were limited to altitudes of 9 to 12 Re because the MMS apogee was 12 Re then. The MMS apogee was raised to 25 Re in March 2017 and we will show how these later microinjection observations compare to the earlier ones. These microinjection clusters are a new phenomenon in this region of the magnetosphere and with the higher orbit we will observe how close to the magnetopause they exist and possibly traverse the source regions. We will provide some statistics on the occurrence of the injections and discuss possible sources and implications.

D3.4-0003-18 ION VELOCITY DISTRIBUTIONS IN FLOW BURSTS DOWNSTREAM FROM THE QUASI-PARALLEL BOW SHOCK

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Ion flow bursts are observed in the magnetosheath downstream from the quasi-parallel bow shock. These flow bursts have anti-sunward velocities that are one to two hundred km/s faster than that in the turbulent downstream magnetosheath. This talk discusses a survey of the occurrence frequency of these bursts using the Magnetospheric Multiscale mission data set. The survey is used to investigate the possibility that flow bursts reach the magnetopause. Also, the ion velocity distributions in flow bursts are used to help identify the origin of these bursts and their dynamic evolution.

D3.4-0004-18 ORIGIN OF NONLINEAR DENSITY FLUCTUATIONS IN THE FORESHOCK REGION

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Density fluctuations appear in various space plasma environments, and are often accompanied by magnetic field fluctuations. The sense of the density fluctuations can be correlated to that of the magnetic field fluctuations like the fast magnetosonic mode, and also anti-correlated like the slow mode or mirror mode. The quasi-static approximation offers a unified view of the density fluctuation such that fast-mode correlation sense is realized in a low-beta plasma, and the slow-mode correlation sense in a high-beta plasma. The quasi-static approximation is tested against 34 events of the Cluster spacecraft encounter with the Earth foreshock region, in which large-amplitude Alfven waves are excited by the shock-reflected backstreaming ions. We obtain two major results from the test. First, in contrast to the expectation from the quasi-static approximation, most of the studied foreshock waves exhibit a correlated sense of fluctuations between the ion density and the magnetic field magnitude both in the low-beta and high-beta plasma events. Second, interestingly, multiple types or branches of correlations are found in the high-beta plasma events. The lesson from the observational test for the quasistatic approximation against the foreshock waves is that a simple or fluid-like treatment of the quasi-static approximation is only valid in the low-beta plasmas and not in the high-beta plasmas. Different wave modes likely co-exist in the high-beta foreshock waves. Also, a kinetic extension of the quasi-static approximation needs to be considered.

D3.4-0005-18 MAGNETOPAUSE FROMATION AND PARTICLE PENETRATION THROUGH THE MAGNETOPAUSE

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Multiple studies of the solar wind flow under the bow shock, near and under the magnetopause made it possible to obtain a more or less accurate picture of such flow. However, the understanding of the processes of formation of magnetosheath turbulence and magnetopause are only at the first stages of extensive study. Such situation is connected to the use of the frozen-in condition and the approximation of the magnetopause as a rigid impenetrable surface during modeling the magnetosheath magnetic field and plasma flow. We analyze the reasons leading to the use of such approximations and show that it was connected to the insufficient attention to the conditions of pressure balance at the magnetopause and conditions leading to ion penetration through the magnetopause. These conditions are different in the cases of high and low shears of the magnetic field at the magnetopause. We studied the properties of the ion spectra in both sides of the magnetopause for the cases of low and high magnetic shears. We show that it is possible to observe high shear and low shear magnetopause crossings independently on the magnetic field direction in the solar wind, which is the natural consequence of the development of magnetosheath turbulence. Our studies also show that using bi-kappa approximation of ion spectra is the very effective tool for the study of ion penetration through the magnetopause. It was found that the fitting parameters of the ion spectra for high and low shears of the magnetic field differ significantly. We found that particle can freely penetrate through magnetopause when its gyroradius, determined by the value of the magnetic field under the magnetopause, is comparable with the magnetopause thickness. We analyzed the role of the change of magnetic field inside the magnetosphere in the change of the

magnetopause form and position. We also show that the value of plasma pressure under the magnetopause determines the configuration of currents inside the magnetosphere.

D3.4-0006-18 THE FLANK MAGNETOPAUSE: THEMIS OBSERVATIONS

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The magnetopause is the boundary that, to first order, shields the Earth's magnetosphere from the shocked solar wind and its embedded interplanetary magnetic field. In this presentation, we show observations from the THEMIS constellation of spacecraft, comparing dayside magnetopause crossings with flank crossings near the terminator. Macroscopic properties such as current density, current sheet thickness, motion and transport across the boundary are examined for a large number of magnetopause crossings. We find that the flank magnetopause current sheet is generally thicker than the dayside magnetopause current sheet, but due to less reconnection activity, there is less transfer of mass and momentum across it. There are also asymmetries between dawn and dusk flanks for a number of properties. Dusk flank crossings typically have more pronounced changes in plasma and field quantities and are therefore easier to detect in the observations.

D3.4-0007-18 SOLAR WIND DRIVERS IN THE MAGNETOSHEATH: LONG-TERM EVOLUTION

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We study the long-term variability of the solar wind - magnetosphere - ionosphere coupling using several coupling functions to describe the solar wind input. As all plasma entering the magnetosphere is processed through the bow shock, magnetosheath, and the magnetopause, the complex dynamics of the solar wind - magnetosphere coupling is affected by the properties of the boundaries at the shock and the magnetopause as well as the dynamics within the magnetosheath. Data from the THEMIS 5-spacecraft mission processed in the magnetosphere interplanetary medium reference frame are used to study the magnetosheath properties. We demonstrate that the magnetosheath dynamics exhibits long-term variability associated with solar cycle evolution, and show how it varies as function of solar wind parameters. Especially, we focus on the energy entering the magnetosphere through the magnetopause in the form of Poynting flux. The IMAGE magnetometer chain measurements are used to trace the corresponding effects in the ionosphere over the THEMIS period, and also in a longer-term solar cycle perspective. The GUMICS-4 global MHD simulation quantitative results of energy entry and of the coupling of the boundary processes to the polar cap are used to provide a context and reference for the statistical observations.

D3.4-0008-18 TOPOLOGY OF MAGNETIC FIELD AND MAGNETOSPHERIC BOUNDARY LAYERS UNDER RADIAL IMF CONDITION: OBSERVATION AND SIMULATION RESULTS

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Magnetospheric boundary layers are frequently found near the magnetopause and the structure of the layers is highly dependent on the interplanetary magnetic field (IMF) orientations. During a radial IMF, the magnetosheath Bz component points to different polarities in both hemispheres. This asymmetry leads to a special structure of boundary layers in the low-latitude region. We investigate the magnetic field and boundary layer structures near the subsolar point recorded by THEMIS spacecraft in course of past few years. The main tool for our study of the structure of the boundary layers is the ion pitch-angle distribution. Both the observations and simulation results are consistent with the suggested scenario. The layers can be classified as: (1) the inner part of the low-latitude boundary layer (LLBL) lying on closed magnetic field lines; (2) the outer LLBL on open field lines; (3) the inner part of the magnetosheath boundary layer (MSBL) formed by dayside reconnection in the southern hemisphere; and (4) the outer MSBL resulting from lobe reconnection in the northern hemisphere.

D3.4-0009-18 MAGNETOSHEATH JETS: MODIFYING MAGNETOSHEATH PLASMA AND FIELDS, AND LINKING THE BOW SHOCK TO THE MAGNETOPAUSE

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Jets in the magnetosheath are local enhancements in dynamic pressure over ambient magnetosheath plasma, typically due to increases in both density in velocity. Undulations or ripples of the quasi-parallel bow shock stemming from impinging foreshock structures seem to constitute a major source of these jets. As they are able to traverse the entire magnetosheath, jets link processes and structures from the foreshock and bow shock with the day side magnetopause, on which they frequently impact. Here, latest statistical results based on THEMIS and MMS multi-spacecraft observations are presented, showing: (1) the plasma flow structure within and around jets as they traverse the magnetosheath and (2) the change in magnetic field orientation within jets resulting from that flow.

(1) The high velocity core jet plasma pushes slower plasma ahead out of the way, thereby setting up a vortical plasma motion in the vicinity. Inside the jet, slower plasma is accelerated in jet propagation direction while being redirected around the core. Outside of the jet, the evasive plasma motion is complemented by a deceleration of plasma in jet propagation direction with respect to the typical magnetosheath plasma flow. (2) The fast motion of jet plasma through the slower magnetosheath leads also to a straightening of the magnetic field in the jet core region, evidenced by consistently lower angles between plasma velocity and magnetic field direction at times of highest plasma velocity.

D3.4-0010-18 EXTERNAL AND INTERNAL CONDITIONS THAT AFFECT THE DAYSIDE MAGNETOPAUSE RECONNECTION LOCATION

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Magnetic reconnection at the Earth's magnetopause is discussed and has been observed as anti-parallel and component reconnection. While anti-parallel reconnection occurs between magnetic field lines of (ideally) exactly opposite polarity, component reconnection (also known as the tilted X-line model) predicts the location of the reconnection line to be anchored at the sub-solar point and extend continuously along the dayside magnetopause, while the ratio of the IMF By/Bz component determines the tilt of the X-line relative to the equatorial plane. A reconnection location prediction model known as the Maximum Magnetic Shear Model combines these two scenarios. The model predicts that during dominant IMF By conditions, magnetic reconnection occurs along an extended line across the dayside magnetopause but generally not through the sub-solar point (as predicted in the original tilted X-line model). Rather, the line follows the ridge of maximum magnetic shear across the dayside magnetopause. The model predicts the reconnection location correctly for about 80% of the time. This investigation uses MMS observations to discuss cases where the combination of large dipole titles with specific IMF clock angles causes the actual component reconnection X-line to be deflected from its predicted location.

D3.4-0011-18 MMS OBSERVATIONS OF HALL CURRENTS AT THE BORDERS OF A CRATER FLUX TRANSFER EVENT

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We present MMS observations of a Flux Transfer Event (FTE) detected on 27 October 2015, during a period of stable southward interplanetary magnetic field. Several reconnection jets were also observed during this period. The FTE is characterized by a clear signature in the magnetic field magnitude, with a maximum of the magnetic field intensity at the FTE centre, flanked by two local minima. This class of FTEs are called 'crater' FTEs, and have been suggested to be connected with an active reconnection X line. The MMS burst mode data allowed for the identification of intense fluctuations in the components of electron velocity and electric field parallel to the magnetic field at the borders of the FTE. In particular, the strong fluctuations of the parallel electron velocity at the borders of the FTE are an evident signature of encounters with magnetic separatrices and suggest that this FTE is connected with an active reconnection X line. This has important consequences for the FTE generation mechanism: in the original Russell and Elphic (1978) model, the FTE is not connected with an active reconnection site, and only in the extended X line models are the separatrices expected at the borders of the FTE. Our observations suggest a stratification of the particles inside the reconnection layer, in which electrons are flowing toward the X line along the separatrix, and flowing away from the X line along the adjacent reconnected field lines. More internally, ions and electrons are flowing away from the X line with comparable velocities, forming the observed reconnection jets.

D3.4-0012-18 DYING FLOW BURSTS AS GENERATORS OF THE SUBSTORM CURRENT WEDGE

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Many theories or conjectures exist on the driver of the substorm current wedge, e.g. rerouting of the tail current, current disruption, flow braking, vortex formation, and current sheet collapse. Magnitude, spatial scale, and temporal development of the related magnetic perturbations suggest that the generator is related to the interaction of the flow bursts with the dipolar magnetosphere after onset of reconnection in the near-Earth tail. The question remains how much of the energy feeding the wedge current is derived from flow braking and how much is contributed by the internal energy of the arriving plasma. In this presentation I argue that after flow braking the plasma attaching to the outer magnetosphere still contributes to current generation. The generator current is the grad-B current at the outer boundary of high-beta plasma compressed by the contracting magnetic field. It needs the sequential arrival of several flow bursts to account for duration and magnitude of the ionospheric closure current.

D3.4-0013-18 PIC SIMULATION OF KELVIN-HELMHOLTZ INSTABILITY AT THE DAYSIDE MAGNETOSPHERE

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Kelvin-Helmholtz instability is one of the most important physical processes operating on the dayside magnetopause. It has been widely investigated within the MHD framework, however, importance of kinetics increases when the thickness of the velocity shear layer becomes comparable to the ion gyroradius. Several observational studies indicate the existence of a thin velocity shear layer at the subsolar region with a thickness on the order of an ion gyroradius. To consider the effects of particle kinetics, we run particle-in-cell (PIC) simulations and investigate how the Kelvin-Helmholtz instability is excited along such a thin dayside magnetopause. Our simulations show dramatic differences in the development phase of Kelvin-Helmholtz instability depending on the relative direction of ion gyromotion to the vortices. We compared multiple simulation cases by changing parameters such as the magnitude of shear velocity and the density ratio obtained from in-situ observations.

D3.4-0014-18 MMS OBSERVATIONS AND PARTICLE-IN-CELL SIMULATIONS OF TRIPOLAR OUT-OF-PLANE MAGNETIC FIELD PERTURBATIONS DURING KELVINHELMHOLTZ WAVES

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We present new MMS observations of tripolar BM guide magnetic field perturbations associated with Kelvin-Helmholtz (KH) waves which are supported by in-plane Hall-like electron current loops. Tripolar BM observations were reproduced by Hall-like current loops in a 3D PIC simulation of vortex-induced driven reconnection during a limited phase of the KH evolution. MMS observations of a significant BN deflection and a strong axial current within a BL=0 plateau are consistent with a small-scale flux rope within one of the current sheets. We explore similarities and differences across several such KH-associated current sheets when MMS recorded a tripolar guide field perturbation.

D3.4-0015-18 MASS AND ENERGY TRANSFER ACROSS THE EARTH'S MAGNETOPAUSE CAUSED BY VORTEX-INDUCED RECONNECTION

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When the interplanetary magnetic field (IMF) is strongly northward, a boundary layer that contains a considerable amount of plasma of solar wind (magnetosheath) origin is often observed along and earthward of the low-latitude magnetopause. Such a pre-existing boundary layer, with a higher density than observed in the adjacent magnetosphere, reduces the local Alfvén speed and allows the Kelvin-Helmholtz (KH) instability to grow more strongly. We employed a large-scale three-dimensional fully kinetic simulation to model an event observed by the Magnetospheric Multiscale (MMS) mission in which the spacecraft detected (i) substantial KH waves between a pre-existing boundary layer and the magnetosheath during strong northward IMF and (ii) small-scale reconnection signatures such as electron-scale energy dissipations and ion-scale reconnection exhausts within the observed KH waves. The simulation successfully demonstrated these reconnection signatures within the non-linearly developed KH vortex, which are in quantitative agreement with the observed signatures. The simulation further demonstrated that a turbulent evolution of this vortex-induced reconnection (VIR) process leads to a large-scale plasma transport across the magnetopause and resulting rapid formation of the new mixing layer along the magnetopause. The VIR also produces a strong parallel electron heating within the new mixing layer. In this presentation, we will show the detailed comparisons between the simulation and the MMS observation, and discuss how the mass and energy transfer occurs near the magnetopause during strong northward IMF.

D3.4-0016-18 SOLAR WIND TRANSPORT INTO THE DUSK MAGNETOPAUSE CAUSED BY KELVIN-HELMHOLTZ VORTICES AS THE RESPONSE TO NORTHWARD TURNING OF THE INTERPLANETARY MAGNETIC FIELD

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Two spacecraft encountered the magnetopause and the low latitude boundary layer (LLBL) periodically with fluctuations of plasma features at the dusk magnetopause when the interplanetary magnetic field (IMF) turned northward abruptly. Although few features of the highvelocity-low-density were found in the plasma flows, the rotation features in the bulk velocity observations adjacent to the magnetopause, the distorted magnetopause as the results of minimum variance analysis (MVA), and the magnetic field deviations indicate the generation of the rolled-up Kelvin-Helmholtz (KH) vortices at the dusk magnetopause. In the KH vortices, the mixtures of the ions from magnetosheath with those from the magnetosphere were observed in the energy spectrum. The plasma flows were more periodic at the upstream spacecraft while more mixed than at the downstream one, suggesting that the plasma transport could occur significantly during the KH wave propagation from the upstream spacecraft to the downstream one. Under new criteria, the typical portrait of the plasma entry into the magnetosphere was made based on the observations of the electron and ion energy spectrums.

D3.4-0017-18 REMOTE SENSING OF A BOW SHOCK AT COMET 67P: THEORY, ICA OBSERVATIONS AND HYBRID MODELLING

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No direct observational evidence of the cometary bow shock around comet 67P/ChuryumovGerasimenko has been presented during the ESA/Rosetta mission. The Rosetta probe, during its escort phase, performed a lengthy dayside excursion up to a cometocentric distance of approximately 1500 kilometers, but no bow shock crossing was observed, implying either a distant bow shock or no bow shock formation at all. However, modelling studies at low heliocentric distances and high outgassing rates consistently predict the formation of a cometary bow shock within several thousands of kilometres of 67P's nucleus.

The Ion Composition Analyzer ICA, of the Rosetta Plasma Consortium, a top-hat ion spectrometer aboard Rosetta, measured solar wind and cometary ion distribution functions during the escort phase. As the length scales of the heavy cometary pickup ions exceed those of the predicted bow shock standoff distance by a factor of two up to an order of magnitude, the pickup ions could provide a remote sensing diagnostic of the cometary environment. A bow shock would present a significant increase in plasma heating and turbulence, leading to a modified acceleration environment for freshly ionized cometary particles and a modulation of the pickup ion energy spectra at the nucleus.

In this work, we summarily present a potential bow shock observation using energy dispersion of cometary ions observed by ICA and provide an interpretation of the observations with a self-consistent, numerical hybrid plasma model. We describe simulated observations of ions from two cometary plasma environments, one shock-producing and one non-shocked, and give guidelines on how the bow shock could be inferred remotely from in-situ observations.

D3.4-0018-18 SOLAR WIND PLASMA/PARTICLE ENTRY DURING NORTHWARD IMF AND ITS RELATED AURORAL ACTIVITIES

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During quiet times when the interplanetary magnetic field (IMF) is northward, using Cluster multi-spacecrafts observation between August to October each year from 2002 to 2004, Shi, et al. [2013] reported an unexpected discovery observation of regions of solar wind entry into the Earth's high-latitude magnetospheric lobes where the solar wind plasmas may penetrate into magnetosphere through the mechanism of high-latitude magnetic reconnection. From statistical analysis, they found that the IMF Bx component may influence the solar wind entry into the magnetosphere by changing the occurring conditions of high-latitude magnetic reconnection. Based on their studies, in this paper we use another period Cluster data which is between January to April each year from 2001 to 2006 to do a further study. As a result, the influence of the IMF Bx component is consistent with the results from [Shi, et al. 2013]. We find that the IMF By component influenced affects the events along with the IMF Bx component, which is consistent with the Parker Spiral of the IMF. We also present some transpolar arc observations occurring in correlation with the solar wind entry events. The properties of entry plasma, electron and ion properties associated with aurorae and correlations with IMF conditions are examined using multiple spacecraft data (Cluster, TIMED, DMSP, IMAGE, POLAR). The time evolution and asymmetries between two hemispheres for these transpolar arcs are studied as well. Using multi satellite, we have studied the geospace effect of the solar electron release. In several events, the electron flux enhanced in different regions of the magnetosphere after some solar electrons arrived at the vicinity of the earth. The entry mechanism of these high energy electrons is discussed.

D3.4-0019-18 STATISTICAL STUDY OF INFLUENCE OF THE ULF WAVES ON EARTH FORESHOCK PLASMA PROPERTIES

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The parameters of the solar wind plasma are modified upstream the Earth,s bow shock, in the ion foreshock region, which is typically observed at quasi-parallel bow shock. Associated ULF waves are created due to the interaction of the solar wind plasma with the ions reflected at the bow shock where they generate fast magnetosonic waves with an in-phase relationship between the ion flux and magnetic field fluctuations. Using multipoint observations from the THEMIS spacecraft fleet located in the foreshock, we present statistical maps of a modification of solar wind parameters due to foreshock processes (solar wind heating and deceleration, enhancements of electric and magnetic field fluctuation levels associated with specific ULF waves, etc.). Special attention is devoted to intervals of the radial interplanetary magnetic field that creates the foreshock upstream of a whole dayside bow shock.

D3.4-0020-18 A STUDY OF SPONTANEOUSLY HOT FLOW ANOMALIES AND CORRESPONDING UPSTREAM CONDITIONS

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Hot flow anomalies (HFAs) are usually formed by the interaction of a solar wind tangential discontinuity with the bow shock but they can also be found without the tangential discontinuity. This kind of HFAs is named spontaneous HFAs (SHFAs). SHFAs are formed by the interaction of particles reflected from the bow shock with the ambient solar wind. Nevertheless, the upstream IMF conditions should also contribute to the formation of SHFAs. In this study, we investigate the SHFAs recorded by Time History of Events and Macroscale Interactions during Substorm (THEMIS) satellites from 2007-2009 and corresponding upstream solar wind conditions monitored by Wind and ACE. The study provides us further information on the SHFA formation.

D3.4-0021-18 SPATIAL DISTRIBUTION OF MAGNETIC FIELD AND PLASMA PARAMETERS IN THE MAGNETOSHEATH DURING PERIODS OF A RADIAL IMF

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The solar wind is slowed down at the bow shock and diverted around the magnetopause creating the magnetosheath. Spatial profiles of the plasma parameters within the magnetosheath were studied theoretically in a gasdynamic approximation under assumptions of the frozen-in interplanetary magnetic field (IMF). Later, global MHD models revealed importance of the IMF orientation in a magnetosheath formation but none of these approaches can reflect kinetic processes connected with the presence of beams of particles accelerated at the bow shock and penetrating into the magnetosheath. These effects would be even more important during intervals of a radial IMF that facilitates a penetration of the energetic particles into the whole magnetosheath. The study uses a huge amount of Cluster and THEMIS magnetosheath observations for a determination of typical profiles of the density, velocity, and temperature as well as the direction and magnitude of the magnetic field in the dayside low-latitude magnetosheath. In order to account for the changing solar wind conditions, the study uses dimensionless quantities normalized to corresponding upstream parameters. Magnetopause and bow shock models reflecting the magnetopause expansion during intervals of the radial IMF serve for a determination of the magnetosheath coordinates. The results obtained for the radial IMF are compared with a similar study of the magnetosheath profile for the strongly northward IMF and with the MHD model.

D3.4-0022-18 SOLAR WIND DYNAMIC PRESSURE CONTROL OF THE DAYSIDE MAGNETOPAUSE LOCATION

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The solar wind dynamic pressure is a principal factor controlling the magnetopause location and a relation between them is usually described by a power-law form but values of suggested indices vary from 1/4.8 to 1/6.6 in magnetopause models developed in course of last years. However, solar wind parameters are modified inside the magnetosheath and this modification depends on the orientation of the interplanetary magnetic field (IMF), thus a relation between the upstream pressure and magnetopause location would be a function of the IMF orientation. On the other hand, the magnetospheric magnetic field that opposes the upstream pressure is affected by a number of processes that, in turn, depend on upstream parameters like the IMF orientation or solar wind velocity. The paper analyzes several thousands of THEMIS dayside magnetopause crossings observed in a broad range of upstream pressures (0.2-20 nPa) and under various IMF orientations with a motivation to validate the power-law form for a description of variations of the magnetopause stand-off distance with the upstream pressure and to determine the factors that furthermore influence an actual value of the power-law index.

D3.4-0023-18 ION RAMPS OF BOW SHOCKS AND INTERPLANETARY SHOCKS: DIFFERENCES AND SIMILARITIES

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Fast forward shocks driven by coronal mass ejections or by interaction of fast and slow solar wind streams can be encountered in the interplanetary space, whereas the bow shock is a standing fast reverse shock formed by an interaction of the supersonic solar wind with the Earth magnetic field. Both types of shocks are responsible for a transformation of a part of the energy of the directed solar wind motion to plasma heating and acceleration of reflected particles to high energies. These processes are closely related to the shock front structure. In the present paper, we compares fast forward interplanetary shocks registered in the solar wind by the DSCOVR, WIND, and ACE with bow shock crossings observed by the Cluster, THEMIS, MMS, and Spektr-R spacecraft with the Alfvén Mach number lower than the first critical Mach number in the small plasma beta (<1) regime. An application of the high-time resolution data facilitates a further discussion on formation mechanisms of both types of shocks and their associated structures.

D3.4-0024-18 GAS-DYNAMIC INTERPRETATION OF STRUCTURES IN THE MAGNETOSHEATH ON THE BASIS OF THEMIS AND CLUSTER MEASUREMENTS

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Our purpose is to analyze structures and processes in the Earth's magnetosheath on the basis of both theoretical modeling and data from recent spacecraft missions. In our investigation we apply plasma measurements, taken onboard the THEMIS and Cluster satellites. The numerical gas-dynamic magnetosheath-magnetosphere model is used as a theoretical tool. For a given solar wind state, the model self-consistently determines the positions of the bow shock and the magnetopause. It also provides the distribution of plasma parameters in the magnetosheath and distribution of magnetic field in the magnetosphere, the latter calculated via a magnetospheric magnetic field model. WIND and ACE data are used as a solar wind monitoring. The capabilities of the model in describing the features of the terrestrial magnetosheath are discussed.

D3.4-0025-18 SPACE WEATHER - TECHNOLOGY, RESEARCH, AND EDUCATION CENTER (SWX-TREC)

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SWx-TREC is a new Center at the University of Colorado - Boulder initiated under a grant intended to create a center of gravity for the many units at CU working on space weather topics. TREC will be in the College of Engineering and Applied Science and the Laboratory for Atmospheric and Space Physics (LASP). It will be able to work across the usual academic boundaries to better develop and integrate space weather models, missions, and data that will have a direct benefit to the operational forecasting offices. TREC will also be the focal point for creating undergraduate, graduate, and professional courses in space weather. TREC is currently making strategic investments in research-to-operations (R2O) projects such as an improved full-physics model of Low-Earth-Orbit satellite and debris drag, as well as operationsto-research (O2R) projects including improvements to solar magnetic field measurements and models that form the basis of operational solar wind forecasting models. In addition, TREC will host a "space weather data portal" and a forecast center "test bed", enabling close interaction between operational forecasters and researchers from around the nation and the world. In short, TREC is a new academic research and technology center dedicated to helping bridge the gap between space weather research and operations, and to educating the space science workforce, from undergraduates to industry professionals. TREC will work with national and international operational forecast centers, industry, other academic groups, and NSF and NASA centers such as the NASA/NSF CCMC, to develop and transition new models and tools that improve space weather forecasting and nowcasting. TREC will also be focusing significant effort on its educational mission in alignment with CU's mission as a leading space science university.

SPACE PLASMAS IN THE SOLAR SYSTEM, INCLUDING PLANETARY MAGNETOSPHERES (D)

PARTICLE ACCELERATION AND LOSS IN THE EARTH AND PLANETARY MAGNETOSPHERES (D3.5)

D3.5-0001-18 PARTICLE ACCELERATION IN MAGNETIC RECONNECTION EVENTS

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The NASA Magnetospheric Multiscale (MMS) mission uses four closely-spaced spacecraft to investigate magnetic reconnection in the boundary regions of the Earth's magnetosphere by measuring charged particles and electric and magnetic fields at the electron scale for the first time in space. Magnetic reconnection involves the conversion of magnetic energy to heat and charged particle kinetic energy. Particle energization is manifested in several different ways including jets of ions streaming away from X lines, electron jets streaming both toward and away from X lines, out-of-plane flows of electrons accelerated by the reconnection electric field, and high-energy ions and electrons produced by induced electric fields and Fermi acceleration. MMS encounters both asymmetric reconnection at the dayside magnetopause and symmetric reconnection in the magnetotail. Particle densities are much lower in the tail so that the available magnetic energy per particle is much higher than on the day side. The sources of accelerated electrons are also different being primarily magnetosheath

electrons on the day side and neutral-sheet electrons on the night side. Meandering, Speiser-type trajectories are important in both regions, which allows for cross-field acceleration by the reconnection electric field. Detailed comparisons are made of various particle acceleration mechanisms in symmetric and asymmetric reconnection, and an overall budget of particle and magnetic energy is derived in order to make better estimates of the reconnection rate.

D3.5-0002-18 ON THE FORMATION OF SATURN'S ELECTRON RADIATION BELTS BY Z-MODE WAVE ACCELERATION

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Saturn's electron radiation belt is most intense just outside the ring system. It consists of high-energy electrons of energies up to several MeV which are accelerated inside the planetary magnetic field. It has long been thought that inward transport and conservation of the first two adiabatic invariants is responsible for the acceleration. Here we show that in-situ acceleration through wave particle interactions, which initial studies dismissed as ineffectual at Saturn, is in fact a vital part of the energetic particle dynamics at Saturn. We present evidence from numerical simulations based on careful modelling of data from the Cassini spacecraft that a particular class of plasma waves, known as Z-mode waves, accelerates electrons to MeV energies inside 4 RS (1 RS = 60,330 km). The acceleration takes place via Doppler shifted cyclotron resonance in regions of low plasma density. Our results show that Z-mode waves propagating almost along the planetary magnetic field are much more effective at electron acceleration than obliquely propagating waves, or O-mode waves. We show that the resulting electron energy spectrum closely approaches that observed, even without transport effects. The results suggest that electron acceleration by Z mode waves plays a major role in the formation of Saturn's electron radiation belt.

D3.5-0003-18 THE STRUCTURE AND PROPERTIES OF MARTIAN MAGNETOSPHERE AT 70° SOLAR-ZENITH ANGLE IN MSE COORDINATES AS OBSERVED ON MAVEN SPACECRAFT

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Results of measurements on MAVEN spacecraft during its 44 passes through dayside solar wind-Mars interaction region are analyzed in MSE coordinate system, arranged by the angle between electric field vector and the projection of spacecraft position radius vector in the YZ plane E. All passes were divided into 3 angular sectors near 0°, 90° and 180° E angles in order to estimate the role of IMF direction in plasma and magnetic properties of dayside Martian dayside magnetosheath and magnetosphere. The observations were performed from January 17 through February 4, 2016 when MAVEN was crossing the dayside magnetosphere at SZA 70°. Magnetosphere as the region with prevailing energetic planetary ions was always found between the magnetosheath and the ionosphere. Magnetic barrier forms in ionosheath in front of the magnetosphere with strong magnetic field and continues within magnetosphere. Magnetopause was defined at the steep increase of the ration of N(O+) + N(O2+)/Np from 0.1 to 1. The number densities of O+ and O2+ ions increase from magnetopause to the interface with ionosphere by the factor of 100 -1000. Within each angular sector of magnetic coordinates there are typical profiles of the magnetosheath, the magnetic barrier and the magnetosphere and relative magnetic field magnitudes in these two domains vary. Plume ions frequently dominate the ion flow in magnetosheath and magnetosphere in the northern MSE sector (E 0-300) where motion electric field is directed from the planet. The high flux of plume protons disturbs the structure of magnetosphere and magnetic barrier. In the equatorial sector (E 60°-120°) magnetic barrier, magnetopause and magnetosphere are very irregular and triple crossings of magnetopause are observed, magnetic barrier has small thickness. Velocity-dispersed ion beams are observed in the magnetosphere. The southern sector (E 160°-180°) is characterized by small scale and small magnitude magnetic barrier. Magnetosheath proton flux weakens but usually keeps the same energy distribution at the magnetopause. Magnetic field magnitude has a minimum at magnetopause. The gradient of planetary ions is steeper at magnetopause than in other sectors. The average height of the boundary with ionosphere is 530 km and the average height of the magnetopause is 730 km. The heights of magnetopause and the interface of magnetosphere with ionosphere in the southern sector are about by 150 km higher than ones in other sectors.

D3.5-0004-18 CRUCIAL CONTRIBUTION OF RAPID INJECTIONS FROM THE TAIL TO RADIATION BELT FORMATION

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Analysis of the radiation belt measurements by the Van Allen Probes reveals evidence that rapid, direct injection of relativistic electrons from the plasma sheet can make a crucial contribution to formation of the outer radiation belt. Simultaneous, prompt, large increases of electron flux, often over a large radial extent, are seen not only at the 10s-100s keV energies that have been suggested to be injected from the plasma sheet and serve as a source population for local acceleration to relativistic energies, but also for MeV electrons. We will show that electrons at MeV energies are frequently injected in association with strong substorm dipolarizations. To recognize these injections, it is necessary to properly take into account how observation of this prompt injection depends on the location of spacecraft and the crucial loss of electrons by magnetopause shadowing at the larger radial distances. For electron enhancement events that have good conjunction with THEMIS and/or MMS spacecraft in the nightside, propagation of the dipolarization front from the tail can be unambiguously identified, and comparison of phase space densities for fixed adiabatic invariant shows the existence of enough population in the plasma sheet to produce the observed enhancement of MeV electrons in the radiation belt. Furthermore, examination of detailed time evolution of relativistic electron intensities reveals that significant electron enhancements are often intermittent rather than continuous, with the timings of identified intermittent flux increases closely matching substorm dipolarization manifested in the magnetic fields and electric fields measurements by the EFW and EMFISIS instruments onboard the Van Allen probes. As a process solely related with substorm activity, the significant contribution of direct injection of MeV electrons is observed regardless of the strength of geomagnetic storm disturbance, and operates in addition to the more gradual effects of wave-driven electron energization and radial diffusion.

D3.5-0005-18 ROLE OF ENERGETIC HEAVY IONS DYNAMICS ON THE RING CURRENT LOSSES

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During geomagnetic storms, magnetic field in the equatorial plane can weaken and deviate from the dipole approximation. Such conditions may cause an onset of nonadiabatic motion of energetic ions and their precipitation into the atmosphere; the effect is expected to be especially profound for heavier ions. The nonadiabatic motion results in diffusion of energetic ions into the loss cone, the phenomenon known as field-line curvature scattering. We explore how this effect influences ion losses in the ring current during disturbed geomagnetic conditions. The ring current decay typically happens in two stages with initial rapid decay followed by a period of slower ring current dissipation. Observations indicate that heavy oxygen ions are preferentially removed during the process, however an exact mechanism causing this decay is a question of ongoing debate. Simulations with a state-of-the-art ring current-atmosphere interactions model with self-consistent magnetic field (RAM-SCB) fail to reproduce correctly the ring current decay. We show that the situation significantly improves when the field-line curvature scattering is taken into account in the RAM-SCB model. In the presentation we also show that for heavy energetic ring-current ions, even for conditions of slight nonadiabaticity, the loss cone shifts from zero-degree pitch angle and we provide a simple way to compute the modification of the loss cone.

D3.5-0006-18 NEW RESULTS CONCERNING PARTICLE ENERGIZATION IN EARTH'S VAN ALLEN RADIATION BELTS

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The energy distribution, spatial extent and particle species makeup of the Van Allen belts has been explored by several space missions. However, recent observations by the NASA dualspacecraft Van Allen Probes mission have revealed wholly unexpected properties of the radiation belts, especially for electrons at highly relativistic (E > 2 MeV) and ultra-relativistic (E > 5 MeV) kinetic energies. In this presentation we show using high spatial and temporal resolution data from the Relativistic Electron-Proton Telescope (REPT) experiment on board the Van Allen Probes that multiple belts can exist concurrently and that an exceedingly sharp inner boundary exists for ultra-relativistic electrons. Using additionally available Van Allen Probes data, we demonstrate that these remarkable features of energetic electrons are driven by strong solar and solar wind forcings. The comprehensive Van Allen Probes data show more broadly and in many ways how extremely high energy particles are accelerated, transported, and lost in the magnetosphere due to interplanetary shock wave interactions, coronal mass ejection impacts, and high-speed solar wind streams. The new data have in many ways rewritten our understanding about the radiation belts as a key space weather threat to human technological systems.

D3.5-0007-18 EXPLAINING THE DIVERSE RESPONSE OF THE ULTRA-RELATIVISTIC VAN ALLEN RADIATION BELT TO SOLAR WIND FORCING

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The NASA Van Allen Probes have opened a new window on the dynamics of ultra-relativistic electrons in the Van Allen radiation belts. Under different solar wind forcing the outer belt is seen to respond in a variety of apparently diverse and sometimes remarkable ways. For example, sometimes a third radiation belt is carved out (e.g., September 2012), or the belts can remain depleted for 10 days or more (September 2014). More usually there is a sequential response of a strong depletion, sometimes even total extinction on hour timescales, followed by a re-energization, the latter increasing outer belt electron flux by orders of magnitude on hour timescales during some of the strongest storms of this solar cycle (e.g., March 2013, March 2015). Such dynamics also appear to be often bounded at low-L by an apparently impenetrable barrier at L 2.8 through which ultra-relativistic electrons do not penetrate. Many studies in the Van Allen Probes era have sought explanations for these apparently diverse features, often incorporating the effects from multiple plasma waves. In contrast, we show how this apparently diverse behaviour can instead be explained by one dominant process: ULF wave radial transport. Once ULF wave transport rates are accurately specified by observations, and coupled to the dynamical variation of the outer boundary condition at the edge of the outer belt, the observed

diverse responses can all be explained. However, in order to get good agreement with observations, the modeling reveals the importance of very fast loss in the main phase which results in an almost total extinction of the belts and decouples preand post-storm ultra-relativistic electron flux on hour timescales, and we show how this can be explained by losses to the last closed drift shell. Similarly, varying source populations at the outer edge of the belt, which might include effects from local acceleration, are seen to be of critical importance such that near-tail dynamics play a crucial role. Nonetheless, simple models incorporating accurate transport rates derived directly from ULF wave measurements are shown to provide a single natural, compelling, and at times elegant explanation for such previously unexplained and apparently diverse responses to solar wind forcing.

D3.5-0008-18 LONG-TERM CORRELATION OF EMIC WAVE ACTIVITY AND RADIATION BELT FLUX VARIATIONS

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Electromagnetic ion cyclotron (EMIC) waves are transverse electromagnetic waves generated in the equatorial magnetosphere that are believed to play an important role in the dynamics of the most energetic, a few MeV radiation belt electron population. We expand on the study by Usanova et al. [2014] demonstrating a clear correlation between ground EMIC wave activity and modulation of ultra-relativistic electron pitch-angle distributions. We will present analysis of long-term (several months) simultaneous radiation belt flux measurements and electron pitchangle distributions observed by the REPT instrument onboard the Van Allen Probes together with ground measurements of EMIC wave power by the CARISMA magnetometer array.

D3.5-0009-18 OBSERVATIONAL EVIDENCE OF ULTRARELATIVISTIC ELECTRON SCATTERING FROM THE EARTH'S RADIATION BELTS

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The process of pitch-angle scattering of ultrarelativistic electrons (multi-MeV energies) from the radiation belts into the Earth's atmosphere by electromagnetic ion cyclotron (EMIC) waves is imprinted in the time-history of radial profiles of electron phase space densities (PSD). Resonating with electrons in a narrow region of space, EMIC waves can leave signatures of deepening minimums in PSD as a function of the third adiabatic invariant. In this work, we use Van Allen Probe measurements to calculate PSD profiles and detect local minimums. We show that the occurrence of the minimums coincides with ground observations of EMIC waves, and in situ observations of narrowing electron pitch angle distributions. We use the Versatile Electron Radiation Belt (VERB) code to simulate the radiation belt dynamics, and further support our findings by analyzing the modeling results.

D3.5-0011-18 DETAILED DISTRIBUTION OF EMIC WAVE EVENT LOCATIONS IN THE VICINITY THE MAGNETOPAUSE

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Wave particle interactions play an important role in the magnetosphere dynamics. ElectroMagnetic ion cyclotron (EMIC) waves are one of the kind of plasma waves involved in these interactions. After the first in situ observations of EMIC waves close to the plasmapause, many statistical studies pointed out that the dayside magnetosphere region close to the magnetopause is the place where the EMIC occurrence rate is the highest. In this region the EMIC wave occurrence is related to magnetosphere compression events, in relation with solar wind kinetic pressure increases. The presentation of the EMIC occurrence rate is usually made with respect to the L-shell value of the observations (the L-shell value of a location in the magnetosphere being the distance to the Earth (in Earth radii), in the magnetic equatorial plane, of the magnetic field line passing through this location). The L-shell value of the region adjacent to the magnetopause can vary by few Earth radii in respect with the solar pressure. In the present study we propose to represent the EMIC wave occurrence in the dayside magnetosphere with respect to the distance from the magnetopause. This provides a new insight of the EMIC wave distribution in this region and a better understanding of the magnetosphere compression influence on the EMIC wave onset. The THEMIS mission offers the best data set for this: THEMIS instruments observed EMIC emissions in this region and the the orbits of the spacecraft (THEMIS/C, D, E and to a lower extent A) often cross the region of interest, including the magnetopause. The magnetopause position is estimated with the Shue et al. model (1998) and compared to the observed position, when possible. We propose here to present in detail our method and the EMIC occurrence rate in function of their distance to the magnetopause. Our study is based on EMIC waves events by Usanova et al. (2012) based on Flux Gate Magnetometers measurements onboard THEMIS spacecraft. The influence of the solar wind pressure is also discussed.

D3.5-0012-18 COMPETITION BETWEEN PROMPT INJECTION AND LOSS DUE TO INWARD MOTION OF THE MAGNETOPAUSE FOLLOWING CME-SHOCK DRIVEN STORM SUDDEN COMMENCEMENT

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Prompt enhancement followed by loss of relativistic electron flux has been reported from Van Allen Probes measurements associated with strong interplanetary shock compression of the dayside magnetopause, for example 8 October 2013, 15 March 2015, 16 July 2017 and 6 September 2017. Acceleration by up to 1 MeV is inferred on less than a drift time scale when magnetopause compression launches a magnetosonic azimuthal electric field impulse tailward. This impulse propagates from the dayside around the flanks accelerating electrons in drift resonance at the dusk flank. Such longitudinally localized acceleration events produce a drift echo signature which is seen with time dispersion corresponding to drift energy. An immediate local response to ULF waves generated by the shock compression is also evident without energy dispersion.

These injection events out-run the magnetopause compression initially, but rarely persist as the magnetopause moves inward, and outward radial diffusion due to enhanced ULF wave power produces loss. MHD-test particle simulations of sample injection events reproduce observed drift echo periods and pitch angles. Competing losses at higher energy and lower L values due to EMIC waves are also examined for the 22 June 2015 storm.

The flux enhancement is short-lived during the Van Allen Probes era because no shock compressions have reached the magnitude of the March 1991 and the Halloween 2003 storms which transported electrons into the slot region (Blake et al., GRL, 1992; Looper et al, GRL, 2005). Prompt acceleration on a drift time scale is contrasted with radial diffusion which smooths out peaks in phase space density resulting from both local heating and drift time scale radial transport.

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Blake, J., W. Kolasinski, R. Fillius, and E. Mullen (1992), Injection of electrons and protons with energies of tens of Mev into l< 3 on 24 March 1991, Geophys. Res. Lett., 19, doi:10.1029/92GL00624.

D3.5-0013-18 VAN ALLEN PROBES OBSERVATIONS OF RADIATION BELT RESPONSE TO INTERPLANETARY SHOCKS DURING SEPTEMBER 2017

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It is well known that interplanetary (IP) shocks can result in rapid injection and energization of energetic electrons. One of the strongest of such an interaction occurred during March 1991 with electrons energized to ultra-relativistic energies and being injected into the inner zone. More recently, during September of 2017 two IP shocks in rapid succession impacted the magnetosphere. We report here detailed observation made by the Relativistic Electron and Proton Telescope and the Magnetic Electron and Ion Sensors on board NASA's Van Allen Probes. The resulting rapid response of the energetic electrons showed shock-induced energization as well as drift echoes in the L range of 4 to 5. Increased electron fluxes were seen to energies up to

>5 MeV with moderate spectral hardening post injection. We also discuss Van Allen Probes observations of solar energetic protons energized by the IP shock.

D3.5-0014-18 SIMULATION STUDY ON THE PROMPT ACCELERATION OF RELATIVISTIC ELECTRONS ASSOCIATED WITH THE SOLAR WIND PRESSURE PULSE

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Relativistic electron fluxes of the outer radiation belt rapidly change associated with enhancement of solar wind dynamic pressure. Fast mode waves associated with the solar wind pressure pulse produe the fast mode waves through the compression of the dayside magnetopause, and the fast mode wave propagation from dayside to night side are observed. In order to investigate this process in detail, we conduct a code-coupling simulation using the GEMSIS-RB test particle simulation (Saito et al., 2010) and the GEMSIS-GM global MHD magnetosphere simulation (Matsumoto et al., 2010). The results indicate that the fast mode waves propagates from the dayside to nightside, interacting with drifted-electrons. Through the interactions between the fast-mode waves and drifted electrons, rapid accelerations of MeV electrons are observed. The energy spectrum showed that the accelerations occur at wide energy range. We derived theoretically the minimum energy for the acceleration that is determined from the propagation speed of the fast mode waves and the speed of drifted electrons. In the simulation, we observed the electron accelerations above the minimum energy, which is consistent with the theoretical estimation.

D3.5-0015-18 GLOBAL TEST PARTICLE SIMULATIONS OF THE RING CURRENT EVOLUTION DURING 17 MARCH 2013 STORM

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During geomagnetic storms a large volume of ions is transported from the magnetotail deep into the inner magnetosphere leading to ion acceleration to the energies of tens to hundreds keV. Energized ions become the dominant source of plasma pressure in the inner magnetosphere. Pressure gradients drive the ring current system that couples the inner magnetosphere and the ionosphere. Ion acceleration and transport from the tail into the inner magnetosphere can occur at different spatial and temporal scales ranging from global quasi-steady convection to localized impulsive injection events. The goal of this study is to investigate mechanisms and properties of the plasma pressure buildup during 17 March 2013 large magnetic storm. For this purpose we use a global three-dimensional test-particle tracer (CHIMP) integrated into a coupled magnetospheric and ring current model (LFM-RCM). LFM-RCM will be used to compute storm-time electromagnetic fields and plasma flows. Then, global test-particle simulations, initialized in the magnetotail with the properties of computed plasma flows, will be used to analyze ion transport into the inner magnetosphere and to derive the buildup and evolution of storm-time plasma pressure. Specifically, we will address the following science questions: How deep into the inner magnetosphere can localized ion injections penetrate? What are their properties (spatial extent, maximum energy, ion composition)? What are the relative roles of the adiabatic and non-adiabatic mechanisms in the acceleration of different ion species (H, He, O)? How does plasma pressure evolution derived from full-particle trajectories compare with the results of global RCM simulations constrained by the slow-flow and adiabaticity assumptions.

D3.5-0016-18 TRANSIENT FLUXES OF HIGH-ENERGY ELECTRONS IN RADIATION BELTS: RESULTS OF MEASUREMENTS ON "VERNOV" AND "LOMONOSOV" SATELLITES

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The report presents an overview of the results on measurements of short-time, milliseconds - second duration, electron fluxes of relativistic and subrelativistic energies in various regions of the Earth's radiation zones and outside the area of stable trapping (Transient Relativistic Electrons Precipitation - TREP), the nature of which is associated with both the acceleration processes and the losses of these particles in the inner magnetosphere. The polar LEO satellites «Vernov» and «Lomonosov», launched in 2014 and 2016 respectively, were equipped with various instruments for measuring high-energy radiation, which have a sufficiently good time resolution and sensitivity for measuring radiation fluxes and doses during events of the TREP type. The results of measurements of hot plasma in the geostationary orbit (Eletro -2 satellite) were used to analyze data on TREP in the auroral zone. Along with possible physical models relevant to the nature of the TREP, various effects from both the effects of the TREP on the Earth's atmosphere and the materials and on-board satellite systems are discussed.

D3.5-0017-18 GLOBAL MHD/TEST PARTICLE SIMULATIONS OF RADIATION BELT DYNAMICS DURING EXTREME SPACE WEATHER EVENTS

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The Van Allen radiation belts respond dynamically to solar wind conditions and present specific difficulties to Space Weather modelling efforts due to the range of scales involved. For example, radiation belt populations can be strongly affected by kinetic effects which can in turn be driven by large-scale magnetospheric compressions and reconfigurations. Extreme magnetospheric behaviour also results in the diffusion theory currently used to model the radiation belts, rapidly diverging from the observed physical processes. To address this challenge, we employ the 3D MHD simulation code, Gorgon (Mejnertsen et al., 2018), coupled to a test particle simulation code. The MHD setup is used to represent the global magnetosphere through the implementation of a dipole field subjected to inflowing plasma, parametrised according to upstream solar wind measurements. Large numbers of test-particles are then spawned and traced through the time-dependent MHD fields to directly model radiation belt behaviour. We present results on the evolution of these simulated populations during scenarios representative of extreme Space Weather events where one or more Interplanetary Coronal Mass Ejections impact upon the magnetosphere. These studies inform how non-diffusive processes can lead to large flux dropouts and the rapid formation of new radiation belt populations.

D3.5-0018-18 ON THE PARAMETERS AFFECTING OBSERVATIONS OF ELECTRON FLUX OSCILLATIONS IN RESPONSE TO BROADBAND ULF WAVES

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We investigate the parameters affecting the appearance and amplitudes of electron flux oscillations, which appear under the effect of Ultra Low Frequency (ULF) fluctuations in the magnetosphere. To this direction, particle tracing simulations are conducted through a parametric study. It is found that the width in energy of electron energy channels are a critical parameter, with narrower energy channels enabling the observation of higher amplitude flux oscillations; this could explain why such features were not routinely observed before the Van Allen Probes era, except for large-amplitude drift echoes following a storm or substorm, as past spacecraft missions generally had lower energy resolution. Flux oscillations are also governed by the local gradient of the Phase Space Density, with steeper gradients leading to higher flux oscillations. A third parameter is the power of ULF wave electric and magnetic fluctuations, with higher field amplitudes leading to higher flux oscillations. Finally, the effects of azimuthal wave number, field power spectrum and ULF wave azimuthal localization are investigated. Such effects are quantified and parameterized.

D3.5-0019-18 RESONANT AND NON-RESONANT WAVE-PARTICLE ENERGIZATION IN EARTH'S RADIATION BELTS

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Earth's Van Allen radiation belts were discovered almost six decades ago and are responsible for much of what we call space weather. However, their formation, dynamics and consequences are still not clearly understood. A critical question concerns how radiation belt electrons and ions are accelerated to energies which may damage satellites and other infrastructure. Several satellite missions and many modelling efforts have been devoted to this problem. It seems clear the Ultra-low Frequency (ULF) plasma waves play an important role. Here we describe a model of ULF wave propagation in Earth's magnetosphere, incorporating realistic ionosphere boundary conditions, interacting with test particles in the radiation belt. Our model parameters are referenced to actual in situ particle and wave observations, and incorporate off-equatorial particle dynamics. We find that internal energization of equatorially mirroring electrons via non-resonant and resonant interactions with low wave number ULF waves can explain these observations. The amount of energization depends upon the ionospheric conductance and wave parameters such as the frequency, wave mode and wave number. Such non-resonant interactions and ionospheric boundary conditions have not been considered previously but play an important role in particle energization.

D3.5-0020-18 SPATIAL CHARACTERIZATION OF RELATIVISTIC ELECTRON ENHANCEMENTS IN THE EARTH'S OUTER RADIATION BELT DURING THE VAN ALLEN PROBES ERA

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Using data from the Van Allen Probes ECT-REPT instrument we have identified 76 relativistic electron enhancement events in the outer radiation belt that occurred between 2012 and 2017 at different L values between L = 2.5 and L = 6.0. We have classified the events according to their characteristic radial propagation, temporal evolution, and flux response at different energy channels ranging from 1.8 MeV to 6.3 MeV and found that enhancement events can be grouped by the "shape" of their spatiotemporal evolution. Using OMNI data, we have studied the solar wind parameters for the events and we have found that, when grouped, events in a group share similar properties in the evolution of fluxes and characteristic solar wind parameters, suggesting that different physical mechanisms play predominant roles for different events. To supplement our study, we have used > 2 MeV electron fluxes at geostationary orbit as measured by the GOES 13 and 15 Energetic Particle Sensor (EPS) instrument to compare our results with the geostationary orbit. We discuss the conditions under which GOES data might be used to predict fluxes at the hearth of the radiation belt and vice-versa.

D3.5-0021-18 RELATIVISTIC ELECTRON FLUXES AND MAGNETOSPHERIC MAGNETIC FIELD DYNAMICS DURING STRONG GEOMAGNETIC STORMS IN 2015

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Solar wind pressure pulses and interplanetary magnetic field variations play the crucial role in the outer Earth's radiation belt dynamics. Unfortunately, the physical mechanisms that control the loss and acceleration of the magnetospheric energetic electrons are still not quite understood. In this study we compared and contrasted some features of relativistic electron flux dynamics during two largest geomagnetic storms in 2015 (17-18 March and 22-23 June) having the similar Dst-variations profiles and amplitudes (200 nT) but accompanied by different conditions in the interplanetary space. Analysis of experimental data from Van Allen Probes (RBSP), GOES, Electro-L, POES, Meteor-M, SAC-D and Jason-2 satellites was combined with magnetic field measurements on-board RBSP satellites and calculations on the base of the A2000 model of the magnetosphere. Multi-satellite observations at GEO and LEO show the dramatic changes in the MeV electron populations during the main phase of the magnetic storms. We have found that solar wind and IMF variations are responsible for large-scale magnetospheric current system changes that reveal themselves in the different dynamics of the relativistic electron fluxes during two major storms occurring in 2015.

D3.5-0022-18 MEASUREMENTS OF ENERGETIC ELECTRONS AND PROTONS ABOARD A CUBESAT ON LOW EARTH ORBIT: AALTO-1 / RADMON

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Aalto-1, a three-unit CubeSat launched to Sun-synchronous Low Earth Orbit on 23 June 2017, is Finland's first satellite in orbit. It carries a payload consisting of three state-of-the-art instruments: a hyperspectral camera, a Plasma Brake for deorbiting demonstration, and a radiation monitor (RADMON) measuring the charged particle radiation in orbit. RADMON is sensitive to >10 MeV protons and >2 MeV electrons. As Aalto-1 spacecraft is still in a tumbling mode, RADMON is rapidly scanning directions in the sky allowing one to generate an omni-directional flux measurement from the counting rates of the detector.

We will present an overview of the first months of RADMON measurements in space. In addition to stably trapped electrons and protons in the Earth's radiation belts, RADMON observes quasi-trapped electron populations, which have been scattered to the drift loss cone and are en route to be precipitated in the atmosphere. In the first half of September, RADMON also observed a solar proton event, which was among the strongest ones in the present solar activity cycle and led to several space weather effects in orbit, including spontaneous reboots of the on-board computer of Aalto-1. During the late phase of the solar event, RADMON also observed a relativistic electron precipitation event, where the disturbed magnetospheric conditions led to loss of trapped electrons to the atmosphere.

D3.5-0023-18 OBSERVATION ON IMPULSE ELECTRIC FIELD INDUCED BY INTERPLANETARY SHOCK

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We investigate the characteristics of impulsive electric field in Earth's magnetosphere associated with induced by interplanetary shocks based on Van Allen Probes measurements from January 2013 to July 2016. Our results show that the electric field impulse is induced by the global compression by the shock and mostly in the azimuthal direction. The amplitude of the initial electric field impulse is positively correlated with the jump of dynamic pressure across the shock in the dayside. The rising time of the impulse is likely related to the changing rate of dynamic pressure of the solar wind, Pd and SYM-H index. It is thus suggested that the first period of the impulse is likely directly controlled by the external solar wind parameters instead of any internal eigen-period of the magnetosphere, and finite changing rate of Pd should be considered in the study of the interaction between solar wind and magnetosphere.

D3.5-0024-18 THE CONTRIBUTION OF ULF-VLF WAVE MECHANISMS TO THE APPEARANCE OF RELATIVISTIC ELECTRONS IN THE OUTER RADIATION BELT DURING MAGNETIC STORM AND WITHOUT IT

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In this study we estimate a possible contribution of ULF and VLF mechanisms to the electron acceleration up to relativistic energies. We analyze storm and non-storm periods during high solar wind streams. GOES satellites data are used to describe the electron fluxes (from 40 keV to > 2 MeV), and magnetic field variations. To characterize the magnetospheric wave activity in the Pc5 frequency range (1-7 mHz) the ground ULF index is used. The VLF data from RBSP satellite and Halley Bay station (Antarctica) are used as the chorus proxy in the magnetosphere. Analysis of several typical events demonstrates that the rate of the electron flux increase does not depend on the geomagnetic storm intensity and a substantial increase can occur even without geomagnetic storm. Two necessary conditions for the substantial intensification of relativistic electron fluxes have been found: an occurrence of high-speed solar wind stream and a prolong substorm activity. A good correspondence between the periods with the high solar wind speed and growth of the relativistic electron fluxes with a 1-2 days delay confirms the notion on important role of the electron drift resonance with ULF waves in electron energization. This resonant interaction leads to a preliminary electron acceleration up to sub-relativistic energies upon the radial diffusion deep into the magnetosphere. According to the RBSP satellite data a substantial growth of magnetospheric VLF activity occurs during approximately one day after the injection of seed electrons (50-100 keV). Supposedly, VLF emissions energize pre-accelerated electrons to relativistic energies.

D3.5-0025-18 MULTIPOINT SPACECRAFT OBSERVATIONS OF LONG-LASTING PC4 PULSATIONS IN THE DAYSIDE MAGNETOSPHERE: THE PARTICLES SIGNATURES

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We use magnetic field and plasma observations from the Van Allen Probes spacecraft to study the spatial and temporal characteristics of long-lasting Pc4 pulsations during six orbits in the dayside magnetosphere. We investigated the nodal structure of the waves. When they exhibit a strong compressional component, the spacecraft observe meridional sloshing of the node. When the node's motion attains maximum amplitude, spacecraft off the equator observe one peak while spacecraft at the equator observe two compressions per cycle. The particles observed by Van Allen Probes, THEMIS A and GOES 13 and 15 over a broad range of energies from tens of eV to 2 MeV exhibit regular periodicity with periods corresponding to the ULF magnetic field waves. We attribute the Pc4 pulsations to a drift bounce resonance mechanism.

D3.5-0026-18 THE DYNAMICS OF RELATIVISTIC ELECTRON IN THE SLOT REGION BETWEEN THE VAN ALLEN RADIATION BELTS

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Using multi-satellite measurements, the dynamics of relativistic electrons in the slot region are investigated from 2000 to 2011. The dependences of relativistic electron enhancements in the slot region on interplanetary and magnetospheric conditions are researched. It is resulted that the relativistic electron enhancements in the slot region occurred under remarkable interplanetary and magnetospheric conditions. A uniquely strong and long-lived relativistic electron slot region refilling event from November 2004 to January 2005 is studied especially. Both empirically modeled and observationally estimated plasmapause locations demonstrate that the plasmasphere eroded significantly prior to the enhancement phase of this event. The estimated diffusion coefficients indicate that the radial diffusion due to ULF waves is insufficient to account for the observed enhancement of slot region electrons. However, the diffusion coefficients evaluated using the distribution of chorus wave intensities derived from low-altitude POES electron observations indicate that the local acceleration induced by chorus could account for the major feature of observed enhancement outside the plasmapause. When the plasmasphere recovered, the refilled slot region was enveloped inside the plasmapause. In the plasmasphere, while the efficiency of hiss scattering loss increases by including unusually low frequency hiss waves, the interaction with hiss alone cannot fully explain the decay of this event, especially at higher energies, which suggests that EMIC waves contribute to the relativistic electron loss process at such low L-shells for this refilling event.

D3.5-0027-18 SUPRATHERMAL FE+ DISCOVERED IN AND NEAR EARTH'S MAGNETOSPHERE

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Suprathermal (87-212 keV/e) singly charged iron, Fe+, has been observed in and near Earth's equatorial magnetosphere using long-term (1995-2015) Geotail/STICS data. Fe+ is rare compared to dominant suprathermal solar wind and ionospheric origin heavy ions, appearing to be positively associated with both geomagnetic and solar activity. The relevance of four candidate sources are compared: charge exchange of nominal solar wind Fe+ 7, solar wind transported inner source pickup Fe+, outflow of ionospheric Fe+ (observed at up to 1000 km), and/or lunar pickup Fe+. Using 26% of low-to-moderate geomagnetic activity level magnetospheredominated data, we show that during those times solar wind Fe charge exchange secondaries are not an obvious Fe+ source. Earth flyby and cruise data from Cassini/CHEMS, a nearly identical instrument, indicate that inner source pickup Fe+ is not present at suprathermal energies. Our observations indicate lunar components, but no lunar Fe+. Therefore, it appears that ionospheric Fe+ constitutes at least an important portion of Earth's suprathermal Fe+, comparable to our observations at Saturn where suprathermal Fe+ has also been observed.

D3.5-0028-18 RELATIVISTIC OUTER RADIATION BELT ELECTRONS OUTWARD DIFFUSED DUE TO ULF WAVES IN THE PC5 FREQUENCY RANGE OBSERVED DEEP IN MAGNETOSPHERE.

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Field line resonances in the magnetic pulsations frequency range named Pc 5 are known to be oscillations of magnetospheric field lines. It is observed as a combination of three fundamental modes, namely poloidal, toroidal and compressional. Such a disturbance may have their energy sources arising from external high dynamic pressure solar wind pulsation that induces waves in the day-side sector magnetosphere. Also, low-frequency instabilities of the ring current ions are candidates to promote ultra-low frequency (ULF) waves in the Pc5 frequency range. The toroidal mode is mainly due to upstream solar wind disturbances and it is observed in the dawndusk flanks, while compressional and poloidal modes can be originated from local disturbances and they can be observed everywhere in the night side sector. On July 19, 2016, at 2309 UT, the ground magnetometers registered a sudden impulse due to an interplanetary coronal mass ejection (ICME) shock arrival. The solar wind parameters registered by ACE satellite showed a sharp increase in the density and velocity, reaching 40 cm-3 and 450 km/s, respectively. GOES15(13) satellite that was at noon-to-dusk (dusk-to-midnight) sector noted a major (minor) increase in the magnetic field, followed by oscillations in the horizontal magnetic field. Data from plasma parameters measured by the Themis-D satellite agreed that the geomagnetic field was compressed, the results from empirical models lead to magnetospheric stand-off position compressed to 6.5 Re. In the following, results from the instruments on board the Van Allen Probes A, which traveled from midnight to dawn sector observed a relativistic electron flux dropout two orders of magnitude long, occurred throughout 3 hours following the shock arrival. The ULF waves in a Pc5 frequency range are observed both at the location of the satellite and on the ground, the different magnetometers show that ULF waves reached midi-to-low latitudes with considerable power spectral densities. Regarding the ULF waves are known to contribute with relativistic particles outward diffusion in the Van Allen belts, including through magnetopause shadowing events, we investigate the ability of the different solar wind parameters to be energy sources to generate Pc5 frequency waves in different modes deep inside the magnetosphere.

D3.5-0029-18 OBSERVATION OF ION INJECTION TRIGGERED EMIC WAVES IN THE EARTH'S MAGNETOSPHERE

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We present a case study and statistics of electromagnetic ion cyclotron (EMIC) waves triggered solely due to substorm injected anisotropic ions using Van Allen Probes observations from 2015. We discuss in detail the EMIC wave event that occurred on 09 August 2015. The EMIC wave onset was associated with the arrival of anisotropic ions along with a dip in the magnetic field. The time at which the injected ions are observed directly corresponds to the onset of EMIC waves at the location of the Van Allen Probe A (L=5.5 and 18:06 MLT). The GOES and LANL geosynchronous spacecraft observed the injected and westward (eastward) drifting ions (electrons) at various local times. Using the observed arrival times of dispersive injections at the LANL and GOES spacecraft, we trace the particles back in a dipolar magnetic field to their injection location centered near 20:00 MLT. GOES and ground magnetometer responses confirm substorm onset at approximately the same local time. The arrival of anisotropic ions together with the concurrent and co-located decrease in the magnetic field favored the growth of the EMIC wave instability based on quasi-linear theory analysis. Further, statistical analysis will give deeper insight on the magnetic field and particle behavior during these events and their local time distribution.

D3.5-0030-18 THE JOINT AND COMPETITIVE EFFECTS OF WHISTLER MODE WAVES AND FAST MAGNETOSONIC WAVES ON RADIATION BELT ELECTRONS

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Using the Van Allen Probe long-term (2013-2015) observations and quasi-linear simulations of wave-particle interactions, we examine the joint and competitive effects of whistler mode waves (chorus and hiss) and magnetosonic (MS) waves on energetic (<0.5 MeV) and relativistic (>0.5 MeV) electrons inside and outside the plasmasphere. Although whistler mode chorus waves and MS waves can singly or jointly accelerate electrons from the hundreds of keV energy to the MeV energy in the low-density trough, most of the relativistic electron enhancement events are best correlated with the chorus wave emissions outside the plasmapause. Inside the plasmasphere, intense plasmaspheric hiss can cause the net loss of relativistic electrons via persistent pitch angle scattering, regardless of whether MS waves were present or not. The intense hiss waves not only create the energy-dependent electron slot region but also remove a lot of the outer radiation belt electrons when the expanding dayside plasmasphere frequently covers the outer zone. Since whistler mode waves (chorus or hiss) can resonate with more electrons than MS waves, they play dominant roles in changing the outer radiation belt and the slot region. However, MS waves can accelerate the energetic electrons below 400 keV and weaken their loss inside the plasmapause. Thus, MS waves and plasmaspheric hiss generate different competing effects on energetic and relativistic electrons in the high-density plasmasphere.

D3.5-0031-18 SOLAR CELL DEGRADATION OF THE ARASE SATELLITE IN THE PROTON RADIATION BELT

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Solar cells mounted on any satellites are susceptible to effect of abundant space radiations. Solar cells on the Arase satellite orbiting in the inner magnetosphere degrade due to trapped protons with energies of more than 6 MeV. The Arase satellite was launched on December 20, 2016 for studying the radiation belt dynamics. However, it observes ions with energies of less than 180 keV, and no MeV ions are measured. In the current study, we try to deduce spatial distribution of the radiation belt protons from analysis of output variation of the SAP (Solar-cell Array Panel) of the Arase satellite. The Van Allen Probes measure no energetic protons between 1 and 20 MeV and our analysis gives a unique information of radiation belt protons around 8 MeV. Analysis of the SAP data showed a clear degradation that could be attributed to trapped MeV protons. Radiation dosage was determined from Voc (Open circuit voltage) variation of the solar cells and we made comparison with those expected from various distribution models (AP8MAX, AP9MEAN and CRRESPRO quiet) of trapped protons. We found a little difference in expected radiation dosage from the model calculations. We introduce modified models to minimize the difference and discuss the spatial distribution of trapped MeV protons.

D3.5-0032-18 ON THE EFFECT OF GEOMAGNETIC STORMS ON RELATIVISTIC ELECTRONS IN THE OUTER RADIATION BELT: VAN ALLEN PROBES OBSERVATIONS

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Using Van Allen Probes Energetic Particle, Composition, and Thermal Plasma-Relativistic Electron-Proton Telescope (ECT-REPT) observations, we performed a statistical study on the effect of geomagnetic storms on relativistic electrons fluxes in the outer radiation belt for 78 storms between September 2012 and June 2016. We found that the probability of enhancement, depletion, and no change in flux values depends strongly on L shell and energy. Enhancement events are more common for 2 MeV electrons at L 5, and the number of enhancement events decreases with increasing energy at any given L. However, considering the percentage of occurrence of each kind of event, enhancements are more probable at higher energies, and the probability of enhancement tends to increases with increasing L shell. Depletion are more probable for 4-5 MeV electrons at the heart of the outer radiation belt, and no-change events are more frequent at $L <$ 3.5 for E 3 MeV particles. Moreover, for $L > 4.5$ the probability of enhancement, depletion, or no-change response presents little variation for all energies. Because these probabilities remain relatively constant as a function of radial distance in the outer radiation belt, measurements obtained at geosynchronous orbit may be used as a proxy to monitor $E \geq 1.8$ MeV electrons in the outer belt.

D3.5-0033-18 CHARGED PARTICLE NONLINEAR BEHAVIOR IN ULTRALOW FREQUENCY WAVES

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In Earth's inner magnetosphere, electromagnetic waves in the ultralow frequency (ULF) range are believed to play an important role in accelerating and diffusing charged particles via a resonant process named drift resonance. In the conventional drift resonance theory, a linearization approach is used to assume a small wave-particle energy exchange so the particle trajectories remain unperturbed. For ULF waves with large amplitudes and/or long durations, however, the conventional theory becomes less accurate since the particle trajectories can be highly modified by the waves. Here we extend the conventional drift resonance theory into the nonlinear regime, and predict from the extended theory the observable signatures of nonlinear wave-particle interactions such as rolled-up structures in the particle energy spectrum. After considering its manifestation in particle data with finite energy resolution, we compare these predicted signatures with observations from Van Allen Probes. The good agreement between them validates the nonlinear theory, and therefore provides an improved understanding of particle dynamics and interactions with ULF waves in the inner magnetosphere.

D3.5-0034-18 RADIATION BELT ELECTRON'S FLUX DROPOUT DURING INTENSE GEOMAGNETIC STORMS

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The solar structures that eventually reach the Earth, causing intense geomagnetic storms, modify the geomagnetic field where the electrons are trapped in the Van Allen radiation belts. The way in which intense geomagnetic storms may affect the variability of the relativistic electron fluxes in the radiation belts is not completely understood, and here we address this point. We used data from

the Relativistic Electron-Proton Telescope (REPT) instrument aboard NASA's twin Van Allen Probes. To identify and quantize the intensity of storms we used the symmetric index, SYM-H, and to identify the cause of the geomagnetic storms, we used data from the solar wind: speed, dynamic pressure and magnetic field as measured by the Advanced Composition Explorer (ACE), and Deep Space Climate Observatory (DSCOVR) satellites, which are orbiting the gravitational balance point between the Sun and the Earth. The comparison of electron fluxes in the outer radiation belts with Interplanetary Medium data showed the importance of the interplanetary magnetic field (IMF) Bz component (in Geocentric Solar Magnetospheric - GSM - coordinates) on the trapped electron flux during the occurrence of geomagnetic storms. Negative values of the IMF Bz component interconnect the interplanetary and geomagnetic fields, allowing particles to escape throughout the magnetosphere to the solar wind, causing decreases in the electron flux in periods that coincide with negative IMF Bz values. This suggests that the particles' flux in the radiation belts depends on the IMF Bz component the same way it does for the occurrence of intense geomagnetic storms. It is necessary a deeper investigation to understand the contribution of the different mechanisms of the internal and external phenomena of the Earth's magnetosphere to fully understand and describe the behavior of trapped particles.

D3.5-0035-18 MATHEMATICS OF IONIC CHARGE STATE DISTRIBUTIONS IN THE EARTH'S RADIATION BELTS

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From a mathematical point of view there are at least two operational techniques for theoretically assessing the distribution over charge state for ionic species confined in the Earth's radiation belts: [1] Direct computation via coupled ionic distribution functions (e.g., Spjeldvik and Fritz, 1978; Spjeldvik, 1979) and [2] Recursive computation via normalized ionic distributions coupled with an overall summed ionic/isotopic species equation, thus yielding an over-determined system of equations (e.g., Spjeldvik, 1990). The latter technique held the promise of usefulness for any ionic species. However, in applications a numerical instability has been discovered which at first threatened the useability of the method. This paper reports an approximate method by which the numerical stability is restored, and it amounts to an alternate approximate evaluation of the charge state averaged radial diffusive transport coefficient. The mathematical algorithm is reviewed and the stability restoring approximation is explored. Application is made in the adiabatic invariant formulation of the radiation belt source/transport/loss description. [References: Spjeldvik and Fritz, J. Geophys. Res., 83, 1583-1594; Spjeldvik, Sp. Sci. Rev., 23, 499-538, 1979; Ann. Geophys., 8, 59-68, 1990].

D3.5-0036-18 ENERGETIC PARTICLE DYNAMICS NEAR CALLISTO

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Callisto's magnetic environment is characterized by a complex admixture of induction signals from its conducting subsurface ocean, the interaction of corotating Jovian magnetospheric plasma with the moon's ionosphere and induced dipole, and the non-linear coupling between these effects. In contrast to other Galilean moons, ion gyroradii near Callisto are comparable to its size, requiring a kinetic treatment of the interaction region near the moon. This is especially true for energetic particles, whose gyroradii may exceed Callisto's radius by orders of magnitude. We therefore use electromagnetic fields calculated by a hybrid (kinetic ions, fluid electrons) model to investigate energetic particle dynamics and loss processes, as well as their effect on Callisto's environment. From this, we are able to provide a map of global energetic particle precipitation onto Callisto's surface, which may be an important contribution to the generation of its atmosphere.

D3.5-0037-18 CHARGE STATES OF KEV AND MEV HEAVY IONS CONFINED IN THE EARTH'S MAGNETOSPHERE

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Heavy ions are present throughout the Earth's magnetosphere in measurable quantities. The question about their origin has long been fairly open, but in a recent paper in JGR-blue, Christon et al. (JGR-blue, Nov. 2017) using S/C Geotail data obtained over a 21-year time span in the outer magnetosphere (where 9 Re R 30 Re) argue that ions of iron most likely stem from the Earth's upper atmosphere where they have their origin in the vaporized meteor metallic gas. Earlier in the space era, Spjeldvik and Fritz (1978a,b) presented Helium ion observations that could have their origin either from interplanetary space (e.g., the sun), and Spjeldvik and Fritz (1978c) computed charge state distributions of ionized atomic oxygen assuming either a solar source (thus with the ion source mostly in the sixth ionic charge state) or an atmospheric source (with the ions source mostly in the first ionic charge state), and they demonstrated that given enough residence (magnetic confinement) time in the magnetosphere - collisional processes tends to redistribute the oxygen ions amongst the available charge states yielding an equilibrium charge state distribution that is fairly independent of the ion source charge state; similar physics also likely works on other ion species. In this work, ions of carbon and iron are considered from an overall distribution evolution point of view at radial distance considered for stable confinement, at geomagnetic L-shells 7, and like the situation from magnetically confined oxygen ions, carbon and iron ions in that inner region also evolve towards radiation belt distributions that obscure the charge state characteristics of their sources. Classic diffusion theory is applied in adiabatic invariant space yielding fluxes of carbon and iron ions distributed over ionic charge states, magnetic moment (first adiabatic invariant), and radial locations from the Earth; the results are also converted to energy spectra. Boundary conditions for the numerical simulations are taken from different spacecraft measurements, and the computed ion distributions at KeV and MeV energies are presented for representative extended quiescent geophysical conditions. The simulations technique can be made time-dependent, and so extended to simulate ion injection events during geomagnetic disturbances, such as magnetic storms, as has earlier been done by the present author for Hydrogen ions.

D3.5-0038-18 MULTI-SATELLITE MEASUREMENTS OF THE OUTER RADIATION BELT DURING GEOMAGNETIC STORMS: VAN ALLEN PROBES AND PROBA-V OBSERVATIONS

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The response of the inner magnetosphere to geomagnetic activity and solar wind conditions is still not fully understood. For example, electron fluxes in the outer radiation belt can be enhanced or depleted depending on the energy of the particles, and the phase or driver of a geomagnetic storm, and solar wind conditions. The Van Allen Probes Relativistic Electron-Proton Telescope (REPT), and the Energetic Particle Telescope (EPT) on board the ESA satellite PROBA-V together provide simultaneous high-resolution measurements of the relativistic electrons of the outer radiation belt at different orbits. Here we analyze MeV electron differential and integrated fluxes measured by the Van Allen Probes and PROBA-V spacecraft at the same L-shell during geomagnetic storm events occurred during 2014 and 2015, comparing similar measurements at different orbit altitudes.

D3.5-0039-18 EXTREME ELECTRON FLUXES DURING SPACE WEATHER EVENTS IN THE RADIATION BELTS AND SOUTH ATLANTIC ANOMALY: EXTREME VALUE ANALYSIS USING DATA FROM THE ARGENTINE SAC-D SPACECRAFT

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The van Allen radiation belts are regions in the terrestrial space environment that present ions and energetic electrons trapped by the geomagnetic field. Since the geomagnetic field in the South Atlantic Anomaly (SAA) region is relatively weakest over the western South Atlantic Ocean, trapped energetic particles of the radiation belts can reach closer distances to the Earth than energetic particles in other regions. The electron population in the outer radiation belt can reach energies mainly in a range from some keV to tens of MeV. During a geomagnetic storm, the population of energetic particles in the radiation belts can significantly increase. The increase of fluxes of these energetic particles has a major interest for Space Weather, mainly because the impact on satellites and human activities in space. The specific effects and impacts will depend upon satellite orbit and the energy of the energetic particles. A detailed knowledge of the highest energies reached as well as the extreme fluxes and frequencies, is essential for the specific design of satellites and for the development of satellite technologies. The main purpose of the present work is to study the extreme electron fluxes in the terrestrial outer radiation belt (L 3-6) and in the SAA, for an energy range between 0.249 MeV and 1.192 MeV at 660 km of altitude above the Earth surface, using measurements made by the detector ICARE-NG/Carmen-1 on board the polar Argentinean satellite SAC-D. A statistical analysis based on the peaks over threshold approach was implemented for the daily average electron fluxes, and we present results of its cumulative probability distribution function, showing that it likely has a finite upper limit for a wide range of energies and in different regions.

SPACE PLASMAS IN THE SOLAR SYSTEM, INCLUDING PLANETARY MAGNETOSPHERES (D)

MAGNETOTAIL DYNAMICS AND SUBSTORMS DURING STORM AND NON-STORM TIME (D3.6)

D3.6-0001-18 SUBSTORM ONSET: A SWITCH ON THE SEQUENCE OF TRANSPORT FROM DECREASING ENTROPY TO INCREASING ENTROPY

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In this study, we propose a scenario about the trigger for substorm onset. In a stable magnetosphere, entropy is an increasing function tailward. However, in the growth phase of a substorm, a later born bubble has lower entropy than earlier born bubbles. When a bubble arrives at its final destination in the near-Earth region, it will spread azimuthally because of its relatively uniform entropy. The magnetic flux tubes of a dying bubble, which cause the most equatorward aurora thin arc, would block the later coming bubble tailward of them, forming an unstable domain. Therefore, an interchange instability develops, which leads to the collapse of the unstable domain, followed by the collapse of the stretched plasma sheet. We regard the substorm onset as a switch on the sequence of transport, i.e., from a decreasing entropy process to an increasing entropy process. We calculated the most unstable growth rates and the wavelengths of instability, and both are in agreement with observations.

D3.6-0002-18 RESPONSE OF PLASMASPHERIC CONFIGURATION TO SUBSTORMS REVEALED BY CHANG'E 3

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The Moon-based Extreme Ultraviolet Camera (EUVC) of the Chang'e 3 mission provides a global and instantaneous meridian view (side view) of the Earth's plasmasphere. The plasmasphere is one inner component of the whole magnetosphere, and the configuration of the plasmasphere is sensitive to magnetospheric activity (storms and substorms). However, the response of the plasmaspheric configuration to substorms is only partially understood, and the EUVC observations provide a good opportunity to investigate this issue. By reconstructing the global plasmaspheric configuration based on the EUVC images observed during 20-22 April 2014, we show that in the observing period, the plasmasphere had three bulges which were located at different geomagnetic longitudes. The inferred midnight transit times of the three bulges, using the rotation rate of the Earth, coincide with the expansion phase of three substorms, which implies a causal relationship between the substorms and the formation of the three bulges on the plasmasphere. Instead of leading to plasmaspheric erosion as geomagnetic storms do, substorms initiated on the nightside of the Earth cause local inflation of the plasmasphere in the midnight region.

D3.6-0003-18 SOLAR-WIND MAGNETOSPHERE COUPLING: A GLOBAL PERSPECTIVE OF SUBSTORM ONSET

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We present a case study of the 25 December 2015 substorm which occurred between 08:15 and 08:45 Universal Time. A fortuitous and unique alignment of several independent spacecraft missions near the Earth-Sun line together with ground based measurements, allows a comprehensive and global analysis of the substorm onset. During this interval, fast particle flows and field geometry consistent with magnetic reconnection were detected in the mid-tail region. An ejected plasmoid was observed by the lunar-orbiting ARTEMIS probes and a corresponding dipolarization signature was observed by the THEMIS spacecraft earthward of the reconnection site, which was determined to be approximately -33 RE. Ground signatures indicative of substorm activity were also observed by the THEMIS ground-based observatories during this interval. The MMS probes, which were in the dayside magnetosheath, detected a strong fluctuation in Bz, with a minimum near -35 nT, at 08:00 UT, consistent with the time delay required for propagation from the magnetosheath to the mid-tail. We analyze and discuss these fluctuations and propose that this strong southward component of Bz in the magnetosheath is possibly associated with the substorm trigger. We simulate the entire magnetosphere for this event using the SWMF/BATS-R-US model with a special, high-resolution grid. The simulations qualitatively agree with the observed substorm flows. The results of this work will be highly relevant to future solar wind observation missions, global-scale space weather models, and the ongoing effort to understand how solar wind energy is coupled to the space environment in near-Earth and at lunar distances.

D3.6-0004-18 MAGNETIC FIELD DISTURBANCES OBSERVED BY ARASE (ERG) ASSOCIATED WITH THE MAGNETIC DIPOLARIZATION

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It is known that magnetic field disturbances often appear in the night-side magnetosphere associated with the magnetic dipolarization. The disturbances carry significant energy which is considered to be released by the global configuration change of the magnetosphere, The energy normally directs to the earth in the inner magnetosphere at the several Re distance from the earth. It suggests that the disturbances are generated in the near-earth magnetotail region, presumably about 10 Re distance from the earth. However, it is not still very clear how the magnetic field disturbances are excited and affect the particle motion in the inner magnetosphere.

The Arase (ERG) satellite was launched on December 20, 2016, to investigate the plasma physics in the inner magnetosphere. The energy exchange between particles and fields is one of the major subjects of the Arase project. We are studying the magnetic dipolarization and associated disturbances observed by Arase. The characteristics (compressibility, polarization, propagation direction, and so on) are investigated for typical events to limit the generation mechanism of the disturbances. Very close investigation of the disturbances should lead to the future statistical study, occurrence ratio, distribution and relation with the particle signature.

D3.6-0005-18 GROUND MAGNETIC PERTURBATIONS ASSOCIATED WITH SUBSTORMS, PSEUDO-BREAKUPS, AURORAL STREAMERS AND OMEGA BANDS

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Strong magnetic perturbations on the ground are a prime cause of Geomagnetically-Induced Currents (GICs) that can have catastrophic effects on a number of engineered technological systems like power grids, communication lines, railways, and pipelines. In recent years we have learned that the strongest dB/dt signals may be confined to relatively localized regions. We also know that a number of localized auroral phenomena occur during highly disturbed intervals including substorms, pseudo-breakups, auroral streamers, torches and omega bands. Here we examine which of these types of disturbances are most related to the localized dB/dt signals associated with harmful GIC events. Preliminary results indicate that many of the auroral disturbances are capable of producing strong, localized dB/dt. However, during storms and long-lived substorms, the repetitive quasi-periodic evolution of PBIs into streamers, torches and omega bands has the potential to result in sustained long-lived production of strong localized dB/dt. A major implication of this finding is that we need to be able to model flow bursts in the tail in a reasonable way in order to capture much of the strong localized dB/dt activity during storms and substorms.

D3.6-0006-18 INVESTIGATION OF LOW-LATITUDE PI2 PULSATIONS USING CONJUGATE OBSERVATIONS FROM LONGITUDINALLY DISTRIBUTED GROUND NETWORK AND SWARM SATELLITES

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Pi2 pulsations are the ultra-low frequency oscillations of the Earth's magnetic field with frequency 6.6 - 25 mHz, and are commonly observed in association with substorm. At the onset of substorm expansion phase, Pi2s are often observed over a wide range of longitude sector, including daytime at low-latitudes. In the present study, low-latitude Pi2 oscillations are investigated using conjugate observations from Swarm satellites in the topside ionosphere and a dense network of ground stations (within 50° magnetic latitude) distributed over all local time

(LT) sectors. This distinct data set comprising satellite and ground observations from different LT sectors provide a unique opportunity to simultaneously observe day and night Pi2 oscillations from both space and ground. The magnetic field data represented in H, D, Z components (geomagnetic coordinates) at ground and the residual magnetic field at Swarm satellites (obtained by subtracting CHAOS5 geomagnetic field model) represented in compressional, toroidal and poloidal components (field-aligned coordinates) are used in this study. Present study reports the identification of coherent Pi2 oscillations in all the three magnetic field components at satellite and ground during nighttime, with analogous magnetic field components (compressional - H and toroidal - D) observed above and below the ionosphere found to have identical phase relations. The characteristic features of daytime Pi2s were found to be different from that of night time ones, indicating different source mechanism responsible for day and night Pi2s. Present study proposes that, the low-latitude Pi2 pulsations are the manifestation of the dynamical coupling of the ionosphere-magnetosphere system through substorm currents, with oscillating substorm current wedge FACs (field-aligned currents) in the night side and the ionospheric currents in the dayside as the possible source mechanism responsible for low-latitude Pi2 oscillations observed at night and day LTs respectively. The observations will be presented and discussed in view of this model.

D3.6-0007-18 KINETIC FEATURES OF EXPLOSIVE ENERGY CONVERSION AND DISSIPATION IN MAGNETOTAIL DIPOLARIZATIONS

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The Earth's magnetosphere is a unique natural laboratory of fully collisionless plasmas. Its magnetotail is particularly significant because it accumulates the energy of the solar wind/magnetosphere interaction and then releases it in the form of substorms, pseudobreakups, bursty bulk flows and dipolarization fronts. The Magnetospheric MultiScale (MMS) mission provides for the first time a critical opportunity to investigate energy conversion in these dipolarization processes in collisionless plasmas, because it enables measurements of 3D vectors of electric and magnetic fields, ion and electron bulk flow velocities, pressure tensor components, and, crucially, their spatial derivatives. However, dissipation in collisionless plasmas cannot be described by the standard resistive MHD parameter, the Joule heating rate, because that fluid parameter cannot distinguish between ion and electron dissipation. Here, using 3D PIC simulations of the magnetotail current sheet, we describe plasma dissipation accompanying tail dipolarization in terms of new kinetic measures different for ions and electrons: the pressure dilatation, as well as the double contraction of deviatoric pressure tensor and traceless strain-rate tensor. Simulations show signatures of dissipation both near new X-lines and near dipolarization fronts, which may form before the magnetic topology change. Dissipation patterns are different for ions and electrons and they reveal characteristic striation features on the scales of the lower hybrid drift instability. We also discuss manifestations of these theoretically predicted features in MMS observations.

D3.6-0008-18 PROPERTIES AND ORIGIN OF RAPID FLUX TRANSPORT EVENTS IN THE MAGNETOTAIL

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It has been noticed that the magnetotail flux transport response to a steady solar wind driving is impulsive. The pulses of magnetic flux transport at rates exceeding 2 mV/m are known as rapid flux transport (RFT) events. We statistically studied earthward RFT events observed by THEMIS probes in the near-Earth plasma sheet at radial distances 7 < R < 25 RE and tailward RFT events observed by ARTEMIS probes in the magnetotail at distances R 60 RE. We compared average plasma parameters such as density, ion and electron temperatures and pressures, their dependencies on magnetic and electric fields, and average energy spectra at both locations. We found that the ion average temperatures and spectral slopes within RFTs at R 60 RE are close to those in RFTs observed at 15 < R < 25 RE. Assuming the plasma sheet pressure balance, the average RFT ion temperature corresponds to the lobe field BL 20 nT. This leads us to suggest that the ion population within the RFTs originated in the mid-tail plasma sheet at R 30 RE. Whereas particle populations in earthwrard RFTs observed at R < 15 RE gain energy from being convected towards the dipole, particles in tailward RFTs propagated to the ARTEMIS location without undergoing energy changes.

D3.6-0009-18 PARTICLE BEHAVIOR NEAR THE DIPOLARIZATION FRONT

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Dipolarization front (DF) is known as the leading edge of earthward high-speed flow with sharp enhancement in the northward magnetic field. Since it is often related with the tail activities, the particle behavior and waves near the front are of great interest. It is shown that not only protons could be reflected at the front, as many researchers have predicted, oxygen ions also follow the similar processes, however, due to their heavy mass and large gyro radius, they also shown some interesting features different from that of protons. Electron are found having the so-called flat-top distributions near the front and also associated with some whistler mode wave activities. Several case studies will be shown and the implications of the particle behaviors will be discussed.

D3.6-0010-18 OSCILLATORY BRAKING OF FAST FLOWS IN THE NEAR-EARTH PLASMA SHEET AND INWARD SPREADING OF PI2 PULSATIONS

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Braking and rebound of earthward reconnection outflows in the Earth's magnetotail can be theoretically approximated as buoyancy oscillations of depleted flux tubes. Spacecraft observations reveal that being a local disturbance, these oscillations launch Pi2 pulsations in parallel and perpendicular B-field directions throughout the night-side inner magnetosphere and down to the ionosphere. In this talk we review examples of oscillatory braking in the near-Earth plasma sheet and discuss initiated by the braking wave modes with their damping mechanisms.

D3.6-0011-18 USING AN EVENT FITTED MAGNETIC FIELD MODEL WITH RAM-SCBE TO REPRODUCE MAGNETOSPHERIC CONFIGURATIONS DURING DISTURBED INTERVALS

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The relationships between the magnetotail configuration and plasma flows from the tail are essential in understanding the development and behavior of storms and substorms. We investigate these relationships by using a state-of-the-art ring current model with a self-consistent, force balanced, magnetic field and self-consistent electric field (RAM-SCBE). Previous work using this model relied on setting the magnetic boundary using empirical models or coupling with the Space Weather Modeling Framework (SWMF). While this approach has been successful in modeling a number of events it is limiting in both modes of operation. When running standalone, the outer boundary is constrained to empirical magnetic field models and when coupled to SWMF we lose the ability to guide the overall solution via data ingestion. Both of these methods prove to be insufficient at capturing the individual storm dynamics and configurations. To solve this issue we have implemented a novel approach for dealing with the boundary conditions and data ingestion problems that offers optimal solutions in both stand-alone and SWMF-coupled modes. This event fitted model uses data from a number of satellites to adjust the input parameters for the TS04 model so that the model field better matches observations for the given time. This new model is expected to reproduce inner magnetospheric configurations with unprecedented accuracy even during highly disturbed intervals. We present preliminary results obtained with RAM-SCBE driven by this event fitted model during a range of active time periods. As a method of model validation we compare our results with measurements from RBSP, focusing primarily on the transport and dispersion of flux through the system.

D3.6-0012-18 MULTI-SCALE INVESTIGATIONS OF EARTH'S MAGNETOTAIL DYNAMICS USING MMS AND CLUSTER OBSERVATIONS

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Both observations and simulations indicate that the Earth's magnetotail dynamics often invoke multi-scale physical processes. The Cluster mission has emphasized multi-scale processes occurring throughout the Earth's magnetosphere since 2000. The MMS mission, launched in 2015, has unraveled, in particular, the electron-scale processes with unprecedented time-resolution measurements of particles and fields. The Cluster and MMS, constituting two tetrahedral configurations, have provided us with an opportunity to capture a micro-to-macroscopic picture of the important magnetotail dynamics including magnetic reconnection, geomagnetic storm and substorm. Here we inspect MMS and Cluster observations of magnetic reconnection and the mid-tail and near-Earth magnetotail topology related to the storm/substorm event as well as using ARTEMIS/Wind/ACE as solar wind inputs. We focus on multi-scale processes embedded in the magnetotail dynamics preconditioning the sudden change of the global magnetic field topology. These dynamics are key to the magnetosphere-ionosphere coupling and Earth's global current system, which will ultimately improve our ability in space weather forecasts under a variety of external interplanetary conditions and structures.

D3.6-0013-18 ARASE OBSERVATIONS OF THE NEAR-EARTH MAGNETOSPHERE

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The Arase (ERG) satellite was launched in December, 2016, and started its regular observation from end of March, 2017. The Arase satellite is equipped with six particle instruments to cover wide energy ranges both for electrons and ions, as well as two field/ wave instruments. Orbit of the Arase satellite is highly elliptic, whose apogee and perigee altitudes are 32,000km and 450km, respectively. The inclication of the orbit is rather high (31deg). Therefore, the satellite can reach high latitude (approx. 30-40deg) plasma sheet (at most L 10) near the plasma sheet boundary when the satellite goes outside the outer radiation belt. Since the regular observation started, Arase encountered several magnetic storms driven by CIR and CMEs, and phenomena related to the transportation / energization and loss of particles, such as energy-dispersed and dispersionless sudden flux enhancements, are observed depending on the geomagnetic activities. In this presentaion, we will present key features of instuments onboard Arase and initial results of Arase observations at the near-Earth magnetosphere.

D3.6-0014-18 THIN CURRENT SHEETS IN THE EARTH'S AND PLANETARY MAGNETOSPHERES

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Current sheets (CSs) are the important objects in space plasma as they separate the regions with different magnetic characteristics, accumulating magnetic energy and releasing it via magnetic reconnection. Numerous observations of the CSs in the Earth's magnetotail provide much information on their spatial structure and evolution. It was revealed that very often the structure of the CS signicantly differs from the simple isotropic Harris CS model. Multipoint spacecraft observations demonstrated that the CSs often exhibit complicated multilayered structure in which a thin and intense current layer is embedded in a thicker layer(s) having a smaller current density. To describe these features the quasi-adiabatic approach is more effective than the classical MHD approximation. With the development of the quasi-adiabatic theory in the last two decades, the existence of a number of new thin current sheet features, such as embedding, asymmetry of the current density spatial profiles, metastability, has been predicted and subsequently confirmed "in situ" observations. The role of individual particle populations in the formation of the CS fine structure has also been investigated. Somewhat counterintuitive but CSs observed in different objects of space plasma (e.g. in the terrestrial and Martian magnetospheres, in the solar wind) exhibit very similar characteristic features in their spatial structures, despite the drastic difference in the formation mechanisms and local plasma characteristics. This phenomenon can be explained by the universal mechansm of their formarion in different natural conditions. Once CS has been formed, then it should be self-consistently supported by the internal coupling of the total current carried by particles in the CS and its magnetic conguration, and as soon as the system achieved the quasi-equilibrium state, it "forgets" the mechanisms of its initial formation, and its emerging structureis controlled only by the general principles of plasma kinetics described by Vlasov-Maxwell equations.

D3.6-0015-18 A DIRECT DIAGNOSIS OF THE PLASMA WAVES RESPONSIBLE FOR THE EXPLOSIVE ENERGY RELEASE OF SUBSTORM ONSET

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During periods where the interplanetary magnetic field has a southward component, reconnection on the dayside magnetopause leads to a build up of magnetic flux in the magnetotail lobes, and the magnetotail acts as a reservoir of plasma and energy. During a substorm this energy is explosively released, leading to the deposition of large quantities of energy into the polar ionospheres and leading to the bright and dynamic substorm aurora. Auroral substorm onset is observed at the equatorward edge of the auroral oval, suggesting that at least some of the processes which play an important role in energy release occur on closed magnetic field lines. Recent work has highlighted that auroral beads embedded within the substorm onset arc grow exponentially through onset, which indicates the action of a plasma instability in this near-Earth region.

We use state of the art auroral measurements from the MOOSE (Multi-spectral Observatory Of Sensitive EM-CCDs) imagers to construct an observational dispersion relation of the plasma sheet instability responsible for the beading signature in the aurora. Informed by in-situ measurements of the plasma parameters in the magnetotail and magnetic field modelling, we extend theory to a high beta regime in the near-Earth plasma sheet. The solutions of the warm plasma dispersion relation in this regime show that

a shear Alfvén wave instability with small perpendicular scales is consistent with the dispersion relation obtained from auroral observations.

D3.6-0016-18 MAGNETOTAIL DYNAMICS IN AND NEAR THE ELECTRON DIFFUSION REGION

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We have been using a combination of a global magnetohydrodynamic (MHD) simulation of the interaction between the solar wind, magnetosphere and ionosphere system and a large scale kinetic simulation (iPic3D) to investigate magnetic reconnection in the magnetotail during substorms. First we run a MHD simulation using observed solar wind input and they run the PIC code on the resulting magnetotail configuration. Magnetotail reconnection is very dynamic and structured. We find that multiple simultaneous neutral lines form and the location of reconnection can move across the tail rapidly. In this study we have examined the structure and dynamics in and near the electron diffusion region (EDR). The reconnection is characterized by large (100s km/s) earthward and tailward electron flows and comparable shear flows in the azimuthal (YGSM) direction. The shear flows form in the EDR. The region of shear flow contains structures in which the work done by the electromagnetic fields on the plasma (J•E′) where J is the current density and E ′is the electric field in the electron frame alternates between positive and negative. These changes in J•E′ mainly come from changes in E ′. This suggests instabilities other than just reconnection may be occurring. A number of studies have investigated instabilities in this region under idealized magnetotail configurations. We are investigating this under more realistic conditions. In our simulation this signature is consistent with a long wavelength variant on the lower hybrid drift instability. Since it is associated with very large shear we also are investigating shear instabilities such as the Kelvin-Helmholtz instability. In the talk we will evaluate the possible instabilities.

D3.6-0017-18 INTERNAL PLASMA SOURCE REQUIREMENT FOR GEOSPACE STORMS

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In our legacy nomenclature, a substorm, consisting of a cycle of stretch and relaxation of the magnetotail, is a necessary but insufficient element of a full-fledged geomagnetic storm. This dates to Davis and Parsatharathy's 1960s finding that the Dst index is well-approximated by integrating the AE index, with a superposed decay rate. Since the disturbance currents clearly exist in space around the Earth rather than inside it where the geomagnetic field originates, the term "geospace" may replace "geomagnetic". But is a geospace storm guaranteed by a sufficiently rapid series of "substorms", or as Feynman [1980 JGR], Kamide [1992 JGR], and Gonzalez [1994 JGR] suggested, must the magnetotail enter a different mode of behavior to develop a full fledged storm time ring current? In this talk, we return to and further explore the observations [Daglis et al., 1999 RG] and a hypothesis [Moore et al., 2001 SSR] that the key element of a geospace storm is a substantial internal source of plasma in a magnetosphere. Models suggest that a storm ring current also forms in response to strong steady magnetospheric convection without any need for substorms [Stephens et al. 2013 JGR]. Thus, a series of substorms does not appear uniquely causal of storms, while the transfer of enhanced mass density from the ionosphere to the magnetosphere may be essential. In the case of Mercury, with a much smaller internal source of plasma than Earth or other planets with magnetospheric ring currents, a magnetosphere has been found to lack a storm time response [Rong et al., 2018 JGR]. In the case of Earth, observations from Geotail [Nosé et al. 2005 JGR], and Cluster [Kistler et al., 2010 JGR] have noted an association of ionospheric source ions with storm time activity. The mechanisms of this association will be considered, with prospects for further exploration by the MMS mission.

D3.6-0018-18 TRANSPORT OF KEV ELECTRONS IN THE NIGHT-SIDE EARTH'S MAGNETOSPHERE DURING SUBSTORMS

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Low energy (< 200 keV) electrons from the magnetotail plasma sheet comprise the majority of the source of inner magnetosphere relativistic electrons, and their distribution is critically important for radiation belt dynamics. The electron flux at keV energies varies significantly with geomagnetic activity driven by the solar wind, especially during substorms. Meanwhile, the exact physical processes of electron transport in the magnetotail and their variations at different distances are still far from being completely understood. We present the results of an investigation of the chain of physical processes starting with the analysis of solar wind driving of the source population in the plasma sheet; and then, transport and acceleration of low energy electrons from the plasma sheet to inner regions during substorms. We analyze the THEMIS ESA and SST data in the plasma sheet in the vicinity of the equatorial plane on the night-side at distances from 6 to 10 RE. All time intervals selected for the analysis are linked with the corresponding solar wind and IMF measurements obtained from ACE and DSCOVER spacecraft, and a statistical pattern of the variations of keV electron fluxes during periodic and isolated substorms is developed.

D3.6-0019-18 NEW INSIGHTS ON ENERGETIC PARTICLE INJECTIONS AND SUBSTORM ACTIVITY FROM NASA'S MAGNETOSPHERIC MULTISCALE (MMS) AND VAN ALLEN PROBES MISSIONS

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Related to substorm activity, energetic particle injections from Earth's magnetotail into the inner magnetosphere ($L < 10$) occur frequently (several per day under normal magnetospheric conditions) and are considered important to source processes of ring current ions and radiation belt electrons. Here, we present a series of new results from multipoint studies using NASA's Magnetospheric Multiscale (MMS) and Van Allen Probes missions plus supplementary data from THEMIS, Geotail, GOES, and LANL-GEO. We focus on new insights gleaned from the recently available microscopic (MMS) and macroscopic (all missions) multipoint capabilities. In particular, we highlight: 1) new results concerning the size (in MLT) and extent (in L-shell and pitch angle space) of the injection region for energetic particles using the unprecedented energy, angular, and temporal resolutions afforded by the MagEIS and FEEPS instruments on Van Allen Probes and MMS, respectively; 2) the relationship between small-scale, localized injections associated with bursty bulk flows and dipolarizing flux bundles and larger-scale more global injections associated with the development of the substorm current wedge; 3) and how energetic particle injections play a critical role in enhancements of Earth's outer radiation belt.

D3.6-0020-18 COMPARING AND CONTRASTING DISPERSIONLESS INJECTIONS AT GEOSYNCHRONOUS ORBIT DURING A SUBSTORM EVENT

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Particle injections are responsible for the transport of energy in the magnetosphere. In this study we consider generation mechanisms, acceleration processes and propagation of "dispersionless" injections, namely, those with simultaneous increase of the particle flux over a wide energy range. We take advantage of multisatellite constellation which simultaneously monitor Earth's magnetospheric dynamics from the tail toward the radiation belts and ground-based observations during a substorm event. We show that dispersionless injections are associated with instabilities in the plasma sheet during the growth phase of the substorm, with a dipolarization front at the onset and with magnetic flux pileup during the expansion phase. The injections show different spatial spread and propagation characteristics. Injection associated with the substorm onset does penetrate into the radiation belts while others not. At geosynchronous orbit (6.6 RE), the electron distributions show a bump on tail centered on about 120 keV during the injections associated with dipolarization. However, electron distributions in the magnetotail (13 RE) do not show such a signature during the injections. We surmise that a resonant acceleration acts in between these locations. We link the acceleration mechanism to the electron drift resonance with ultralow frequency waves localized in the inner magnetosphere.

D3.6-0021-18 MMS OBSERVATIONS OF MAGNETIC RECONNECTION ASSOCIATED WITH KELVIN-HELMHOLTZ WAVES DURING NORTHWARD IMF CONDITIONS

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The four Magnetospheric Multiscale (MMS) spacecraft recorded the first direct evidence of reconnection exhausts associated with Kelvin-Helmholtz (KH) waves at the duskside magnetopause on 8 September 2015, which allows for local mass and energy transport across the flank magnetopause. This period provides the first direct evidence of equatorial plane ion exhausts at 22 of 42 compressed KH-related current sheets as well as one of the first electron-diffusion region encounters in a significant guide magnetic field. MMS observed an equal probability of inward and outward directed ion exhausts along the magnetopause. MMS also recorded asymmetric Hall magnetic and electric fields consistent with a strong guide-field and a weak density asymmetry. Finally, we explore whether the 20 current sheets without a clear ion exhaust instead support a presence of electron exhausts as would be expected in a region closer to a reconnection X-line.

D3.6-0022-18 THE STATISTICS OF TRIGGERING EFFECTS FOR MAGNETOSPHERIC SUBSTORMS

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For understanding the magnetospheric substorm onset it is necessary to find out whether substorm onset is always externally triggered or sometimes is a result of internal processes, which can be observed for example during northward oriented interplanetary magnetic field i.e. in the time when there is no significant flux transfer. Large directional changes in the solar wind flow, especially observed during the northward oriented interplanetary magnetic field, can result in large-scale windsock motion of magnetotail. It can lead to current sheet thinning and force magnetic reconnection in magnetospheric tail, which consequently can lead to substorm onset. We analysed concurrent observations in the solar wind OMNI and Geotail data of distant tail's response. We present here a statistical study of the temporal resposes of magnetotail to the vertical directional changes in the solar wind flow.

D3.6-0023-18 PLASMA PRESSURE DISTRIBUTION IN THE GEOMAGNETOSPHERE

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Direct observations of plasma distribution in the magnetosphere are faced with large difficulties, because pressure must be known everywhere in the plasma sheet at high resolution, which in situ satellites have been unable to provide. The equations of the two-fluid or one-fluid magnetohydrodynamics with isotropic or anisotropic pressure are as a rule applied to describe collisionless magnetospheric plasma. In this case any dissipative processes in the system are considered inessential. This statement is usually valid for ohmic loss and loss by radiation. However, particles (and energy) also escape from the magnetospheric plasma into the atmosphere through open ends of flux tubes. This type of loss can be very substantial and should be taken into account. The combined action of plasma convection and pitch-angle diffusion of electrons and protons lead to the formation of plasma pressure distribution in the magnetosphere. Specifying the initial pressure at the boundary, we can find the resultant pressure at any point on the flux line. In such a way, the field of plasma pressures in the entire magnetosphere is calculated. We are unique research team in our country, which has developed the original method of plasma pressure distribution calculation (3D). The others only copy our ideas, and unfortunately without references on my papers. The projection (mapping) of the plasma pressure distribution onto the ionosphere corresponds to the form and position of the auroral oval. This projection, like the real oval, executes a motion with a change of the convection electric field, and expands with an enhancement of the field. Steady bulk currents are connected to distribution of plasma pressure. The divergence of these bulk currents brings about a spatial distribution of field-aligned currents, i.e. magnetospheric sources of ionospheric current systems. The problem of compatibility of field-aligned currents generated in the magnetosphere, and of field-aligned currents, which are produced as a result of a spatial inhomogeneity of conductivity (and to a lesser extent, of the electric field), that is, as if they were "generated" in the ionosphere, is part of the problem of ionosphere-magnetosphere coupling. The problem of ionosphere-magnetosphere coupling primarily implies that it is necessary to solve the question as to how the magnetospheric producer of current and power "adjusts itself" to the ionospheric consumer.

D3.6-0024-18 DEPENDENCE ON THE ION MASS AND CHARGE OF A FERMI-LIKE ACCELERATION MECHANISM IN THE EARTH'S MAGNETOTAIL

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Abstract Energetic particles with energies from tens of keV to a few hundred keV are frequently observed in the Earth's magnetotail, but the mechanism that can generate such heated particles is not fully understood. Here we study, by means of a test particle numerical simulation, the acceleration of different ion species (H+, He+, He++, and On+ with n = 1 -6) in the presence of transient electromagnetic perturbations. The equilibrium magnetic and electric field configuration is obtained from the generalized Harris solutions, and the 3-D time-dependent electromagnetic perturbations are superimposed. We injected 104 particles for each run, varying parameters like the ion mass, the ion charge, the initial energy, and the perturbation size. The efficiency of the acceleration process has a parametric dependence on the initial energy and on the perturbation size, while the dependence on the ion charge and mass is not affected by the particular initial condition. All the considered ions develop power law tails at high energies, except for O+ ions. This is strongly correlated to the time that the particle spends in the current sheet, where they frequently interact with the perturbations. Ion acceleration is found to be proportional to the charge state, while it grows in a weaker way with the ion mass. We find that O5+/6+ can reach energies higher than 500 keV. These results may explain the strong oxygen acceleration observed in the magnetotail.

D3.6-0025-18 VORTEX, ULF WAVE AND AURORA AFTER SOLAR WIND DYNAMIC PRESSURE CHANGE: THEMIS OBSERVATIONS AND SIMULATIONS FOR A GLOBAL VIEW

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We will summarize our recent study and show some new results on the Magnetosphere and Ionosphere Response to Dynamic Pressure Change/disturbances in the Solar Wind and foreshock regions. We study the step function type solar wind dynamic pressure change (increase/decrease) interaction with the magnetosphere using THEMIS satellites at both dayside and nightside in different geocentric distances. Vortices generated by the dynamic pressure change passing along the magnetopause are found and compared with model predictions. ULF waves and vortices are excited in the dayside and nightside plasma sheet when dynamic pressure change hit the magnetotail. The related ionospheric responses, such as aurora and TCVs, are also investigated. We compare Global MHD simulations with the observations. We will also show some new results that dayside magnetospheric FLRs might be caused by foreshock structures.

D3.6-0026-18 INFLUENCE OF THE IMF CONE ANGLE ON INVARIANT LATITUDES OF POLAR REGION FOOTPRINTS OF FACS IN THE MAGNETOTAIL: CLUSTER OBSERVATION

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The influence of the interplanetary magnetic field (IMF) cone angle (the angle between the IMF direction and the Sun-Earth line) on the invariant latitudes (ILATs) of the footprints of the field-aligned currents (FACs) in the magnetotail has been investigated. We performed a statistical study of 542 FAC cases observed by the four Cluster spacecraft in the northern hemisphere. The results show that there are almost no FACs when the IMF cone angle is less than 10º, and there are indications of the FACs in the PSBLs being weak under the radial IMF conditions. The footprints of the large FAC (>10 nA/m2) cases are within ILATs <71º and mainly within IMF cone angles >60º, which implies that the footprints of the large FACs mainly expand equatorward with large IMF cone angle. The equatorward boundary of the FAC footprints in the polar region decreases with increasing IMF cone angle (and has a better correlation for northward IMF), which shows that the IMF cone angle plays an important controlling role in FAC distributions in the magnetosphere-ionosphere coupling system. There is almost no correlation between the poleward boundary and the IMF cone angle for both northward and southward IMF. This is because the poleward boundary movement is limited by an enhanced lobe magnetic flux. This is the first time a correlation between FAC foot prints in the polar region and IMF cone angles has been determined.

D3.6-0027-18 INTENSE CURRENT STRUCTURES OBSERVED AT ELECTRON SCALES DURING DIPOLARIZATION AND SUBSTORM CURRENT WEDGE FORMATION

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We study multiscale magnetic structures in 14 substorm-related prolonged dipolarization events in the near-Earth magnetotail by using data from the Cluster Inner Magnetosphere Campaign. The dipolarizations were associated with the arrival and braking of multiple Bursty Bulk Flows and Dipolarization Fronts (DFs). The very small separation (electron inertia length) between Cluster-3 and Cluster-4 permits, for the first time, the observation of strong magnetic gradients at electron scales. These structures were transiently (2s) observed during prolonged dipolarization growth at the leading and trailing edges of DFs. The values of magnetic gradients observed at electron scales are several dozen times larger than the corresponding values of magnetic gradients simultaneously detected at ion scales. These nonlinear features in magnetic field gradients denote the formation of intense and localized (a few electron inertia lengths) current structures during the dipolarization and substorm current wedge formation. These observations highlight the importance of electron-scale processes in the formation of a 3D substorm current system.

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D3.6-0028-18 EFFECT OF GEOMAGNETIC SUPER SUBSTORM AT LOW LATITUDE STATIONS

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Phenomena like solar energetic particles, geomagnetically induced currents and ionospheric disturbances that can cause frequent radio and radar scintillations, failure of power grids, disruption of navigation by magnetic compass and auroral displays at much lower latitudes than normal in the earth are associated with geomagnetic storms. Substorm occurs more frequently during a geomagnetic storm and one substorm may follow the previous before its completion. The geomagnetic Northward component (X) Field of the four stations in the equatorial and low latitude region was taken to study their variations during super substorm events of April 05 2010, August 24 2005 and November 24 2001. The location of stations extends from Asia to South America across Africa. We studied the storm time (Dst) variations in the Northward component (X) of the geomagnetic field at low latitude stations during super substorm events and to substantiate the results, wavelet transform and cross-correlation techniques were used. We checked the correlation of Northward component (X) with Dst, SYM-H, Bz, X, Y and Ey individually to show that geomagnetic effect during the super substorm events at low latitude is significant. The power regions with the maximum fluctuation were analyzed using the continuous wavelet transform.

D3.6-0029-18 PRINCIPAL COMPONENTS OF RESIDUAL GEOMAGNETIC FIELD VARIABILITY IN THE NORTHERN HEMISPHERE

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The residual magnetic field (Hand Z-component) from 15 geomagnetic observatories have been subjected to principal component analysis (PCA). The technique has been used in other to identify dominant sources of residual field across different latitudes and the influence of solar activity on these residual fields on annual and semi-annual scales.The first three principal components: PC1, PC2 and PC3, accounted for 93-97% of the variances in the monthly mean and the PC1for H-component showed semiannual variation associated with the ring current with two peaks in April and October/November particularly in the midand lowlatitudes. The Z-components semiannual variation equally exhibited the same trend especially in the mid and low latitudes with negative peaks in April/May and September/October. The PC1 for the yearly mean residual of the H-component revealed solar activity dependence in the mid-latitudes and low-latitudes. The physical mechanisms involved in the residuals of the Z component are yet to be fully understood.These finding have important implications for our present understanding of the North-South migration of the ring current and the role of solar activity in modulating the geomagnetic field strength.

D3.6-0030-18 MESOSCALE FLOW CHANNELS AND FIELD ALIGNED CURRENT STRUCTURES IN A GLOBAL MAGNETOHYDRODYNAMIC SIMULATION OF A SUBSTORM

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The dynamics of flow channels and dipolarizations complicate the field aligned current pattern during substorms. We have used a global magnetohydrodynamic simulation to investigate how meso-scale magnetotail structures determine the substorm current configuration. We have extensively analyzed a substorm event for which we have observations from THEMIS spacecraft. The available data include an extensive network of all sky cameras and ground magnetometers that establish the times of various auroral and magnetic events. The simulation of this event shows a sequence of fast flows and dipolarization events similar to what is seen in the data, though not at precisely the same times or locations. Both earthward and tailward flows were found in both the observations and the simulations. Fast earthward flows have convoluted paths that are diverted or reflected as they reach the inner magnetosphere. We will use our simulation results combined with the observations to investigate the global convection system and current sheet structure during this event. Our study includes determining the location, timing and strength of several current wedges and expansion onsets during an eight-hour interval.

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Research in Astrophysics from Space (E)

COSPAR 2018
42ND ASSEMBLY | 60TH ANNIVERSARY

RESEARCH IN ASTROPHYSICS FROM SPACE (E)

DARK ENERGY AT 20 (E1.1)

E1.1-0001-18 DARK ENERGY AND MODIFIED GRAVITY

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The recent direct detections of gravitational waves represent a direct manifestation of the propagating degrees of freedom of gravity. While the recent detections have been successfully used to examine the basic properties of these gravitational degrees of freedom and set an upper bound on its mass and constrain its speed of propagation with unprecedented accuracy, I will explore the possibility for this mass to be sufficiently small to pass current tests of gravity and yet sufficiently large to have deep potential implications on our observable Universe and particularly for dark energy and the cosmological constant problem.

E1.1-0002-18 COSMOLOGY RESULTS FROM THE DARK ENERGY SURVEY

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This talk presents cosmology constraints from a combined analysis of galaxy clustering and weak gravitational lensing, using 1321 deg2 of griz imaging data from the first year of the Dark Energy Survey (DES Y1). The analysis combines (i) the cosmic shear correlation function of 26 million source galaxies in four redshift bins, (ii) the galaxy angular autocorrelation function of 650,000 luminous red galaxies in five redshift bins, and (iii) the galaxy-shear cross-correlation of luminous red galaxy positions and source galaxy shears. These three measurements yield consistent cosmological results, and provide constraints on the amplitude of density fluctuations (S8 = 0.794+0.029-0.027) and dark energy equation of state (w = -0.80+0.20-0.22) that are competitive with those from Planck cosmic microwave background measurements. I will describe the validation of measurements and modeling from catalogs to cosmology, and highlight cosmology constraints from the combination of DES Y1 with external data sets. Based on DES Collaboration 2017 (1708.01530) and supporting papers.

E1.1-0003-18 DARK ENERGY RESULTS FROM PLANCK

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The ESA Planck satellite provides the currently best measurements of the anisotropies of the cosmic microwave background, and of its gravitational lensing, on large and intermediate scales. This data set provides important constraints on cosmology at early and late times. In my talk I will specifically focus on what we have learned from Planck, alone and when combined with observations of the late-time universe like weak lensing and redshift space distortions, about dark energy and modified gravity models

E1.1-0004-18 DARK ENERGY RESULTS FROM KIDS

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Cosmic shear tomography yields cosmological insights complementary to other probes like the cosmic microwave background (CMB). Ongoing wide-field imaging surveys exploit this to come up with competitive constraints on important cosmological parameters like the matter density, the amplitude of the matter power spectrum, and the dark energy equation-of-state. In this talk I will concentrate on results from the ongoing European KiDS (Kilo Degree Survey) project and its infrared complement VIKING (VISTA Kilo Degree Infrared Galaxy Survey). This unique combination of an optical and an infrared imaging survey over hundreds of square degrees on the sky allows us to reach an unprecedented accuracy in the redshift calibration of the sources used in the weak lensing measurement. In combination with the well-calibrated KiDS shape measurements this will reveal whether the recently reported tension between Planck CMB measurements and KiDS optical-only cosmic shear results (Hildebrandt et al. 2017) still holds in this improved analysis. I will further discuss constraints on possible extensions to the standard model of cosmology, including massive neutrinos, non-zero curvature, and evolving dark energy. Combined with Planck, the first KiDS results showed some mild preference for an evolving dark energy component, and in this extended model the tension between Planck and KiDS was alleviated. With the greater systematic accuracy of the KiDS+VIKING data set we will revisit this model and put even tighter constraints on the dark energy equation-of-state.

E1.1-0005-18 FIRST-YEAR COSMOLOGICAL RESULTS FROM THE SUBARU HYPER SUPRIMECAM SURVEY

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Hyper Suprime-Cam (HSC) is the newly developed wide-field prime focus camera on the Subaru Telescope, which provides a 1.77 sq. degree field-of-view with superb image quality (0.6" seeing FWHM) and large light-gathering power enabled by the 8.2-m primary mirror. HSC started the wide, deep optical/near infrared imaging survey in 2014 that covers 1,400 sq. degree of the sky down to the i-band limiting magnitude of i 26. The primary goal of the HSC survey is constraining the nature of cosmic acceleration through the measurement of structure growth using weak gravitational lensing. In this talk, we will present our cosmological results based on our first-year galaxy shape catalog which consists of six distinct fields that cover 170 sq. degrees in total with full color and full depth. We first describe details of the shape catalog production including systematic tests and simulation-based calibrations. We then present our cosmological results from our cosmic shear measurement and joint measurements of galaxy-galaxy lensing and auto-correlation of galaxies. For the latter, we use a spectroscopic sample of galaxies taken from the SDSS to cross-correlate the distribution with shapes of background HSC galaxies, which enables us to resolve uncertainties in galaxy bias and nonlinear clustering.

E1.1-0006-18 RESULTS FROM BOSS

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The SDSS-III's Baryon Oscillation Spectroscopic Survey (BOSS) mapped the spatial distribution of luminous red galaxies (LRGs) and quasars to detect the characteristic scale imprinted by baryon acoustic oscillations in the early universe. Sound waves that propagate in the early universe, like spreading ripples in a pond, imprint a characteristic scale on cosmic microwave background fluctuations. These fluctuations have evolved into today's walls and voids of galaxies, meaning this baryon acoustic oscillation (BAO) scale (about 150 Mpc) is visible among galaxies today. BOSS presents a one per cent measurement of the cos- mic distance scale from the detections of the baryon acoustic oscillations in the clustering of galaxies. Our results come from the Data Release 11 (DR11) sample, containing nearly one million galaxies and covering approximately 8500 square degrees and the redshift range 0.2<z<0.7. Assuming a concordance CDM cosmological model, the sample covers a volume of 13 (Gpc/h) 3 and is the largest region of the Universe ever surveyed at this density. We measure the correlation of field reconstruction of the baryon acoustic oscillation (BAO) feature. Our measurements of the distances cal.

E1.1-0007-18 DIRECT DETECTION OF DARK ENERGY IN THE SOLAR SYSTEM

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Dark energy remains one of the most profound mysteries of our time and a major focus of observational investigation and theoretical modeling. However, to date all the evidence for cosmic acceleration is indirect, relying on information from the expansion history of the universe as a whole and measurements of the cosmic structure on scales that are a significant fraction of the observable universe. In the meantime, the theoretical fine-tuning problems associated with the baseline cosmological constant model have motivated significant work on extensions to General Relativity and alternative models of gravity. The opening of the theory space in combination with the limits of the current observational program suggest that we should take a new look at local, experimental constraints on the nature of gravity. In this talk I will review some current prospects for constraints on the nature of gravity and dark energy models from laboratory and solar system tests.

E1.1-0008-18 TESTING COSMOLOGICAL GRAVITY ON ALL SCALES

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One popular explanation for the acceleration of the cosmic expansion—dark energy—is that general relativity is modified on large scales. Modern cosmologically relevant theories of gravity predict novel dynamics for astrophysical objects including stars, galaxies, and clusters. In this talk, I will review how different astrophysical objects can be used to test different theories of cosmological gravity and discuss the possible constraints that could be placed.

E1.1-0009-18 THE MICROSCOPE MISSION: FIRST CONSTRAINTS ON THEORIES OF MODIFIED GRAVITY.

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MICROSCOPE is a French space mission developed by ONERA and CNES, launched on the 25th of April 2016, which aims to improve the test of the Weak Equivalence Principle (WEP)

by two orders of magnitude and reach a level of 10–15 on the Eötvos parameter. The experiment is based on testing the WEP's experimental manifestation known as the Universality of Free

Fall, with an ultrasensitive accelerometer composed of two test masses of different composition. Although not a cosmology experiment, MICROSCOPE can provide constraints on dark energy complementary and directly related, to those obtained by large scale surveys.

Indeed, the results of the mission should have implications on alternatives theories of gravity, designed to solve the dark energy problem and/or unify gravity with quantum physics. Scalartensor theories represent a class of such theories that could be constrained by MICROSCOPE: they introduce a new scalar field to Einstein's gravity, which by coupling to matter gives rise to a 5th force that can violate WEP. A simple example is the string-theory-inspired dilaton, a light scalar field which couples with a different strength to each component of matter. Another model that MICROSCOPE should also be able to constrain is the Chameleon model. This scalar field was proposed as a dark energy candidate that could satisfy local gravity constraints through a screening mechanism: due to such a mechanism, the dynamics of the field is

highly coupled to the local density of matter, therefore effectively hiding the field from on-ground experiments. Being in a less dense environment, MICROSCOPE was expected to be able to provide a smoking gun for the existence of a chameleon.

A first result with a sample of the data collected by MICROSCOPE has been published in December 2017, and has shown that the WEP is still valid at a level of 2 10−14, improving the previous constraint put on ground by one order of magnitude. In this talk, after introducing the

MICROSCOPE mission, I will present its first constraints on such models as the dilaton (the limits on its coupling parameters and its range are already improved by an order of magnitude) and the chameleon scalar fields.

E1.1-0010-18 COSMOLOGY WITH COSMIC VOIDS

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Modern surveys allow us to access to high quality measurements on large areas in the sky and at high redshift - thus sampling the galaxy distribution in detail also in the emptier regions, voids. Void cosmology is hence becoming an increasingly active sector of galaxy clustering analysis: by measuring void properties, such as the abundance or the density profiles, it is possible to constrain cosmological parameters.

The void perspective is particularly promising to better understand dark energy: voids being by definition devoid of matter, their dominant component is dark energy and the effects of this component are expected to be more evident on voids. However another possibility to justify current observations is to consider a modification of the laws of General Relativity. Cosmic voids constitute a sweet spot where the effects of modifications of General Relativity would be more prominent.

In this talk I briefly illustrate the use of cosmic voids as a tool for cosmology, I present recent developments on the field and discuss on the constraining power of voids that will be observed by upcoming surveys such as the NASA's Wide Field Infrared Survey Telescope (WFIRST) and the ESA's Euclid space mission.

E1.1-0011-18 DARK ENERGY WITH THE SIMONS OBSERVATORY

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The Simons Observatory (SO) is a next generation cosmic microwave background (CMB) experiment optimized to make precise measurements over frequencies spanning 30-300 GHz. The observatory will be built with a combination of 6 meter class and 0.4 meter class telescopes located in the Atacama Desert and will make unprecedented measurements of secondary anisotropies in the CMB. I will present forecasts that illustrate SO's potential to constrain properties of Dark Energy using CMB lensing cross-correlations, galaxy cluster abundances selected by their thermal Sunyaev-Zel'dovich (SZ) signal, and thermal and kinetic SZ statistics.

E1.1-0012-18 FINDING THE UNEXPECTED: THE DISCOVERY OF THE ACCELERATING EXPANSION

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In the 1990s, several groups studying the expansion of the universe found an astonishing result. Rather than the expansion slowing down due to gravity, the rate of expansion was accelerating, implying the need for new physics. This unexpected result points to a universe that is dominated by a mysterious phenomenon called dark energy. I'll describe the personal journey that led to this discovery and how we are looking to create the ultimate dark energy experiments in the coming decade.

E1.1-0013-18 THE EUCLID MISSION

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In the early 2020s the Euclid space telescope will be launched. From the second Lagrangian point in far Earth orbit, it will survey the full extragalactic sky. The mission's goal will be nothing less than understanding the dark universe. This talk will overview Euclid's main scientific goals. It will review the tools we are building that will enable us to probe the expansion history of our universe as well as the nature of gravity. As a Stage IV dark energy mission, Euclid will no longer be limited by statistics as much as it will be challenged by systematics. This talk will discuss some of those challenges and present some recent updates on how these challenges are being tackled. Finally, it will present the most up-to-date forecasts for some of the main cosmological parameters that we will use to constrain our cosmological model.

E1.1-0014-18 DARK ENERGY IN THE ERA OF LSST

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The Large Synoptic Survey Telescope (LSST) will provide us with an unprecedented view of the Universe. During the 10 years of operation, it will map out half of the visible sky every three days, reaching a median redshift of 1.2. Exploiting the information one can extract from this data set may give us the key to understanding the nature of Dark Energy and open up windows for new physics. In this talk I will introduce the various venues LSST will be able to constrain Dark Energy and some of the effort in the LSST Dark Energy Science Collaboration (DESC) where we prepare ourselves for the start of the survey in 2021.

E1.1-0015-18 DARK ENERGY WITH DESI

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The study of the large scale structure of the Universe can answer some of the most important and challenging questions in physics: the nature of the dark energy causing the acceleration of the Universe; the inflationary origin of the density fluctuations; the physical properties of the dark matter component; and the number of neutrino species and their mass.

In particular, one of the most powerful and robust cosmological probes is the measurement of Baryon Acoustic Oscillations (BAO) in the distribution of matter. In the last few years, the Baryon Oscillation Spectroscopic Survey (BOSS) has provided a 1% measurement of the scale of these oscillations at intermediate redshifts (z=0.6), using a catalog of over a million galaxy redshifts. BOSS also measured the oscillations in the distribution of neutral hydrogen at a much higher redshifts (z=2.4), using a phenomenon known as the Lyman alpha forest.

Starting in 2019, the Dark Energy Spectroscopic Instrument (DESI) will increase these datasets by an order of magnitude, and it will provide an exquisite measurement of the expansion over cosmic time. These BAO measurements will be very complementary to other cosmological probes, like weak lensing, supernovae distances or the fluctuations in the cosmic microwave background.

E1.1-0016-18 WFIRST AS A PROBE OF DARK ENERGY

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WFIRST will be a highly capable telescope for studying dark energy. The WFIRST mission has been optimized to minimize systematic errors in dark energy measurements and to use multiple techniques to probe the growth of structure and the geometry of the universe. WFIRST will be able to trace the geometry of the universe through both supernova observations and baryon acoustic oscillation measurements. WFIRST will be able to measure the growth rate of the structure through lensing observations and measurements of the evolution of clustering.

E1.1-0017-18 DARK ENERGY WITH HIRAX 21CM INTENSITY MAPPING

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Observations of redshifted 21-cm emission of neutral hydrogen over a wide range of radio frequencies allow us to access redshifts that encompass a vast comoving volume, including the era of dark energy. In this talk I will present the HIRAX project, which is a proposed 21cm intensity mapping experiment operating at 400-800 MHz that will measure the evolution of dark energy over the redshift range z=0.8-2.5 by using the characteristic baryonic acoustic oscillation scale as a standard ruler. The HIRAX radio telescope array will be sited in the radio-quiet Karoo astronomy reserve in South Africa and will ultimately comprise 1024 dishes, each six metres in diameter, placed in a compact configuration. The construction of the first eight-element HIRAX prototype is currently near completion. I will discuss the design and project status of HIRAX and its scientific prospects. This includes dark energy forecasts as well as prospects for interesting cosmological constraints from cross-correlations of HIRAX data with other large-area cosmological surveys in the southern sky.

E1.1-0018-18 DARK ENERGY WITH THE SQUARE KILOMETRE ARRAY

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The Square Kilometre Array (SKA) is an international radio observatory administered by ten member countries, guided by scientific contributions of thousands of scientists and engineers around the globe. The SKA instrument design is composed of two radio interferometric arrays covering the low and high radio frequencies to be placed in South Africa and Australia over two stages within the next decades. The wide frequency coverage and versatility of the array composition drive a multitude of science cases in cosmology, galaxy evolution, and the transient universe. The SKA will enable novel cosmological observations in the radio wavelengths such as galaxy surveys using the neutral hydrogen (HI) spectral line emission at 21cm, radio weak lensing, radio continuum galaxy surveys, and HI intensity mapping. The HI intensity maps trace the large-scale structure via the integrated HI line emission, a new technique avoiding selection biases while testing the continuous gas field over all redshifts up to six. Additionally, the full sky coverage of the intensity mapping observations gives access to ultra-large scales with potential to constrain non-gaussianity effects. HI galaxy surveys target the detection of a million to a billion objects over 5,000 and 25,000 sqdeg during SKA stage 1 and 2, respectively. The SKA HI galaxy surveys and SKA HI intensity mapping experiments are forecasted to detect the Baryon Acoustic Scale, acting as a standard ruler for distance measurements, for redshifts up to 2, resulting in Figures of Merit for the Dark Energy equation of state parameters highly competitive with the next generation of optical experiments. The combination of radio and optical data products is predicted to increase Dark Energy constraints through reducing cosmic variance with multi-tracer techniques, as well as mitigating instrumental systematics.

This abstract will be presented on behalf of the SKA Cosmology Science Working Group.

E1.1-0019-18 THE SUBARU PRIME FOCUS SPECTROGRAPH

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Prime Focus Spectrograph (PFS) is a highly multiplexed fiber spectrograph for the Subaru telescope. Thanks to the large aperture and large field of view, it will allow for a very efficient survey for cosmology, galaxy evolution, and galactic archeology science. I will describe the state of the development of the instrument, and present major science objectives of the 300-night survey proposal with emphasis on dark energy science.

E1.1-0020-18 LEARNING THE SHAPE OF AND WHAT SHAPES DARK STRUCTURE

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LCDM shows some tension with observations in the non-linear regime of structure formation. This includes abundance, density profiles and substructure amount for dark matter haloes at a range of masses and redshifts. Several recipes have been suggested to remedy such tensions including more detailed modelling of baryonic physics, modifications to gravity or variations to the collisionless, cold dark matter paradigm. However, current observational signatures to distinguish such models are elusive due to the vast information compression in the characterisation of observed dark matter structure via e.g. two-point correlation functions or 1D functional forms of density profiles. I will present a full morphological analysis of dark matter structure in the sky based on optimal mass mapping, computer vision and machine learning that alleviates this shortcoming. More specifically, I will focus on two characterisation schemes. The first one derives from classical computer vision and machine learning and extracts up to 3500 characterising elements directly from dark matter mass or shear maps, several of their transformations (Fourier, Chebyshev, Edge, Wavelet, .) and transformation of transformations. The second approach is based on deep learning and applies a multi-layered convolutional neural network, including state-of-the-art methods such as inception layers and region detection, to learn the main characterising features in the dark matter mass and shear maps. We apply these techniques to several sets of numerical simulations, all of which explore different aspects of the underlying model of structure formation. This includes several models of modified gravity, the degeneracy between modified gravity and the presence of massive neutrino, baryonic feedback and models of self-interacting dark matter. I will close with the application of this technique to classify the underlying structure formation model of real data coming from the KiDS and CLASH surveys and will give an outlook on the potential of future space and ground-based experiments such as Euclid, WFIRST and LSST.

E1.1-0021-18 QUASARS FROM LSST AS DARK ENERGY TRACERS

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With the prospect of new data, new cosmological tools are being devised to supplement the well established methods (Czerny et al. 2018) since the systematic errors will dominate the statistical errors. Quasars are not standard nandles but there are methods to determine absolute luminosity of each quasar at the basis of quasar variability. The most direct method relies on the delay of emission lines with respect to the continuum. Having 6 photometric channels and knowing their profiles we can disentangle strong lines from the continuum. With 10 millions of quasars measured with LSST, and out of that 100 000 quasars with high quality 10 year lightcurves in six band we will be able to measure all wOwaCDM model parameters with statistical accuracy of 0.2%.

E1.1-0022-18 DARK ENERGY INFLUENCING POLYTROPIC SPHERES MODELLING DARK MATTER HALOS

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We discuss in the framework of general relativity the role of the dark energy represented by the cosmological constant, restricted due to cosmological tests, in the polytropic mod- els of dark matter halos. The internal spacetime of the polytropic spheres governs circular geodesic orbits that can be compared with the velocity curves observed in large galaxies, indicating the possibility to use for the halo model both non-relativistic very extended and diluted polytropes, or relativistic polytropes with nearly critical value of the relativistic parameter sigma = pmathrmc/varrhomathrmc enabling extremely large polytrope extension, limited efficiently by the influence of the dark energy to agree with extension of dark matter halos of large galaxies. We also show that the so-called trapping relativistic polytropes with extremely large extension allow for gravitational instability of their central parts leading to the creation of a supermassive black hole inside of such an extremely extended polytrope representing galactic halo.

E1.1-0023-18 IN SEARCH OF DIVINE COSMOS UNDER SHADE

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From atomic scale to cosmic scale -Anoraneeyan Mahato Maheeyan-the science in philosophy comes in to prominence through Cosmic consciousness. Science frontiers cannot afford to move away from Nature, philosophy, Cosmology leading to Origins. Obviously, this search needs navigation like Dva-suparnatwin cosmic birds,one under a shade and the other searching beyond trying to catch-up prime functional Cosmic flows that spread around through visible-invisible matrix modes in nature. The Plasma Regulated Electro-Magnetic phenomena [PREM] in Magnetic field environment enshrines through 12 Jyothir-lingam concept with spread-functional routes at the base level to interlink vedas through 12 Adityas as groups of sun-shine in 3- tier Cosmic-pot Energy structures. This Divine scientific essence of Cosmic flow-field aligned knowledge becomes an attraction to all Astronomers, Cosmologists, philosophers alike looking for paradigm shift. Search from Van-Allen belts creates the necessty-demand-curiosity-Sustain management structure as a base ground mat for Spirit of Scientific research with a Noble cause beyond Heart of the Universe around 100,000 LY .Search from such a Knowledge base of Universe looks forward for cause-effect and stability index from and above Milky-way Galactic Frame as a Reflector beyond dark shades and dogmas. This prevents a state of anarchy prevailing through chaotic states adding confusion. Research reports by author over past 20 years reveal the creative function as inputs to bridge Core, Subtle and Wide observational frames under 3-tier cosmological structures to transcend super-imposition matrix towards prime Source, prime fields, Prime Reflectors with protective index in search of prime flows. Divine cosmos with float-mode structures may reveal through dimensional knowledge and the Space-Cosmological data-sets provide the trend to the next millenium with up-end universe. This mode of cosmolgy digest inter-twines consonance and resonance through nature and scienific edge in Philosophy.

key words: Cosmology vedas

E1.1-0024-18 DARK SHADOWS AROUND SUPERMASSIVE BLACK HOLES AS A TOOL TO EVALUATE DARK ENERGY AND DISCOVER EXTRA DIMENSION

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There are many different suggestions to evaluate dark energy for different astronomical objects, such as Solar System, galaxies, galactic clusters and cosmology. If dark energy is indeed not the cosmological constant it would very important to investigate its possible variation. We obtain relations of black hole shadow sizes from local dark energy parameter and tidal charge which characterizes extra dimension. Evaluations of shadow size could be done for the Galactic Center and the shadow in center of galaxy M81 with the Event Horizon Telescope and projected space ground interferometer Millimetron.

E1.2-0001-18 INTRODUCTION TO THE PLANCK DAY AT COSPAR

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I will introduce the Planck day at COSPAR. I will start by an overview of the main scientific achievements of Planck and implications for our understanding of the Cosmos today.

Planck results will be viewed in the context of the CMB session at COSPAR with special attention to current and future CMB experiments and the ongoing search for a stochastic background of gravitational waves that should leave a faint polarized signal in the CMB, the so-called B-modes.

E1.2-0002-18 THE PLANCK MISSION

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Please see https://www.cosmos.esa.int/web/planck/planck-collaboration for a full list of members.

I will provide introductory context for this full day of presentations on Planck at COSPAR, which follows and summarizes the recent "Legacy" release of Planck data. I will describe the history of the development of Planck reminding the main milestones of the project. I will present an overview of all the data products which have been released to the public by ESA and the Planck Collaboration since 2011, and will introduce the Planck Legacy Archive. Finally, I will highlight some of the main scientific achievements of Planck, relative to the initial objectives of the mission.

E1.2-0003-18 LFI MAPS

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Please see https://www.cosmos.esa.int/web/planck/planck-collaboration for a full list of members.

We present the description of the data processing pipeline for the Planck Low Frequency Instrument (LFI) implemented for the final 2018 data release. Several improvements have been made especially in the calibration procedure and in the correction of instrumental effects. We tested our results with a battery of null-tests and systematic effects simulations, dedicated to assess their impact on the calibration process, that demonstrate clearly the improvements with respect to previous release in particular at 30 and 44 GHz.

E1.2-0004-18 THE HIGH FREQUENCY MAPS

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A new map making software has allowed a much better correction of a number of systematic effects which were affecting the Planck HFI maps. These were affecting mostly polarization at large scales but their correction improved significantly also the high spatial frequencies. The maps and their testing through very complete end to end simulations will be presented. The determination of the low value of the reionization parameter through the use of the large scale EE polarized modes is confirmed. The determination of the kinetic dipole boost due to the motion of the solar system with respect to the CMB has been measured with unprecedented accuracy and provides one of the lasting legacies of the new release. The new map making paves the way to a new type of analysis of CMB data by integrating map making and component separation, which will become critical for the very weak primordial B modes search.

E1.2-0005-18 THE PLANCK LIKELIHOOD ANALYSIS

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The Planck Likelihood is one of the main cosmological products of the Planck mission. It compresses the Planck data into a set of statistical descriptions of our best full sky determination of the CMB temperature and polarization, and constitutes an important element of the Planck Legacy. Until a new satellite mission, with both improved resolution and sensitivity, can provide us with a new full sky determination of the CMB, some of the scales probed by the Planck data will remain a reference for all CMB observations. Thanks to numerous improvement at all steps of the Planck data processing, the legacy likelihood represents a solid improvement over the 2015 Planck Likelihood, both at large scales (with a greatly improved constraint on the large scale polarization) and at small scales (with a solid leakage model, allowing to recommend the use of the polarized data for cosmology). I will review the determination and validation of the Planck Likelihood. I will describe the different choices made to build at each of the scales probed by Planck a good approximation of the likelihood. I will explain how we modelled and mitigated the different non-idealities of the data (e.g. astrophysical foregrounds, instrumental effects.), describe the different validation we performed, based on comparing different data cuts, or using extensive End-to-End simulations, and finally give an estimate of the level of possible residual systematics.

E1.2-0006-18 COSMOLOGICAL PARAMETERS DERIVED FROM PLANCK

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Planck is an ESA satellite aimed at the observation of the Cosmic Microwave Background. This year, the Planck collaboration is publishing its third and last data release. In this talk, I will present the results on cosmological parameters of this year release, showing the most important changes with respect to the 2015 release, and I will discuss the consistency of our results with respect to other cosmological probes.

E1.2-0007-18 THE PLANCK 2018 CMB MAPS

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Please see https://www.cosmos.esa.int/web/planck/planck-collaboration for a full list of members

We present the CMB temperature and polarization maps derived from the third and last Planck data release. Full-sky maps are provided, including also confidence masks that exclude the unreliable regions of the sky. Four conceptually different pipelines, already adopted in previous releases, have been applied (Commander, NILC, SEVEM and SMICA) to extract the cosmological signal, showing a good level of agreement. The new versions of the CMB temperature maps agree very well with the ones in the previous release, as one would expect due to the low level of systematics, and the high signal-to-noise ratio. For polarization, the new maps provide a substantial improvement with respect to the previous version, with significantly reduced contamination from instrumental systematic effects. However, the noise properties of the polarization signal are complicated and not completely reproduced by the current best end-to-end simulations, which should be taken into account when carrying out cosmological analyses. To mitigate these limitations, we also provide CMB estimates for different data splits, which are very useful to carry out further analyses of the data. The temperature and polarization maps derived from the Planck 2018 data provide the best CMB maps up to date, and it is foreseen that this will remain the case for many years.

E1.2-0008-18 ISOTROPY AND STATISTICS OF THE PLANCK MAPS

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Precise full sky measurements of the CMB anisotropies enabled important studies of the primordial seeds of structure observed in the universe. Planck Isotropy and Statistics program pursues a phenomenological investigation of the CMB maps generated by Planck mission focused on those features, mostly at relatively large angular scales, that appear anomalous with respect to the characteristics of the CMB sky expected in the standard Lambda-CDM model (that fits the data well at intermediate to small angular scales). Previous Planck data releases were accompanied by I&S publications focused on the CMB temperature anisotropy, which confirmed that such morphological oddities of our CMB sky as first noticed in the WMAP sky maps were indeed the real features of the observed universe, rather than instrumental artifacts. While the modest statistical significance of these findings did not merit serious revisions of the standard cosmological model, it remains of utmost importance to investigate whether such effects are present in the full sky CMB polarization maps. While prior Planck data releases did not allow sufficiently precise assessment of these effects, the present, definitive Planck data release comes with improved large scale polarization anisotropy maps. This talk will present the results of Isotropy and Statistics studies conducted on the final Planck CMB polarization maps.

E1.2-0009-18 PLANCK 2018 CMB LENSING

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Please see https://www.cosmos.esa.int/web/planck/planck-collaboration for a full list of members

Gravitational lensing by large-scale structures along the line of sight slightly distorts the temperature and polarization anisotropies of the cosmic microwave background (CMB). Planck data allows lensing mass reconstruction over most of the sky, and has definitely established CMB lensing as a precision probe of matter clustering in the late-time Universe. I will present the final 2018 Planck lensing results, including improved lensing spectrum band-powers in temperature and polarization, combined lensing constraints with galaxy lensing from the Dark Energy Survey, and a high-fidelity lensing mass map constructed in combination with the Cosmic Infrared Background as seen by Planck. I will also present the delensing of the Planck maps using our lensing tracers, with re-sharpening of the acoustic peaks and reduction of the B-mode power measured at high significance.

E1.2-0010-18 COSMOLOGICAL NON-GAUSSIANITY IN THE PLANCK MAPS

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Planck Collaboration

Please see https://www.cosmos.esa.int/web/planck/planck-collaboration for a full list of members.

The Planck mission has left a legacy of high-precision constraints on the inflationary epoch. The most precise inflationary constraint resulting from the Planck mission is on physically motivated forms of non-Gaussianity of the primordial seed perturbations. Planck constrains large classes of models that predict non-Gaussian features in the cosmic microwave background anisotropies. These features correspond to precise terms in the Lagrangian governing the very first instances of cosmogenesis. In addition to these fingerprints of physics in the very early Universe, there is a guaranteed signal of non-Gaussianity that arises from cosmic structure in a dark energy dominated phase. This effect has been detected in Planck. In this talk I will present, on behalf of the Planck team, the latest results from high-precision studies of the Planck maps and give an outlook for constraining the primordial fluctuations in the coming decade.

E1.2-0011-18 CONSTRAINTS ON INFLATION FROM PLANCK

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We present the implications for cosmic inflation of the Planck Legacy Release in combination with other data sets. We first show the constraints on the power spectra of primordial fluctuations and on single field slow-roll inflationary models. We then present the status of inflation beyond the single field slow-roll paradigm, summarizing the constraints on features in the primordial power spectrum, on isocurvature perturbations and on statistically anisotropic inflationary models.

E1.2-0012-18 THE ASTROPHYSICS OF THE MAGNETIZED DUSTY INTERSTELLAR MEDIUM

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Please see https://www.cosmos.esa.int/web/planck/planck-collaboration for a full list of members.

Observations of Galactic dust are a highlight and a lasting legacy of the Planck space mission. Spectacular images combining the intensity of dust emission with the texture derived from polarization data have received world-wide attention and become part of the general scientific knowledge. Beyond this popular success, the dust maps are an immense step forward for Galactic astrophysics, greatly superseding earlier observations. Planck has provided astrophysicists with the data they needed to statistically characterize the structure of the Galactic magnetic field and its coupling with interstellar matter and turbulence. Planck multi-frequency observations have also opened a new perspective on interstellar dust, upsetting existing models. Futrhermore, the astrophysics of dust emission has become inter-connected to a paramount objective of observational cosmology: the quest for curl-like (B-mode) polarization of the cosmic microwave background expected to arise from primordial gravitational waves produced during the inflation era in the very early Universe. The need to achieve an accurate removal of the dust foreground binds the search for primordial B-modes to the astrophysics of the dusty magnetized interstellar medium. The promise of future CMB experiments depends not only on their sensitivity, but also on our ability to master the foreground interstellar dusty screen.

E1.2-0013-18 THE PLANCK SCIENTIFIC LEGACY

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The Planck collaboration has produced about 150 scientific papers, half of them on cosmology, and these results have had a transformative impact on cosmology. Planck has measured LCDM fundamental parameters with a precision at the one percent level, setting the framework used in many other areas of physics and astronomy. It did establish at more than 5 sigmas the expected deviation from scale invariance of the initial distribution of power in generic inflationary models. It has dispelled many once popular variants of that base inflationary cosmology, in particular through its very tight constraints on the presence of any Primordial Non-Gaussian features. Planck has also opened the era of CMB lensing which will be a major scientific endeavor of future experiments. This is not to say that there are no more questions to answer, if anything because of a number of CMB anomalies as well as tensions when other cosmological probes are analyzed assuming LCDM. In this talk, the main Planck results on the basic cosmological model and their implications for fundamental physics, structure formation, and astrophysical cosmology will be presented and brought into context.

E1.2-0014-18 BEYOND PLANCK

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The Planck project spanned some 25 years from conception to delivery of the final set of papers. During this long timeframe, Science has evolved and priorities shifted. Nonetheless, the Planck team was able to cope with the changes, and the mission has been a universally recognized success. A legitimate question is whether Planck really ends with the final set of papers. I will advocate that this is not the case, and there is still considerable potential to be exploited in the Planck data for CMB polarization, in addition to better characterization and cleaning up of smaller and smaller systematics. The immediate future, after the final products delivery, will undoubtedly see many projects with this aim: those that are more respectable will build upon the lessons learnt on the instruments, calibration, and systematics. At some point, however, we will exhaust Planck's information content. I will advocate that despite the tremendous effort in ground-based and balloon-borne experiments, a future space mission is necessary to exploit CMB polarization in a way analogous to what Planck has done for temperature. International collaboration is key for the success of these projects: the JAXA-led LiteBIRD might greatly benefit from an ESA mission of opportunity, while the very ambitious (and expensive) CORE may gain new life from a very timely collaboration with India.

E1.2-0015-18 THE COSMIC INFRARED BACKGROUND AS SEEN BY PLANCK: NEW INSIGHTS INTO THE CIB-CMB LENSING CROSS CORRELATION

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The cosmic infrared background (CIB) is a powerful probe of large-scale structure across a very large redshift range, consisting of unresolved FIR emission from dusty galaxies. It can be used to study the astrophysics of galaxies, the star formation history of the Universe, and the connection between dark and luminous matter. The major difficulty here lies in obtaining accurate and unbiased large-scale CIB images that are cleaned from the contamination by Galactic dust. We used data of neutral atomic hydrogen from the recently-release HI4PI Survey to create template maps of Galactic dust, allowing us to remove this component from the Planck intensity maps. I will present our final CIB maps and the various processingand validation steps that we have performed to ensure the high quality of these maps. Based on these new CIB maps, I will also present a cross correlation analysis of the CIB signal and the Planck CMB lensing map, which can be used to study the primordial non-Gaussianity through a scale-dependent bias term. Aside from this particular application, the soon-to-be public maps will enable the community to investigate a wide range of questions, related to the Universe's large-scale structure.

E1.2-0016-18 WHY B MODES?

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In this talk I will discuss the several ways in which the measurement of B modes in the CMB polarization can advance the study of the origin and evolution of the Universe and simultaneously probe new physics. The principal motivation for many of those involved in the quest for cosmic B modes is the large-angle signal from inflation. The prevailing single-field slow-roll models of inflation predict a signal in the realm of detectability within the next decade. If no such B modes are seen, it will force us to seriously reconsider the basic inflationary paradigm. However, B modes can also be used to look for novel parity-violating new physics from the early Universe (e.g., chiral gravitational waves) or late Universe (cosmic birefringence). And measurement of B modes expected from gravitational lensing are already being used as a tool in precision-cosmology endeavor. Finally, any cosmic polarization signal must be distinguished from polarized emission from the Milky Way, and the B modes associated with these "foregrounds" will provide valuable information on the physics of the interstellar medium.

E1.2-0017-18 NATURAL INFLATION: COMPARISON TO CMB DATA AND NEW DEVELOPMENTS

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I will discuss the status of Natural Inflation, a model that my collaborators and I originally proposed in 1990, as well as modern variants. Natural inflation uses an "axion" as the inflaton, where the term "axion" is used generically for a field with a flat potential as a result of a shift symmetry. I will compare variants of natural inflation to current and upcoming CMB data. Further, I will discuss new theoretical developments including a model of baryogenesis requiring only particles from the Standard Model of particle physics, ordinary neutrinos, and an axion as the inflaton.

E1.2-0018-18 MEASURING THE DIFFUSE FIR POLARIZED DUST EMISSION WITH PILOT FOR THE QUEST OF CMB B-MODES

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Measuring precisely the faint polarization of the far-infrared and sub-millimetre sky is one of the next observational challenges of CMB cosmology. In particular, the recent BICEP2 episode has demonstrated that dust cannot be ignored when searching for B-modes in the CMB polarized signal. Indeed, precise knowledge of the dust polarization SED, and its possible variations on the sky will be necessary in the future, and very little is understood about the physics of dust alignment and processes leading to emission of polarized light. Constraining models of dust polarized emission will require far more measurements than are currently available. I will show preliminary observational results relevant to this important topic, from the analysis of the PILOT balloon-borne experiment data obtained during its last flight from Alice Springs, Australia in April 2017, during which the BICEP2 field has been observed in polarization in the far-infrared.

E1.2-0019-18 PASIPHAE: CLEARING THE PATH TO EXPERIMENTAL TESTS OF INFLATION

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An inflation-probing B-mode signal in the polarization of the cosmic microwave background (CMB) would be a discovery of utmost importance in physics. Any inflationary B-mode signal, however, is contaminated by what currently constitutes a natural noise floor, produced by 3-dimensional effects in the most important CMB polarization foreground: emission from interstellar dust. I will discuss how the upcoming Polar Areas Stellar Imaging in Polarization High Accuracy Experiment (PASIPHAE) will revolutionise our ability to remove the dust foreground and beat this apparently irreducible noise floor through the newly developed technique of optopolarimetric magnetic tomography of the interstellar medium. PASIPHAE will take place simultaneously at the Skinakas observatory in Crete and the South African Astronomical Observatory. It will measure linear optical polarization at 0.1% accuracy of over 360 stars per square degree, a 1000-fold increase over the state of the art. Such a map will not only boost CMB polarization foreground removal beyond what is currently considered feasible, but it will also have a profound impact in a wide range of astrophysical research, including interstellar medium physics, high-energy astrophysics, and galactic evolution.

E1.2-0020-18 LITEBIRD FOR B-MODE FROM SPACE

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LiteBIRD is a JAXA-led international satellite project with an expected launch in the middle of 2020s with a H3 rocket. Its mission is to perform stringent tests of the cosmic inflation with full-sky cosmic microwave background (CMB) polarization surveys at degree scales with unprecedented precision. The full success of LiteBIRD is to achieve $\delta r < 0.001$, where δr is the total error on the tensor-to-scalar ratio r. This allows us to test well-motivated cosmic inflation models. The required angular coverage corresponds to 2 /i 200, where /i is the multipole moment. LiteBIRD will carry out full-sky surveys for three years at a Lagrangian point L2 for 15 frequency bands between 34 and 448 GHz. LiteBIRD will employ two telescopes to achieve the total sensitivity of 2.5 μKl with a typical angular resolution of 0.5° at 150 GHz. Each telescope has a half-wave plate system for modulation of polarization signals and a focal plane filled with polarization-sensitive transition-edge sensor (TES) bolometers. A cooling system provides a 100 mK base temperature for two focal planes and 2 K and 5 K stages for optical components. Although the payload module is designed to satisfy the very focused mission mentioned above, expected science outcomes of LiteBIRD are not limited to the measurement of r. In this talk, the mission, system, project and science outcomes of LiteBIRD will be reviewed.

E1.2-0021-18 PICO – THE PROBE OF INFLATION AND COSMIC ORIGINS

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PICO — the Probe of Inflation and Cosmic Origins — is a concept for NASA's possible future Probe line of competed missions. Designed to explore how the Universe began and evolved, PICO will survey the sky for four years with thousands of detectors over a wide frequency range. The ambitious goal of detecting or setting an upper bound on the tensor-to-scalar ratio for fluctuations of the cosmic microwave background of $r < 10{-}4$ will require exquisite control of foregrounds and systematics.

E1.2-0022-18 THE PRIMORDIAL INFLATION EXPLORER

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The Primordial Inflation Explorer (PIXIE) is an Explorer-class mission to characterize the signature of primordial inflation through its distinctive imprint on the cosmic microwave background. PIXIE uses a double-nulled Fourier Transform spectrometer to measure both linear polarization and the absolute intensity spectrum of the CMB and astrophysical foregrounds to background-limited sensitivity in 400 frequency channels spanning 30 GHz to 6 THz (1 cm to 50 micron wavelength). In addition to testing inflation by mapping the power spectrum of B-mode polarization, PIXIE will search for distortions in the CMB blackbody spectrum with sensitivity three orders of magnitude beyond the COBE/FIRAS limits. Sensitivity at these levels opens a new window to the early universe, probing physical processes ranging from Big Bang cosmology to dark matter decay/annihilation to the star formation history of the universe. I describe the PIXIE instrument and mission architecture needed for these new tests of the early universe.

E1.2-0023-18 THE NEXT GENERATION GROUND-BASED COSMIC MICROWAVE BACKGROUND EXPERIMENT CMB-S4

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Measurements of the CMB have driven our understanding of the universe and the physics that govern its evolution from primordial quantum fluctuations to its present state. They provide the foundation for the remarkable 6-parameter cosmological model, CDM, which fits all cosmological data, although there are some tensions that may possibly hint at new physics. Far from being the last word in cosmology, the model raises deep questions: Is Inflation correct? What is its energy scale? What is the dark matter? What is the nature of dark energy? Are there light sterile neutrinos, or other light relics? This talk will describe progress on the next generation ground-based CMB experiment, CMB-S4, that is being designed to have sufficient sensitivity and control of systematics to make breakthroughs in many of these areas, i.e., to cross critical thresholds in parameter values or show that CDM is incomplete.

E1.2-0024-18 BICEP CONSTRAINTS ON PRIMORDIAL GRAVITATIONAL WAVES, CURRENT AND FUTURE

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The BICEP/Keck Array is suite of small microwave telescopes at the South Pole working together, and in conjunction with other surveys, to measure polarization patterns in the cosmic microwave background (CMB) that would arise from gravitational waves spawned in the earliest instants of time. If inflation is the process that produced the observable universe we inhabit and seeded primordial density fluctuations through quantum fluctuations operating at around GUT energy scales, then it will have produced a gravitational-wave background that may be detectable now via a faint "B-mode" pattern imprinted in the polarization of the CMB. Testing the prediction, or ruling it out for this range of energy scales, is a major goal of current CMB observations.

Detecting this faint pattern requires making maps of unprecedented sensitivity, while separating the faint polarization signals intrinsic to the CMB from other signals including polarized emission from dust and electrons in our own galaxy and patterns caused by weak gravitational lensing of large scale structure. The small-aperture BICEP/Keck Array telescopes have produced the deepest-ever maps of CMB polarization in four frequency bands. With the new BICEP3 and upcoming BICEP Array telescopes, the BICEP telescopes are exploiting the unique South Pole atmosphere to push these maps to cover a wide frequency range (30 - 270 GHz) to separate galactic emission from CMB signals. Data from other surveys including Planck, WMAP, and dedicated low-frequency instruments further improves foreground separation, while overlapping observations with the 10m South Pole Telescope provides resolution sufficient to reconstruct the weak lensing patterns of the CMB and to separate these from primordial B-mode patterns. The BICEP/Keck program is producing the most sensitive constraints yet on primordial gravitational waves, and is likely to improve these constraints over the next five years by nearly an order of magnitude.

E1.2-0025-18 THE POLARBEAR AND SIMONS ARRAY CMB POLARIZATION EXPERIMENTS

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POLARBEAR is a cosmic microwave background (CMB) polarization experiment located in the Atacama desert in Chile, which has been performing a deep search for CMB B-mode polarization from gravitational lensing. POLARBEAR-1 started observations in 2012, and the POLARBEAR team has published a series of results from its first two seasons of observations. The Simons Array expands POLARBEAR to include an additional two telescopes with nextgeneration POLARBEAR-2 multi-chroic receivers, observing at 95, 150, 220, and 270 GHz. The POLARBEAR-2 focal plane has 7,588 transition-edge sensor bolometers, read out with frequency-division multiplexing. In 2018, the Simons Array: an array of three POLARBEAR2 receivers and 3.5 meter diameter telescopes was commissioned, and two more telescopes will be outfitted with multichroic detectors in the coming years. We present results from the characterization, tuning, and operation of the fully integrated focal plane and readout for the first POLARBEAR-2 receiver, POLARBEAR-2A and discuss the capability of the three telescope Simons Array in the coming years.

E1.2-0026-18 COSMOLOGY WITH THE SOUTH POLE TELESCOPE: STATUS AND FUTURE PLANS

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I will give an overview of the South Pole Telescope (SPT), a 10-meter diameter telescope at the South Pole designed to measure the cosmic microwave background (CMB). The SPT recently completed 10 years of observations, over which time it has been equipped with three different cameras: SPT-SZ, SPTpol, and SPT-3G. I will discuss recent results from the SPT-SZ and SPTpol surveys, including: an update on the SPT Sunyaev-Zel'dovich (SZ) cluster survey and joint analyses with the optical dark energy survey (DES); a comparison of CMB measurements between SPT-SZ and the Planck satellite; and the latest CMB polarization power spectrum constraints from SPTpol. In addition, I will discuss the status of the recently deployed SPT-3G camera, which achieved first light on the SPT in January 2017. The SPT-3G camera consists of 2710 trichroic pixels, each simultaneously measuring two orthogonal linear polarizations in frequency bands centered at 95, 150, and 220 GHz, and a total of 16,200 superconducting transition edge sensor (TES) bolometers, a factor of ten increase over the previously installed SPTpol camera. I will discuss the deployment of SPT-3G, its current status, and summarize the science goals of the SPT-3G experiment.

E1.3-0001-18 GAMMA-RAY/X-RAY EMISSION FROM MILLISECOND PULSAR BINARY

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In this presentation, gamma-ray and X-ray emission from millisecond pulsar binary will be discussed. The GeV gamma-ray emission is probably originated from the pulsar magnetosphere. But unexpected enhancement of GeV emission during the accretion power stage of the transient millisecond pulsar binary suggests the emission from the cold-relativistic pulsar wind or intrabinary shock or the disk matter injected by the propeller effects contribute to the observations. The X-ray emission can be originated from the heated polar cap, pulsar magnetosphere and intra-binary shock. By comparing the theoretical model and observation, we will discuss the magnetospheric non-thermal emission is negligible comparing to the heated polar cap and intrabinary shock emission. For redback millisecond pulsar, the X-ray emission is dominated by the intra-binary shock. For some black widow system, on the other hand, the heated polar cap emission can dominate in the observed emission.

E1.3-0002-18 PULSAR GAMMA-RAY EMISSION: MACROSCOPIC AND KINETIC MODELS

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Fermi, since its launch in 2008, has played a catalytic role in the discovery of millisecond pulsars. I will present dissipative macroscopic models and kinetic PIC models that reproduce the observed phenomenology of the gamma-ray young and millisecond pulsars. Our models indicate that the gamma-ray emission is produced in regions outside the light cylinder near the equatorial current sheet. A detailed comparison of the model spectral properties with those observed by Fermi reveals the dependence of the macroscopic parameters (e.g. conductivity) and microphysical properties (e.g. particle multiplicities, particle injection rates) on the spindown rate providing a unique insight into the understanding of the physical mechanisms behind the high-energy emission of both young and millisecond pulsars.

E1.3-0003-18 RADIATION AND POLARIZATION FROM AN OFF-CENTRED ROTATING DIPOLE

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When a neutron star forms, a strong magnetic field survives in its interior. This magnetic topology is usually assumed to be well approximated by a dipole located at the centre of the star. However, a slight shift from the centre has strong implications for the surrounding electromagnetic field. We study the effect of an off-centred dipole anchored in the neutron star interior. Exact analytical solutions are given in vacuum to any order of accuracy. The spindown luminosity and the torque exerted on its crust are computed to the lowest leading order. Results are compared to earlier works and a discussion on repercussions on pulsar braking index and multi-wavelength light curves is proposed.

Moreover, radio polarization measurements of pulsed emission from pulsars offer a valuable insight into the basic geometry of the neutron star: inclination angle between the magnetic and rotation axis, inclination of the line of sight and magnetic topology. So far, all studies about radio polarization focused on the standard rotating vector model with the underlying assumption of a centred dipole. This model is generalized to an off-centred dipole with an exact analytic expression for the phase-resolved polarization angle. The polarization angle now also depends on the emission altitude. The time lag between radio pulse profiles and surface thermal X-ray emission is naturally explained in this model.

E1.3-0004-18 PLASMA MAGNETOSPHERE OF OSCILLATING AND ROTATING MAGNETIZED NEUTRON STARS

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We discuss a number of analytical studies, aimed at adding the influence of oscillations experienced by a pulsar/magnetar on its plasma magnetopshere. We show that particular modes of oscillations may considerably increase the pulsar/magnetar luminosity and apply the obtained theoretical results on the plasma magnetosphere of oscillating and rotating neutron stars i) to propose a qualitative model for the explanation of the phenomenology of intermittent part time pulsars, ii) to study the conditions for radio emission in rotating and oscillating magnetars by focusing on the main physical processes determining the position of their death lines, i.e. of those lines that separate the regions where the neutron star may be radio loud or radio quiet, iii) to explain the subpulse drift phenomena adopting the space-charge limited ow model and comparing the plasma drift velocity in the inner region of pulsar magnetospheres with the observed velocity of drifting subpulses.

E1.3-0005-18 THE ORIGIN OF THE POLARIZED RADIO PROFILES OF MILLISECOND PULSARS

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Observed polarisation of radio pulsar profiles either follows the rotating vector model (RVM) or exhibits peculiar phenomena which result from birefringent propagation effects. Oftentimes both cases occur in different parts of the same profile. The peculiarities involve strong distortions of polarization angle from the RVM and a high circular polarization which can be maximum (instead of zero) at orthogonal polarization jumps. I will show that the peculiar polarization features can be understood in terms of coherent addition of radiation in two orthogonal polarization modes. Even simple parametrizations of the added waves' phase lag produce effects observed in radio pulsar data. In particular, the polarization profile of the 59 ms pulsar B1913+16 can be understood within a nearly full pulse window. I will also briefly describe what the intensity profiles are telling us about the dynamics of plasma in the emission region and on the geometry of the millisecond radio pulsar beam.

E1.3-0006-18 HOW TO TRIAGE RADIO PULSAR DISCOVERIES?

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The SUrvey for Pulsars and Extragalactic Radio Bursts (SUPERB) is ongoing at Parkes since 2014. It is an example of a short-pointing multi-pass radio pulsar survey, operating at 1.4 GHz. Another example, operating at 10 times lower radio frequency, is the LOFAR Tied-Array AllSky Survey (LOTAAS), which has been running since 2013. By design, these surveys are well suited to finding nulling and intermittent radio pulsars, eclipsing systems, interesting binaries, up-scintillated and nearby sources. Processing the data from these surveys is a considerable task, but has been successful with 100 pulsar discoveries between them (1/3 SUPERB, 2/3 LOTAAS). These two projects are analogues of pulsar surveys that the Square Kilometre Array will perform with SKA1-Mid and -Low, respectively. However with the SKA the discovery rate will be two orders of magnitude higher. Classifying the SKA pulsar candidates to make discoveries is a large computational problem in and of itself, but triaging the resultant discoveries to find the most interesting sources is also very challenging. Being able to recognise that we have discovered such systems in as close to real time as possible is crucial, e.g. we want to realise when a transitional MSP is on in the radio before it turns off! In this talk I propose some initial ideas on this topic and hope to kick-start an open collaboration for new ideas in this area.

E1.3-0007-18 RADIATION FROM SHOCKS IN MILLISECOND PULSAR BINARIES

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A large number of new Black Widow and Redback rotation-powered millisecond pulsars have been discovered through radio searches of unidentified Fermi sources, increasing the known number of these systems from 4 to 28. We model the high-energy emission from particles accelerated to several TeV in the intrabinary shocks in these systems, and its modulation at the binary orbital period. Constructing a geometric model of the shock, we use radio eclipse data in conjunction with optical constraints on the binary inclination angle to constrain the shock stagnation point distance from either the pulsar or companion star. We next model the X-ray synchrotron orbital light curves from accelerated particles convecting downstream of the shock. Fitting our model light curves to those observed from a number of binaries we find a correlation that constrains the bulk Lorentz factor of the wind flow as well as the orbital inclination angles.

E1.3-0008-18 COMPACT BINARY PULSAR SEARCH (COBIPULSE): FIRST RESULTS

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In the past decade, the large area telescope (LAT) aboard Fermi has uncovered more than three thousand gamma-ray sources. As a consequence, compact binary millisecond pulsars (with orbital periods shorter than about a day) are becoming a sizeable and rapidly-growing pulsar population. Pulsars are the main Galactic class among the known gamma-ray sources, yet nearly a thousand LAT sources remain unidentified. We present the first results from our COBIPULSE survey: a systematic search for optical variable and X-ray counterparts to Fermi-LAT pulsar candidates. These include the discovery of a new redback candidate in a 21-hr orbit (3FGL J0212.1+5320), the brightest of its kind in the optical band.

E1.3-0009-18 THERMONUCLEAR PROBES OF MILLISECOND PULSARS

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Every few hours some accreting neutron stars in close binary systems erupt in powerful thermonuclear conflagrations. These X-ray bursts rapidly heat the surface layers, and sometimes in a nonuniform way. Rotational modulation of the anisotropic surface emission can produce X-ray pulsations at or near the neutron star spin frequency. These "burst oscillations" were first seen with NASA's Rossi X-ray Timing Explorer (RXTE) and provide a new way to see the spin periods of accreting neutron stars. I will provide an overview of this phenomenon with a focus on what detailed spectral-timing studies of these oscillations can tell us about neutron stars, including the dense matter equation of state, and thermonuclear burning on them. I will also discuss burst oscillations and nuclear burning from accreting millisecond pulsar systems and present some new results obtained with NASA's Neutron Star Interior Composition Explorer (NICER) on the recently discovered millisecond pulsar IGR J17062-6143.

E1.3-0010-18 NEW BURNING PHYSICS AND BURST OSCILLATIONS

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Accreting neutron stars (NS) can exhibit high-frequency modulations in their lightcurves during thermonuclear X-ray bursts, known as burst oscillations. Their frequencies can be offset from the spin frequency of the NS by several Hz (known independently), and can drift by 1-3 Hz. New X-ray missions with improved sensitivity (such as eXTP and Strobe-X) aim to use the burst oscillation phenomenon to measure NS parameters, an effort that would be helped by a thorough understanding of the underlying mechanism. One plausible explanation is that a wave is present in the bursting ocean that decreases in frequency (in the rotating frame) as the burst cools, hence explaining the drifts. The strongest candidate is the buoyant r-mode, however, models for the ocean background used in previous studies over-predict frequency drifts by several Hz. Using new background models that were developed to explain the short recurrence times of some bursts (which include shallow heating, and burning in the tail of the burst), the evolution of the buoyant r-mode was calculated. The resulting frequency drifts are smaller, in line with observations.

E1.3-0011-18 TWENTY YEARS OF ACCRETING MILLISECOND PULSARS

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In the last 20 years, since the discovery in 1998 of the first Accreting Millisecond Pulsar SAX J1808.4-3658, our understanding of the millisecond pulsar population changed dramatically. Thanks to the large effective area and good time resolution of the NASA X-ray observatory Rossi X-ray Timing Explorer first and the ESA XMM-Newton after, we discovered that neutron stars in Low Mass X-ray Binaries (LMXBs) spins at frequencies between 200 and 750 Hz, indirectly confirming the recycling scenario, according to which neutron stars are spun up to millisecond periods during the LMXB-phase. In this review I describe the properties of accreting millisecond pulsars, with particular attention to the last discoveries and to the long-term orbital and spin evolution. I will highlight what we know and what we have still to learn about in order to fully understand the (sometime puzzling) behaviour of these systems and their evolutionary connection to the rotation-powered millisecond pulsars population.

E1.3-0012-18 OBSERVATIONAL UPDATES ON ACCRETING MILLISECOND X-RAY PULSARS

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After almost two decades from the discovery of the first accreting millisecond X-ray pulsar (AMXP) SAX J1808.4-3658, the sample of accreting rapidly-rotating neutron stars harboured in low mass X-ray binary systems has increased in number up to 20. The extremely short spin periods shown by the accreting millisecond X-ray pulsars are the result of long-lasting mass transfer from low mass companion stars through an accretion disc onto a slow-rotating NS as predicted by the so-called "recycling scenario". At the end of the mass transfer phase, a millisecond pulsar shining from the radio to the gamma-ray band, and powered by the rotation of its magnetic field, is expected to turn on. The close link shared by radio millisecond pulsars and AMXPs has been observationally confirmed by the transitional binary systems IGR J18245 2452 as well as by other transitional millisecond pulsars. Here I will discuss the temporal and spectral properties of the recently discovered AXMPs MAXI J0911-655 and IGR J16597- 3704. Moreover, I will present the latest updates on the long-term orbital evolution of the intermittent AMXP SAX J1748.9-2021 obtained combining the updated set of ephemeris from its 2017 outburst with those of the previous outbursts. The orbital period derivative will be then discussed in terms of the possible evolutionary scenarios of the binary system.

E1.3-0013-18 MULTI-EPOCH MODELLING OF THE HOT SPOT OF THE ACCRETING MILLISECOND X-RAY PULSAR SAX J1808-3658

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SAX J1808-3658 is an accreting millisecond X-ray pulsar. The X-ray pulse shape depends on the intrinsic properties of the emission spot (size, shape, location, and emissivity) as well as the neutron star's properties (mass, radius, and spin). This was shown by the first pulse shape analysis by Poutanen and Gierlinski (2003, MNRAS, 343, 1301). The goal of such modelling is a measurement of mass and radius, which leads to constraints on the EOS of supernuclear density material. Improved modelling and constraints for SAX J1808 were carried out by Morsink and Leahy (2011, ApJ, 726, 56) and for XTE J1807-294 by Leahy, Morsink and Chou (2011, ApJ, 742,17). The current work further improves this modelling by simultaneous fitting of multiple different pulse shapes from SAX J1808-3658.

E1.3-0014-18 SPECTRAL AND TIMING ANALYSIS OF THE ACCRETING MILLISECOND PULSAR IGR J17511-3057 WITH NUSTAR, SWIFT/XRT AND XMM-NEWTON OF THE LATEST OUTBURST

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Accretion-powered millisecond pulsars are transient low mass X-ray binaries, which show a coherent modulation of their X-ray fluxes with periods of the order of few milliseconds. Up to now, 20 accreting millisecond pulsars are known. Of these, only a few have shown more than an outburst and thus permitting to study the evolution of such a systems. We present a detailed broad band spectral analysis of the 2015 outburst of the accreting millisecond pulsar IGR J17511-3057 as simultaneously seen by NuSTAR and Swift, and compare our results with the XMM-Newton observation of the same outburst and the first outburst. We obtained a very precise orbital solution for the 2015 outburst through timing analysis of both NuSTAR and XMM-Newton observations. Moreover, comparing the this orbital solution with the one for the 2009 outburst, we are able to pose strong constraints on the orbital period derivative and the orbital evolution of the source.

E1.3-0015-18 QPO FREQUENCY CORRELATIONS IN AMXPS

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We present the comparative analysis of the RXTE archival X-ray timing data on 13 burst oscillation sources to those on 6 AMXPs. In particular, we compare the correlations best characterised by a power law between centroid frequencies of low frequency (<100 Hz) and kHz QPOs in the two source types. We test if our results match the theoretical prediction that a combination of magnetic torques, classical and nodal precession gives rise to overall net precession of an accretion disc causing such frequency correlations.

E1.3-0016-18 TRANSITIONAL MILLISECOND PULSARS

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Millisecond pulsars attain their very quick rotation during a Gyr-long, X-ray bright phase of accretion of matter from a low mass companion star. When the mass transfer stops, magnetospheric pulsed emission powered by the star rotation and observed preferentially in the radio and gamma-ray bands, switches on. This complex evolution has been recently demonstrated by the discovery of transitional millisecond pulsars that swing between an accretion-powered X-ray pulsar regime and a rotationally-powered radio pulsar state on a time scale of a few weeks, or even shorter. These pulsars show an incredibly rich phenomenology that reflects all the possible outcomes of the interaction between the pulsar wind of particles and radiation and matter in an accretion disk. Recently, also optical pulsations have also observed from a transitional pulsar (Ambrosino, Papitto et al., 2017, Nature Astronomy), the first ever from a millisecond spinning neutron star. The pulsations were observed by using the fast photometer SiFAP at the INAF Galileo Telescope. Optical pulses were detected when the pulsar was surrounded by an accretion disk, but they are most likely originated by a rotation-powered magnetospheric process. The profound implications for our understanding of the pulsar disk/magnetosphere interaction will be discussed.

E1.3-0017-18 MULTI-BAND ORBITAL VARIABILITY IN REDBACKS AND TRANSITIONAL MSEC PULSAR BINARIES

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We will discuss the multi-band orbital variability and the long-term behaviour observed in the two transitional msec pulsars (tMSPs) XSSJ12270-4859 and PSRJ1023+0038 and other redbacks to understand the role of the intrabinary shock during the radio pulsar state and the effects of irradiation on the companion star to shed light into the possible mechanism driving the dramatic state changes seen in tMSPs.

E1.3-0018-18 GRO J1744-28: THE SLOWEST TRANSITIONAL PULSAR?

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GRO J1744-28 (the Bursting Pulsar) is an Eddington-limited accreting pulsar which shows highly structured X-ray variability near the end of its outbursts. We find that this variability is analogous to that seen in Transitional Millisecond Pulsars such as PSR J1023+0038: 'missing link' systems consisting of a pulsar nearing the end of a phase of recycling spin up. As such, we show that the Bursting Pulsar may also be associated with this class of objects. We discuss the implications of this scenario; in particular, we discuss the fact that the Bursting Pulsar has a significantly higher spin period and magnetic field than any other known Transitional Pulsar. If the Bursting Pulsar is indeed transitional, then this source opens a new window of opportunity to test our understanding of these systems in an entirely unexplored physical regime.

E1.3-0019-18 ACCRETION AND PROPELLER TORQUE IN THE SPIN-DOWN PHASE OF NEUTRON STARS: THE CASE OF TRANSITIONAL MILLISECOND PULSAR PSR J1023+0038

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The torque acting on PSR J1023+0038, one of the three confirmed transitional millisecond pulsars, was measured in radio pulsar and X-ray pulsar states. The source spins down in both states, and the torque in the X-ray pulsar phase is only about 27 % greater than in the radio pulsar phase (Jaodand et al. 2016). Using the inner disk radius, obtained recently by Ertan (2017) for the propeller phase which is close to the co-rotation radius and insensitive to the mass inflow rate, we have modelled the torque acting on PSR J1023+0038. The model can reproduce the observed torques consistently with the X-ray luminosities. The high and low X-ray luminosities in these sates correspond to accretion with spin-down (weak propeller) and strong propeller situations respectively. Several times increase in the disk mass-flow rate takes the source from the low-Lx, strong propeller to the high-Lx, accretion with spin-down phase. The resultant decrease in the inner disk radius increases the magnetic torque slightly, explaining the observed small increase in the spin-down rate. We have found that the spinup torque exerted by accreting material is much smaller than the magnetic spin-down torque exerted by the disk in both in both Lx states.

E1.3-0020-18 SIFAP: HIGH SPEED PHOTOMETRY FOR VARIABLE SOURCES IN THE OPTICAL BAND

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The recent advent of solid-state detectors originally developed for high energy physics is revolutionizing astrophysical measurements. An ultra-fast photometer based on the Silicon Photo Multiplier technology (SiFAP, Silicon Fast Astronomical Photometer) and capable of the single photon detection in the Optical band (320-900 nm) with a time resolution down to 25 ns was developed at the Department of Physics of Sapienza Università di Roma since 2009 to study astrophysical variable sources. I will show the working principle of SiFAP and its first results obtained from observations of the Crab Pulsar, Hz Her/Her X-1, Aql X-1, and the transitional millisecond pulsar PSR J1023+0038, performed at the 1.52 m Cassini Telescope at Loiano and the 3.58 m Telescopio Nazionale Galileo (TNG). I will discuss the properties of the optical pulsations observed from the millisecond pulsar PSR J1023+0038 (Ambrosino, Papitto et al., 2017, Nature Astronomy), as well as future prospects for fast optical photometry with SiFAP.

E1.3-0021-18 NEUTRON STAR PROPERTIES AND THE EVOLUTION OF MILLISECOND PULSARS

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I will review open questions on the spin and magnetic evolution of millisecond pulsars, as well as efforts to use millisecond pulsar observations to constrain neutron star properties.

E1.3-0022-18 TWO COEXISTING FAMILIES OF COMPACT STARS: THEORETICAL BACKGROUND AND ASTROPHYSICAL IMPLICATIONS

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It is usually thought that a single equation of state (EoS) model "correctly" represents all compact stars. In the present talk I will emphasize that two families of compact stars, viz., "normal" neutron stars and strange quark stars, can coexist in nature, and that neutron stars can get converted to strange quark stars through the nucleation process of quark matter in the stellar center. I will first briefly discuss the theoretical framework for the quark deconfinement phase transition in dense matter and in neutron star cores. Next, I will discuss some of the astrophysical consequences of the conversion process of neutron stars to quark stars, and particularly for the concept of limiting mass of compact stars (to be compared with measured neutron star masses) and the observational implications for millisecond pulsars. Finally, I will emphasize the additional complexity for constraining EoS models, for example, by stellar radius measurements using X-ray observations, if two families of compact stars coexist.

E1.3-0023-18 CONSTRAINING THE NEUTRON STAR MASS RADIUS RELATION WITH NICER OBSERVATIONS OF MILLISECOND PULSARS

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One of the primary goals of the Neutron Star Interior Composition Explorer (NICER) is to carry out sensitive X-ray observations of neutron stars in order to constrain the poorly understood equation of state of cold matter at densities exceeding the nuclear saturation density. The NICER mission is focusing on measuring the masses and radii of several relatively bright, thermally-emitting, rotation-powered millisecond pulsars, by fitting sophisticated models that incorporate all relevant relativistic effects and atmospheric radiation transfer processes to their periodic soft X-ray modulations. We will present NICER data of the targets observed for this purpose, and the technique and models that have been developed by the NICER team to estimate the masses and radii of these pulsars.

E1.3-0024-18 HOW CAN TRANSIENT ACCRETION CRUCIALLY AFFECT THE SPIN RATES OF MILLISECOND PULSARS?

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A crucial but previously unrecognized factor governing the spin evolution of millisecond pulsars is transient accretion. We numerically show that X-ray transients can spin up neutron stars to rates several times higher than can persistent accretors, for the same long-term average accretion rate. We analytically show that this happens because the equilibrium spin frequency for a transient can be several times higher than that for a persistent source with the same average accretion rate. Note that, as we explicitly argue for the first time, the spin equilibrium condition for a transient source is the zero net angular momentum transfer to the neutron star in each outburst cycle. Our results imply the existence of a population of submillisecond pulsars, which is not observed. This may require an additional spin-down mechanism, such as gravitational radiation, for the fastest-spinning accreting pulsars.

E1.3-0025-18 FROM TRANSIENT LOW-MASS X-RAY BINARIES TO REDBACK MILLISECOND PULSARS

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Redback millisecond pulsars (MSPs; hereafter redbacks) are a subpopulation of eclipsing MSPs in close binaries. The formation processes of these systems are not clear. The three pulsars showing transitions between rotationand accretion-powered states belong to both redbacks and transient low-mass X-ray binaries (LMXBs), suggesting a possible evolutionary link between them. Through binary evolution calculations, we show that the accretion disks in almost all LMXBs are subject to the thermal-viscous instability during certain evolutionary stages, and the parameter space for the disk instability covers the distribution of known redbacks in the orbital period-companion mass plane. We accordingly suggest that the abrupt reduction of the mass accretion rate during quiescence of transient LMXBs provides a plausible way to switch on the pulsar activity, leading to the formation of redbacks, if the neutron star has been spun up to be an energetic MSP. We investigate the evolution of redbacks, taking into account the evaporation feedback, and discuss its possible influence on the formation of black widow MSPs.

E1.3-0026-18 MASS MEASUREMENTS FOR MILLISECOND PULSARS AND A NEW CLASS OF ECCENTRIC BINARY MILLISECOND PULSARS

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In this talk, I will review recent and upcoming measurements of the masses of millisecond pulsars (MSPs) in a diverse set of binary systems. These measurements have showed conclusively that MSPs have a very wide range of masses; significantly wider than the range observed for neutron stars in double neutron star systems; these have introduced important constraints on the equation of state of dense matter, a fundamental problem of nuclear physics. Somewhat surprisingly, MSP masses show no relation to any spin characteristics of the systems or the orbital characteristics of their host systems, nor their kinematic properties. I then focus on a new class of binary MSPs with eccentric orbits. The characteristics of these systems are at odds with the predictions of standard stellar evolution theories. I then show how the recent mass measurements for MSPs in these systems have ruled out most of the hypotheses advanced to explain their formation, and confirm the lack of any correlation of the MSP mass and the host system. I finally discuss the evidence on whether MSP masses are bimodal or not.

E1.3-0027-18 INCLINED MAGNETIC DIPOLE ACCRETION ONTO ROTATING NEUTRON STARS

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The estimate of the magnetospheric radius, marking the boundary between the closed magnetosphere of an accreting neutron star and the material in the surrounding Keplerian accretion disk, is a long standing problem in high energy Astrophysics. We review the magnetospheric radius calculations in the so-called magnetically threaded disk model, comparing the simplified approach originally proposed by Ghosh Lamb (1979) with the revised version proposed by Wang (1987), Wang (1995), and Wang (1997). We show that for a given set of parameters the revised magnetically threaded disk model predicts a magnetospheric radius that is significantly smaller than that derived from the Ghosh Lamb (1979) treatment, especially when large inclination angles between the neutron star rotation and magnetic field axes (60 deg) are considered. Accretion onto a fast rotating neutron star is thus allowed in the Wang (1987), Wang (1995), and Wang (1997) prescriptions at lower mass inflow rates before it gets inhibited by the onset of the propeller regime. As an example, we apply these calculations to the case of transitional pulsars, which have shown X-ray pulsations at an unprecedented low luminosity level compared to other neutron stars in X-ray binaries. Assuming that the transitional pulsars are endowed with large inclination angles between the magnetic and rotation axes, we show that accretion at luminosities of 10 33 erg s 1 (and thus X-ray pulsations) may still be expected without invoking strong propeller outflows. More generally, we propose that accretion driven X-ray pulsations from rotating neutron stars in X-ray binaries can take place at a very low luminosity level in all those sources characterized by a large inclination angle between the rotation and magnetic field axes.

E1.3-0028-18 THE COLD SURFACE OF MILLISECOND PULSARS: A GOLD MINE FOR FUNDAMENTAL PHYSICS

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The small hot polar cap emission (106K) of millisecond pulsars generates the pulsations that are modelled to d magnetic field objects. But the cold thermal emission from the remainder of their surface (at colder temperature term evolution and the amplitudes of r–modes inside these old objects. In this talk, I will present some effortst U V and soft X – ray bands, in order to determine its properties.

E1.3-0029-18 X-RAY BOUNDS ON THE R-MODE AMPLITUDE IN MILLISECOND PULSARS

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Istanbul University, Faculty of Science, Istanbul, Turkey Tugçe Kocabıyık, tugcekocabiyik3406@gmail.com Istanbul University, Faculty of Science, Istanbul, Turkey r-modes are global unstable oscillations expected to occur in rapidly rotating neutron stars. Because these modes are unstable, if not damped they are expected to grow and emit gravitational waves, which should spin the neutron star down. On the other hand the damping of these modes inside the neutron star should dissipate a significant amount of energy that heats the star, which depends on the interior composition of the object. Observations or limits on the surface emission of millisecond pulsars may prove to be a very useful probe to put constrains on the amplitude of r-mode oscillations and hence the interior of neutron stars. In this talk we present the first results of our search for thermal surface emission from some of the fastest known millisecond pulsars analyzing X-ray data via a novel neutron star atmosphere model, which takes into account the general relativistic effects due to rapid rotation. Our initial results show that the present data imposes very strong limits on the amplitude of r-modes, which shows that there is significant damping in these objects

E1.3-0030-18 THE NORTH-AMERICAN NANOHERTZ OBSERVATORY FOR GRAVITATIONAL WAVES: STATUS, RESULTS, AND PROSPECTS

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The NANOGrav Physics Frontiers Center uses the Arecibo Observatory and the Green Bank Telescope (the two most sensitive radio telescopes in the world) to monitor very stable millisecond pulsars with very high precision. Our goal is to detect low-frequency gravitational waves and use them to learn about supermassive black-hole binaries and other gravitationalwave sources in the nanohertz band. Our access to these observatories has allowed us to reach unprecedented sensitivities, and we expect to make a detection soon. In this talk I discuss the status and prospects of our searches.

E1.3-0031-18 EROSITA – STATUS AND SCIENTIFIC PROSPECTS

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Max Planck Institute for Extraterrestrial Physics, Garching, Germany eROSITA (extended ROentgen Survey with an Imaging Telescope Array) is the core instrument on the Russian Spektrum-Roentgen-Gamma (SRG) mission which is currently scheduled for launch in fall 2018. eROSITA will perform a deep survey of the entire X-ray sky. In the soft band (0.5-2 keV), it will be about 30 times more sensitive than ROSAT, while in the hard band (2-8 keV) it will provide the first ever true imaging survey of the sky. The design driving science is the detection of large samples of galaxy clusters to redshifts $z > 1$ in order to study the large scale structure in the Universe and test cosmological models including Dark Energy. In addition, eROSITA is expected to yield a sample of a few million AGN, including obscured objects, revolutionizing our view of the evolution of supermassive black holes. The survey will also provide new insights into a wide range of astrophysical phenomena, including neutron stars and pulsars, X-ray binaries, active stars and diffuse emission from supernova remnants. The talk reports on the status of eROSITA and its scientific prospects with the main focus on pulsars.

E1.3-0032-18 ORBITAL DYNAMICS OF CANDIDATE TRANSITIONAL MILLISECOND PULSAR 3FGL J1544.6-1125: AN UNUSUALLY FACE-ON SYSTEM

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We present the orbital solution for the donor star of the candidate transitional millisecond pulsar 3FGL J1544.6-1125, currently observed as an accreting low-mass X-ray binary. The orbital period is 0.2415361(36) days, entirely consistent with the spectral classification of the donor star as a mid to late K dwarf. The semi-amplitude of the radial velocity curve is exceptionally low at K2 = 39.3 ± 1.5 km s−1, implying a remarkably face-on inclination in the range 5- 8°, depending on the neutron star and donor masses. After determining the veiling of the secondary, we derive a distance to the binary of 3.8 ± 0.7 kpc, yielding a 0.3-10 keV Xray luminosity of 6.1±1.9×1033 erg s−1, similar to confirmed transitional millisecond pulsars. As face-on binaries rarely occur by chance, we discuss the possibility that Fermi-selected samples of transitional millisecond pulsars in the sub-luminous disk state are affected by beaming. By phasing emission line strength on the spectroscopic ephemeris, we find coherent variations, and argue that these variations are most consistent with emission from an asymmetric shock originating near the inner disk.

E1.3-0033-18 A HIGHLY MAGNETIC SPIDER: PSR J2129-0429 IN THE X-RAY AND OPTICAL BANDS

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Redback pulsars are eclipsing millisecond pulsars (MSP) binaries that have short orbital spin periods and companion masses Mc > 0.2 M. PSR J21290429 is a 7.62 ms redback with a nondegenerate binary companion that is likely in an early stage of pulsar recycling. It has one of the largest companion masses for a redback system (0.4 M) and has an unusually high surface magnetic field for an MSP. We study X-ray and optical emission from PSR J21290429 using new NuSTAR and LCOGT data of the system as well as archival Swift and XMM-Newton data. The system is peculiar in several ways. It's light-curve exhibits a persistent double-peaked feature centered of inferior conjunction, and shows orbital modulation 5 times greater than is typical for similar systems. Its X-ray spectrum has a very hard power-law component (= 1.1 1.2) which, extends to 40 keV and exhibits an efficiency of up to a few percent in the X-ray band. The spectrum's hardness is suggestive of driven magnetic reconnection occurring at the shock. In addition, our optical observations suggest that the companion is expanding and may overflow its Roche lobe and begin accreting.

E1.3-0034-18 AN UPDATED RELATIONSHIP BETWEEN THERMAL X-RAY LUMINOSITY AND SPIN-DOWN POWER FOR MILLISECOND PULSARS.

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Thermal emission from millisecond pulsars (MSPs) is thought to be primarily a result of heating by particles accelerated in the magnetosphere which in turn should relate to the spin-down power. Previous studies of the relationship between the spin-down power and the thermal X-ray luminosity of MSPs have been hindered by distance uncertainties and inconsistent analysis techniques.There is also the issue of untangling intrinsic spin-down from apparent due to the Schklovskii effect which requres a determination of proper motion. In recent years, both VLBI studies and pulsar timing arrays have resulted in many new, robust determinations of parallax distances to MSPs as well as proper motions. We will present an updated relationship derived only from MSPs with well determined distances using consistent analysis techniques. In principle, this could be the basis of X-ray derived estimates of distances as well as an aid to discriminating thermal emission from magnetospheric emission in more distant MSPs.

E1.3-0036-18 UNCERTAINTIES IN MASS AND RADIUS MEASUREMENTS FOR HERCULES X-1 AND SELECT MILLISECOND X-RAY PULSARS

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X-ray pulse shapes depend on the properties of the emission spot or emission column on the surface of the neutron star (size, shape, location, and emissivity) and on the neutron star's properties (mass, radius, and spin). The goal of modelling X-ray pulse shapes is to measure or constrain mass and radius values for neutron stars. These can then be compared to predictions from calculations from various equations of state (EOS) in order to test the EOS of supernuclear density material. Here, recent modelling work on Hercules X-1 and millisecond X-ray pulsars (SAX J1808-3654, XTE J1807-294 and XTE J1814-338) is studied, with emphasis on determining uncertainties in mass and radius values, and their comparison with theoretical mass-radius calculations.

E1.3-0037-18 COORDINATED MULTI-WAVELENGTH STUDIES OF TRANSITIONAL MSPS

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Within the past few years, three neutron star binaries have been observed to switch between accreting and rotation-powered pulsar states, cementing the standard model for the formation of rotation-powered millisecond pulsars via spin-up by accretion in a low-mass X-ray binary. These so-called transitional millisecond (tMSPs) pulsars exhibit intriguing behavior spanning from radio frequencies to the GeV gamma-ray range. Multi-wavelength observations of tMSPs hold the promise of providing fresh insight into the physics of accretion and shocks, as well as compact binary evolution. I will present an overview of our extensive coordinated multiwavelength observing campaigns of confirmed and candidate tMSPs, as well as on-going surveys to uncover new systems.

RESEARCH IN ASTROPHYSICS FROM SPACE (E)

BLACK HOLE ASTROPHYSICS: OBSERVATIONAL EVIDENCE OF THEORETICAL MODELS (E1.4)

E1.4-0001-18 WHAT DO THE SPECTRAL AND TIMING PROPERTIES OF BLACK HOLES TELL US ABOUT THE ACCRETION FLOW?

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It is well understood that viscosity maintains the total angular momentum distribution in an accretion flow but it is difficult to maintain viscosity itself by any known self-regulating process. or a given injected flow at the outer edge, it is the viscous mechanism which eventually decides how the matter is distributed in the flow. Thus, fixing the flow rate or specific angular momentum distribution ab initio could be. From the first principles, I show beyond reasonable doubt that the disk must have, in general, at least two independent components, Keplerian and sub-Keplerian, which have higher and lower viscosity parameters respectively. Their relative importance primarily dictates the spectral and timing properties of the black holes. We show that the entire accretion-ejection jigsaw puzzle is also neatly resolved with Two Component Advective flow (TCAF) model. Fits by TCAF enables one to have physical parameters such as the two accretion rates and the size and optical depths of the Compton cloud, assumed to be the post-shock region of the disk in TCAF paradigm. We also get QPO frequencies using resonance condition between the infall and the cooling time scales. We require only four parameters to fit the spectra and extract mass of black holes. The Normalization is also constant for a given object across the spectral states. Jets are produced from the Compton cloud region. They are acceleterated by collapse of magnetized Compton clouds and collimated by toroidal flux tubes.

E1.4-0002-18 BLACK HOLE MHD

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It is now widely accepted that much of the activity observed around black holes is mediated by relatively strong electromagnetic field. This can be responsible for transporting angular momentum in a disk, energizing a corona and a "lamppost", driving a centrifugal wind and extracting power from a spinning black hole. Some progress, problems and prospects on each of these topics will be discussed.

E1.4-0003-18 GEODESIC MESH MHD, A NEW PARADIGM FOR COMPUTATIONAL ASTROPHYSICS APPLIED TO SPHERICAL SYSTEMS

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Most astrophysical systems are spherical; even so, they are simulated with codes that are either Cartesian or logically rectangular. This fundamental dichotomy introduces substantial difficulties in the simulation of several astrophysical systems. In addition, most astrophysics problems involve MHD turbulence which requires at least fourth order accurate codes for their faithful simulation. However, most MHD codes tend to be second order accurate. It is, therefore, important to fundamentally rethink what simulation capabilities are desired and how one can deliver on the goals of such a simulational capability. In this paper we present a constraint-preserving MHD scheme on geodesic meshes which fundamentally bypass the coordinate singularities that occur on logically rectangular meshes. Furthermore, the scheme is up to fourth order accurate. The talk will focus on presenting the novel method and also describing frontline astrophysical applications where such a pathbreaking capability is needed.

E1.4-0004-18 UNDERSTANDING THE INNER ACCRETION FLOW AROUND GALACTIC X-RAY BINARIES WITH NUSTAR

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Over the last six years, NuSTAR has performed broad band X-ray spectral and timing studies of Galactic black holes. These have constrained black hole spins, and probed the geometry and physics of the accretion flow near the central compact object. I will present an observational review, highlighting progress made using NuSTAR together with Swift and XMM. I will also point out outstanding questions that can be addressed through a combination of observations and improved modeling techniques.

E1.4-0005-18 MHD WINDS AS X-RAY ACSORBERS IN AGN ACROSS THE BLACK HOLE MASS SCALES

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We present detailed photoionization calculations of MHD winds off accretion disks associated with AGN and/or LMXRBs, by following the transfer of radiation along the observer's Line of Sight (LoS), to model the properties of the ubiquitous X-ray absorbers in the spectra of accreting black holes. We argue that the self-similarity of these winds implies that their photoionization properties are independent of the mass of the accreting object, if the luminosity and wind mass loss are scaled to their Eddington values. Our models reproduce the Absorption Measure Distribution (AMD), introduced to account for the observed Hydrogen-equivalent column, NH, of a large number of ionic species as a function of their ionization parameter ξ. Furthermore, since our wind models determine also the winds' local velocities, we also compute and present the profiles of the absorption lines of the corresponding transitions. These compare favorably to those observed in both AGN (NGC 3783) and LMXRB (GRO 1655-40). Successful fits to the data provide both the wind mass flux as function of radius and the observer inclination angle .

Most importantly, the mass flux in the winds is found to increase with distance, with m˙ ∝ rs with s 0.3 0.5, indicating that most of the available mass is lost at the largest accretion disk radii. We present simulations of the line profiles for the AGN and LMXRB which yield well constrained values for m˙ (r) and ϑ.

E1.4-0006-18 MAGNETIZED ADVECTIVE ACCRETION FLOWS AROUND BLACK HOLES

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Advective, sub-Keplerian accretion flows appear to be indispensable to explain observed data, particularly to explain hard spectral states in black hole sources. Such flows are hot enough, of two temperature in nature: e.g. two component advective flow (TCAF), to name as one of the successful models. This talk will explore the magnetized version of this model and its several natural implications. I will attempt to demonstrate that along with gravitational force and centrifugal barrier, strong magnetic fields and related barrier(s), if present, may play interesting (additional) roles to reveal astrophysical features like, multiple QPOs from the same source, outflows/jets etc. In addition, large scale strong fields can help transporting angular momentum even without any α-viscosity, when indeed strong fields suppress MRI and related transport.

E1.4-0007-18 ON RELATIVISTIC FLOWS AROUND BLACK HOLES

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We study accreting matter described by relativistic equation state onto a general black hole. The infalling matter is subjected to viscous dissipation and general radiative cooling processes. We present all possible transonic accretion solutions. We show how the solutions change with the change in flow composition, accretion rate and viscosity parameter. The effect of black hole spin is also discussed. We also discuss observational consequences of such solutions.

E1.4-0008-18 THE FORMATION OF STELLAR BLACK HOLES: OBSERVATIONS VERSUS THEORETICAL MODELS

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I will review the observational insights on Black Holes (BHs) formed by implosion without large natal kicks from: (1) the kinematics in three dimensions of space of five Galactic BH X-ray binaries (BH-XRBs), (2) the diversity of optical and infrared observations of massive stars that collapse in the dark, with no luminous SN explosions, possibly leading to the formation of BHs, and (3) the sources of gravitational waves produced by mergers of stellar BHs detected with LIGO-Virgo. Multiple indications of BH formation without ejection of a significant amount of matter and with no natal kicks obtained from these different areas of observational astrophysics, and the recent observational confirmation of the expected dependence of BH formation on metallicity and redshift, are qualitatively consistent with the high merger rates of binary black holes inferred from the first detections with LIGO-Virgo.

E1.4-0009-18 MASS ACCRETION RATE FLUCTUATIONS IN BLACK HOLE X-RAY BINARIES

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Over the past 20 years, a consistent phenomenology has been established to describe the variability properties of Black Hole X-ray Binaries (BHBs). However, the physics behind the observational data is still poorly understood. The recently proposed model PROPFLUC assumes a truncated disc/hot inner flow geometry, with mass accretion rate fluctuations propagating through a precessing inner flow. These two processes give rise respectively to broad band variability and a quasi-periodic oscillation (QPO). In this scenario, because of propagation, the emission from different regions of the disc/hot flow geometry is correlated. In our study we applied the model PROPFLUC on different BHBs (including XTE J1550-564 and Cygnus X-1) in different spectral states, fitting jointly the power spectra in two energy bands and the crossspectrum between these two bands. This represents the first study to utilize quantitive fitting of a physical model simultaneously to observed power and cross-spectra. In some case (XTE J1550-564), we found quantitative and qualitative discrepancies between model predictions and data. We concluded that those discrepancies are generic to the propagating fluctuations paradigm and may be related to the mechanism originating the QPO.

E1.4-0010-18 GENERAL RELATIVISTIC NUMERICAL SIMULATION OF SUB-KEPLERIAN TRANSONIC ACCRETION FLOWS ONTO BLACK HOLES

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We study time evolution of sub-Keplerian transonic accretion flows onto black holes using a general relativistic numerical simulation code. We perform simulations around the black holes having zero as well as non-zero rotation. We first compare one-dimensional simulation results with theoretical results and validate the performance of our code. Next, we present results of axisymmetric, two-dimensional simulation of advective flows. We find that even in this case, for which no complete theoretical analysis is present in the literature, steady state shock formation is possible.

E1.4-0011-18 PROBING THE INNER REGIONS AROUND ACCRETING BLACK HOLES

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Accretion of matter onto compact objects such as black holes (BHs) displays a common phenomenology based on the fact that the physical processes acting on these systems are the same and appear to scale with the mass of the BH, covering a wide range of values from stellar-mass (e.g. black hole binaries; BHBs) to supermassive (e.g., active galactic nuclei; AGN). Most of this phenomenology is observed in the X-ray band, including relativistic and ionized reflection, reverberation time lags, and quasi period oscillations (QPOs). Here we discuss several controversial results derived from our analysis of the observational data for several accreting BHs. In particular, the physical origin of the hard X-ray continuum in accreting black holes is still unknown, as it can be explained by either a Comptonizing gas of hot electrons (the "corona") or the base of a relativistic jet. The geometry and properties of this central source of X-rays are still a mystery. In BHBs, the truncation of the accretion disk is also a controversial subject, with predictions that differ by orders of magnitude when reflection spectroscopy and/or timing techniques are implemented. Another unexpected result is the questionably large abundance of iron required by

most reflection models to explain the observable data from both BHB and AGN alike. The strong correlations among these and other important parameters pose serious limitations on the understanding of accreting sources. We present concrete efforts in answering these questions for several emblematic BHBs and AGNs, with particular emphasis on the advances and limitations of current models for ionized X-ray reflection in strong gravitational fields.

E1.4-0012-18 A NEW LAMPPOST REFLECTION MODEL AND ITS APPLICATION TO NGC 4151 AND CYG X-1

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We study the X-ray emission in the lamppost geometry, which has become a popular model for both X-ray binaries and AGNs. We point out the importance of the reduction of the observed luminosity due to photon trapping, time dilation and gravitational redshift, which effects have been neglected in most of lamppost studies. We also point out a major effect overlooked so far, namely that of the emission of the bottom lamp being gravitationally focused toward an observer on the top side of the accretion disc. These effects, with several other improvements in modeling the observed spectra of thermal Comptonization and its reflection, are implemented in our new xspec model for the lamppost geometry. We apply the model to the Suzaku/NuSTAR observations of NGC 4151 and Cyg X-1 in its hard state and we find that in both cases it favors truncation of an optically thick disc above 10 gravitational radii.

E1.4-0013-18 FORMATION OF TWO-COMPONENT ADVECTIVE FLOWS AROUND NEUTRON STARS

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We use the Smoothed Particle Hydrodynamics (SPH) method to simulate the behavior of viscous matter accreting on a neutron star. The fundamental difference between accretion onto black holes and neutron stars is the presence of a hard surface for the latter, which forces matter to stop moving in the radial direction at the surface of the star, making the flow subsonic. On the contrary, for black holes, matter is advected into the horizon supersonically. Thus, apart from the immediate vicinity of the compact object, the flow should be similar for both the objects. We show that for an advective flow with nominal viscosity and angular momentum, the solution allows two shocks in the flow. The outer one, forms due to strong centrifugal barrier and is called CENtrifugal pressure dominated Boundary Layer or CENBOL, which is a common feature for both neutron stars and black holes. The inner shock forms very close to the surface of a neutron star, due to the presence of the physical boundary. We use different viscosity prescriptions to study the behavior of the shock wave. The cases we study show a significant deviation from the ones studied in the context of black holes. We show how the angular momentum distribution deviates from a Keplerian distribution when 1) the spin of the neutron star is varied, 2) the radiative pressure effect from NBOL is added. The behavior of shock wave with the variation of viscosity parameter is also studied to determine the critical value of the viscosity parameter, up to which shocks are allowed in the flow. We study 1) the time evolution of such a viscous flow, 2) the oscillation of the post-shock region with viscous time-scale for intermediate viscosity. When cooling effects are added, the CENBOL cools down and the outer shock moves in towards the star and is seen to be oscillating steadily. If the viscous stress is above its critical value in the equatorial plane, angular momentum is redistributed faster and a Keplerian-like disk is produced. In presence of strong cooling (blackbody emission from the optically thick region), a disk is formed along the equatorial plane. The two-components, disk, and halo are disaggregated out of the halo component and remains steadily oscillating through hundreds of dynamical timescales. This indicates that the TCAF is the most general flow configuration for a neutron star when the magnetic field is weak.

E1.4-0014-18 HYPERMAGNETIZED ACCRETION DISKS: A GLOBAL STABILITY ANALYSIS

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We examine the stability properties of hypermagnetized accretion disks in a global framework, with a particular focus on the evolution of the weak-field magnetorotational instability (MRI), which is believed to trigger angular momentum transport in accretion flows. Local magnetohydrodynamic (MHD) simulations have shown that in the presence of a sufficiently strong but subthermal (plasma-β 1) vertical magnetic flux, a large-scale, suprathermal (plasma-β

< 1) toroidal field is generated, which becomes the dominant source of pressure support in the accretion disk. We term such magnetically dominated disks as hypermagnetized accretion disks, which have the potential to resolve several observational shortcomings of the standard, geometrically thin, accretion disk model. The suprathermal toroidal field makes the curvature effects due to the cylindrical geometry of the disk non-negligible, which are otherwise ignored in weak-field studies. Furthermore, these intrinsically global effects may not be accurately captured in a local model. Hence, in order to self-consistently account for the curvature effects, we perform a global eigenvalue analysis of the linearized MHD equations for a compressible, differentially rotating flow in cylindrical geometry. We find that MRI gets highly suppressed at a critical suprathermal toroidal field and two new instabilities appear beyond this limit. These results are additionally verified using numerical simulations. Our analysis partly confirms the predictions of a local model but reveals important differences, which highlight the necessity of a global treatment to accurately model hypermagnetized accretion disks.

E1.4-0015-18 RADIATION SPECTRA OF TWO TEMPERATURE ACCRETION DISCS AROUND ROTATING BLACK HOLES

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The self-consistent two temperature transonic accretion solutions around rotating black holes are important to understand the observed spectro-temporal features. We study the twotemperature accretion solutions in presence of radiative dissipations and use these solutions to compute the emitted radiation spectrum from the accretion disc. We have taken into account several general relativistic effects on the emitted radiation. We aim to compare our model calculations with the observed spectra of few black hole candidates and estimate the flow parameters.

E1.4-0016-18 A NON-KERR EXTENSION OF THE RELXILL X-RAY REFLECTION MODEL

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The X-Ray reflection spectrum produced by accretion disks around black holes is one of a few electromagnetic observations of black holes that can be used to test the Kerr hypothesis and General Relativity in the strong gravity regime. RELXILL is currently the most advanced model for the X-Ray reflection spectrum, but it cannot model the spectrum for non-Kerr spacetimes. In this talk I will present a recent extension of RELXILL to a generic stationary, axisymmetric, and asymptotically flat black hole metric (Astrophys.J. 842: 76, 2017). I will show that this extension retains the accuracy for the Kerr spacetime that is expected of the RELXILL model, but can also be used to test the Kerr hypothesis. I will also present the results from recent work in placing constraints on deviations from the Kerr metric using observational data (Phys. Rev.Lett. 120, 051101, 2018).

E1.4-0017-18 VERTICAL OSCILLATION IN THICK ACCRETION FLOW AND ITS EFFECT ON OUTFLOWS

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We study the time evolution of two-dimensional inviscid accretion flows around black without reflection symmetry on the equatorial plane in order to inspect if the disk along with the centrifugal barrier oscillated vertically. In the inviscid limit, we find that the CENtrifugal pressure supported BOundary Layer (CENBOL) is oscillating vertically, more so, when the specific angular momentum is higher. As a result, the rate of outflow produced from the CENBOL also oscillates and also, outflow rates in the upper half and the lower half are found to be anti-correlated. The cause of oscillation appears to be due to the interaction among the backflow from the centrifugal barrier, the outflowing winds and the inflow. We carry out the exercise for a series of specific angular momentum (Λ) of the flow in order to demonstrate effects of the centrifugal force on this interesting behavior. We find that, as predicted in theoretical models of disks in vertical equilibrium, the CENBOL is produced only when the centrifugal force is significant and more specifically when $\Lambda > 1.5$. Outflow rate itself is found to increase with Λ as well and so is the oscillation amplitude. For low angular momentum, the backflow as well as the oscillation are missing.

E1.4-0018-18 PHOTON MOTION IN THE FRAMEWORK OF GENERAL RELATIVITY COUPLED TO NON-LINEAR ELECTRODYNAMICS

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We discuss the photon motion in the framework of general relativity coupled to non-linear electrodynamics. Photons no longer follow the null-geodesics of the spacetime but rather nullgeodesics of associated effective metric. Here we compare structure of circular geodesics and time-delays of neutrinos in Bardeen spacetimes with those of photons in effective geometry. We also discuss construction the Keplerian disks images in the Bardeen spacetimes and compare them with the images of Keplerian disks in RN spacetime.

E1.4-0019-18 TCAF SOLUTION AS AN ADDITIVE TABLE MODEL IN XSPEC: AN EFFICIENT TOOL TO UNDERSTAND ACCRETION FLOW PROPERTIES OF BLACK HOLES

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It has been more than two decades since Chakrabarti and his collaborators for introduced the two component advective flow (TCAF) model as a global solution to accretion flow processes around black holes. In 2014, we successfully been able to implement this solution into HEASARC's spectral analysis software package XSPEC as an additive table model to fit energy spectra from black hole candidates (BHCs) and obtain physical informations about accretion flow processes such as, two component (Keplerian disk and sub-Keplerian halo) accretion rates, shock (location, i.e., the size of the Compton cloud, and the compression ratio) parameters, mass of the black hole. Evolutions of spectral and timing properties during active phases of black hole X-ray binaries are now more transparent from the nature of the variations of the TCAF model fitted/derived physical parameters. Reasons of different spectral states and their transitions (if any) of BHCs are also clear. One can predict frequencies of the dominating type-C quasi-periodic oscillations (QPOs) from TCAF model fitted shock parameters and even estimate most accurate mass range of an unknown BHC from TCAF fits. One can estimate Xray flux contributions from jets/outflows (if present) from TCAF model fitted spectral analysis as well. To our knowledge this gives us the most physical tool to investigate the accretion flow dynamics of BHCs during their active phases.

Chakrabarti, S.K., Titarchuk, L.G., 1995, ApJ, 455, 623

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E1.4-0020-18 SPECTRAL AND TEMPORAL PROPERTIES OF THE X-RAY QPO IN ACCRETING BLACK HOLE SYSTEMS.

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X-ray quasi-periodic oscillations are an interesting phenomenon, as they show the existence of a (quasi-) clock in otherwise broad band timescale systems. I am going to review the observed spectral and temporal properties of both the lowand high-frequency QPO across the range of black hole masses. Then I will consider those models of the QPO which can make predictions of their spectral and timing properties, i.e. models that consider the spectral formation of the X-ray emission, including the specific process of QPO. Finally I will compare the model predictions with the observations.

E1.4-0021-18 THE REFLECTION SPECTRUM OF CYGNUS X-1 AS MEASURED BY NUSTAR

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Cygnus X-1 is an accreting black hole binary that has been persistently bright throughout the history of X-ray astronomy. Over the years, observations of Cyg X-1 across the electromagnetic spectrum have led to breakthrough results, including dynamical evidence that its compact object is a black hole, measurements indicating that the black hole is rapidly rotating, resolving its compact jet in the radio band, obtaining parallax distance and proper motion measurements, and the discovery of soft and hard spectral states. The NuSTAR satellite has obtained 3-79 keV observations of Cyg X-1, sampling soft, hard, and intermediate states over the past several years. The NuSTAR bandpass, energy resolution, and throughput provide measurements of the Compton reflection component with unprecedented quality, and results have been reported for the soft state (e.g., Tomsick et al. 2014; Walton et al. 2016), the hard state (e.g., Parker et al. 2015; Basak et al. 2017), and the intermediate state (Tomsick et al. 2018). The relativistic distortion of the reflection component depends on the location of the inner radius of the disk and the geometry of the source, and spectral modeling can lead to constraints. However, in some cases, the models also lead to unphysically high iron abundances, and this may be a source of systematic uncertainty for the other model parameters. Here, we investigate possible reasons for the high iron abundances, focusing on detailed modeling of one of the intermediate state Cyg X-1 spectra.

E1.4-0022-18 SIGNATURES OF BLACK HOLES – STAR MOTION, ACCRETION DISKS, AND SHADOWS

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We consider the effects of Black Holes on nearby objects, like stars, light, and accretion disks. All the effects related to the various objects can be used to identify the properties of the Black Hole, that is, mass, spin, and perhaps additional parameters. For the description of the effects we work within a wide class of analytically given Black Hole space-times, namely the PlebanskiDemianski electrovac solutions of the Einstein field equations. We introduce the basic notions of Black Holes like the horizon, the singularities, the ergoregion, causality violation regions, and the region of outer communication.

At first we describe the motion of stars around Black Holes by analytically solving the geodesic equation. From these solution we can analytically calculate the perihelion shift, the LenseThirring effect and the conicity as major observables. From corresponding observations the Black Hole parameters can be deduced. We also discuss the motion of spinning stars.

Next we introduce the notion of the shadow of a Black Hole. We analytically calculate the shadow for all Plebanski-Demianski Black Holes. We also calculate the shadow for moving observers. Based on these analytical results we, among others, determine the exact shape and the size of the shadow of the Black Holes SgrA* and of M87 which will be observed with the EHT.

At last we discuss accretion disks. We analytically determine the shape of thick disks and show how their shape depends on the Black Hole's space-time geometry.

E1.4-0023-18 TIME LAG PROPERTIES OF THE BLACK HOLE X-RAY TRANSIENTS: A COMPARISON OF HIGH AND LOW INCLINATION SOURCES

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We study the variability properties of black hole X-ray transients during outbursts for the low (GX339-4, XTE J1650-500, XTE J1752-223, XTE J1817-330 etc.) and high inclination (H1743-322, XTE J1859+226, XTE J1748-288, XTE J1550-564, GRO J1655-40, GRS 1915+105

etc.) sources. We closely compare the evolution of the sources in terms of Quasi Periodic Oscillation (QPO) frequency and time lag. We study the energy dependence of time lag and QPO amplitude. We find that time lag is always positive (i.e., hard lag) for lower inclination objects and time lag switches from hard to soft for the higher inclination sources. We concluded that the evolution of QPO frequency is independent of the inclination of the source whereas time lag depends on the inclination. These behaviors indicate the implication of specified accretion geometry during the evolution of the source.

E1.4-0024-18 SPECTRAL STUDY OF DIFFERENT BLACK HOLE CANDIDATES AND MEASUREMENT OF SPIN PARAMETER

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We study different black hole candidates using different satellites (RXTE, Swift and NuSTAR) data. We show how the spectral shape changes with the change in geometry of the disk and accretion rates. Our analysis attempts to explain these using TCAF model fitted physical parameters. We also explain different spectral states of a complete outburst from the accretion rate behavior. It is evident that the evolution of flow parameters in the decline phase may not retrace path of the rising phase. We shed light on that from our model fitting. The presence of Fe Kα line is well detected in accretion disk for Galactic X-ray sources and active galactic nuclei due to the rotating matter around the central object. We study the presence of Fe Kα line emission from the NuSTAR observation of transient source GX 339-4 during its 2013 outburst. Throughout the outburst, to fit the spectra with TCAF model, we require LAOR model. Our estimated value of spin parameter is 0.99 for this candidate.

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E1.4-0025-18 NATURE OF XTE J1118+480 DURING ITS APPARENT 2000 OUTBURST

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Detailed spectral and temporal study of Galactic halo black hole candidate XTE J1118+480 has been done using the archival data of RXTE PCA and HEXTE instruments to study nature of the source in a broad energy range. During 2000 outburst of the source, very low frequency quasi-periodic oscillations (QPOs) are observed. The spectral analysis of the source has been done with two types of models: the phenomenological power-law (PL) and the physical two component advective flow (TCAF) fits file in XSPEC. From the nature of the evolution of the spectral fitted parameters, it is evident that the 2000 outburst or active phase is not similar to a 'conventional' type outbursts. During the entire phase of the so-called outburst, source remained in hard/low hard spectral state with low photon index values and high dominance of PL flux or sub-Keplerian halo matters. The source was highly dominated by jets/outflow, which was evident from high radio fluxes during most period of the outburst. More interestingly, during the late declining phase of the outburst, PL indices increased slowly, i.e., spectra become slightly softer (within the hard spectral band) with a slow rise in Keplerian disk rate. This feature is also quite uncommon. So, we feel that this 2000 active phase of the source could not be termed as 'outburst'. We also estimate the mass of the BHC and contribution of the jet X-rays from our TCAF model fitted spectral analysis.

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E1.4-0026-18 CONSTRAINING THE MASS OF CYGNUS X-1 USING TWO COMPONENT ADVECTIVE FLOW SOLUTION

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The galactic black hole candidate Cygnus X-1, one of the brightest sources in the sky, is the first ever black hole candidate to be discovered. Despite being a very well-studied source due to its persistent brightness in X-rays, there has been a lot of difficulty in determining its mass since its discovery. While Bolton (1972) and Paczynski (1974) estimated the lower limit of the mass of the black hole to be ~ 4M0, Gies and Bolton (1986) reported that the mass of the compact object should lie in the range 7 M0 to 16 M0. Ninkov et al. (1987) further estimated the mass of the compact object to be 10 ± 1M0 while according to Herrero et al. (1995) the estimated mass is between 5M0 15M0. All these mass measurements are subject to several uncertainties because of the high degree of errors associated with the measurement of the distance. Once Reid et al. (2011) constrained the distance to be ~ 1.86 kpc, Orosz et al. (2011) provided a stronger constraint on the mass of the BHC in Cygnus X-1 to be M = 14.8 1.0M0. In this work, we estimate the mass of Cygnus X-1 by analyzing its spectral properties. We use RXTE/PCA archival data and implement the Two Component Advective Flow Solution for spectral analysis. Since mass of the black hole is also an input parameter of the TCAF model, we obtain a constraint on the mass of the black hole from each of the spectral fits. The object exhibits both persistent and flaring behavior and we analyze data during both these phases for constraining the mass of the source. For Cygnus X-1, our estimated mass appears to be

Mavg = 14.57 ± 0.68M0 which is consistent with previous estimates reported in the literature.

E1.4-0027-18 DOES CYG X-1 HAVE A TINY ACCRETION DISK?

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Results of analysis of several outbursts in a few transient sources are studied using the RXTE/PCA (2.5-25 keV) data as well as RXTE/ASM (1.5-12 keV) data spanning over a long time. A typical time lag is found between the arrival times of the Keplerian disk component and the halo component of the Two-Component Advective Flow (TCAF) when the spectral data is fitted with TCAF solution. This is due to the fact that Keplerian disks have higher viscosity and matter takes a longer time to fall, while the halo has a lower viscosity and falls almost in the free-fall time scale. The wind-fed high-mass X-ray binaries have low angular momentum dominated flow and the lag is expected to be smaller due to the difficulty in making a large Keplerian disk and the arrival time would not differ significantly in the two components of TCAF. On the contrary, a bigger Keplerian disk is likely to form when the accretion is through the Roche-lobe overflow in LMXBs and thus the lag is expected to be very large. Using earlier results in several outburst LMXBs and fitting with TCAF during state transitions of a well known HMXB Cyg X-1, we find that this is indeed the case. Several days of time lags were found in LMXBs while for Cyg X-1 the lag is negligible. We also computed the cross-correlation between the disk and the halo accretion rates and found that the lag is roughly what is observed directly from TCAF extracted parameters. This confirms that the size of the Keplerian disk in Cyg X-1 must be relatively smaller than that in LMXBs studied here.

E1.4-0028-18 A WINGED MICROQUASAR NEAR THE GALACTIC CENTRE

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GRS 1758-258 is one of the two Galactic Center microquasars together with its twin 1E 1740.7- 2942. Here we report a deep radio observation of GRS 1758-258 that combines both archival and present-day observing runs obtained with the Jansky Very Large Array. As a result, we find that the system of radio jets and its terminal lobes strongly resemble the Z-shaped morphology typical of some winged radio galaxies. This opens a new perspective for a comparative understanding of relativistic outflows in stellar and super massive black holes. In particular, the winged appearance of this microquasar is better understood in terms of simple hydrodynamic backflow when the relativistic ejecta collides with the dense interstellar medium surroundings. By extrapolating our findings to the extragalactic case, we suggest that that spin-flip models involving the merger of super-massive black holes are not necessarily the preferred scenario in all cases.

E1.4-0029-18 FAST VARIABILITY IN BLACK-HOLE BINARIES: ACCRETION AND GENERAL RELATIVITY

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I will review the current standpoint of fast variability from black-hole binary systems. The large amount of data obtained in the past two decades has led to a significant advancement in our knowledge, although it still needs to be consolidated through new observations. I will present the more recent evidences of General Relativistic effects obtained from RossiXTE data and will present new data from the Astrosat mission.

E1.4-0030-18 SPECTRAL EVOLUTION OF IGR J17091–3642 DURING ITS 2016 OUTBURST AND THE HEARTBEATS

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We present simultaneous NuSTAR and SWIFT observations of the black hole transient IGR J17091– 3642 during its 2016 outburst. By jointly fitting six NuSTAR and four SWIFT average spectra,

we found that during this outburst the source evolves from the hard to the hard/soft intermediate and back to the hard state, similar to the 2011 outburst. One difference with respect to the previous outburst is that in this case we observed both a broad emission and a narrow absorption line in those observations. Our fits favour an accretion disc with relatively low inclination angle of 45o with respect to the line of sight and a high iron abundance of 3.5 in units of the solar abundance. This high iron abundance, however, is likely model-dependent. We also observed heartbeat variability in one NuSTAR observation. We fitted the phase-resolved spectra of this observation and found that the direct emission varies independently from the reflection component, which suggests that during the heartbeat state the corona is very far away from the disc in IGR J17091–3642. Assuming that in IGR J17091–3642 the inner radius of the disc both in the average and the phase-resolved spectra is located at the radius of the innermost stable circular orbit, with 90% confidence the spin parameter of the black hole in this system is $-0.13 \le a* \le 0.27$.

E1.4-0031-18 X-RAY REFLECTION SPECTROSCOPY OF BLACK HOLE BINARY XTE J1550- 564: EXPLORING ACCRETION EVOLUTION WITH IMPROVED SENSITIVITY

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Black hole binaries exhibit a wealth of astrophysical phenomena as they go into outburst, evolving through two principal spectral states: hard and soft. Since BHB accretion flows evolve on such short timescales (typical duty cycles are on the order of years to decades) we can track the structural changes to their accretion flows in realtime with a multitude of ground and space based observatories across the electromagnetic spectrum. One useful technique for probing the accretion flows of BHBs is to model the X-ray reflection spectrum, a signature of the reflection of the primary continuum off the accretion disc. The characteristic relativistically broadened Iron K-alpha line and Compton reflection hump allow us to constrain the black hole spin, inner disc radius, and other key properties of the accretion disc such as the abundance of iron and the inclination of the disc with respect to the line of sight. Such modeling depends on high sensitivity spectral observations in order to distinguish these reflection features and therefore constrain key physical parameters. I present ongoing reflection modeling of newly calibrated RXTE PCA-and-HEXTE X-ray spectra of the BHB XTE J1550-564, covering multiple outburst cycles across all spectral states, using the most-up-date X-ray reflection spectroscopic code, relxill. The archival dataset includes 517 spectra with a total exposure of 971 ks, making use of 876 million PCA (3-45 keV) counts and 114 million HEXTE (20-200) counts. We utilize the drastically improved calibration of RXTE's PCA and HEXTE (cluster B) instruments-using the publicly available recalibration tools pcacorr and hexBcorr-which allows us to increase the data precision by up to an order of magnitude over previous studies, and reduces instrumental features typically present in the residuals. The goal is to track key physical parameters of XTE J1550-564 (black hole spin, inner disc radius, iron abundance) as it evolves through its spectral states. We optimize the prominence of reflection features in the spectrum (such as the iron line and Compton reflection hump) by combining multiple spectra in groups according to spectral hardness and intensity, and employ Markov Chain Monte Carlo techniques to explore the statistical landscape and constrain key model parameters. This work is part of a broader campaign to systematically analyze several bright black holes. With the increased instrument sensitivity we will be able to better constrain the evolution of the inner disc radii of a number of BHBs during multiple outbursts, as well as their black hole spins, building a more complete picture of the physics of black hole accretion.

E1.4-0032-18 X-RAY MONITORING OF THE GALACTIC MICROQUASAR V4641 SGR

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V4641 Sgr is the black hole (BH) candidate which exhibits a giant outburst with an X-ray intensity up to 12 Crab on September 1999. Since then, several small outbursts with 1-100 mCrab level have been observed almost every year. However, it remains unclear whether this source has typical spectral states such low/hard and high/soft states seen in BH candidates and what X-ray emission mechanisms are. Large-scale radio jets have also benn observed from this source, hence it is very important source to study the relation between jets and accretion flows. Since 2008, we have monitored this source in an outburst with MAXI/GSC and Swift/XRT, and carried out detailed observations with Suzaku and NuSTAR in 2014. The observed X-ray flux ranges up to 40 mCrab. The spectra of this source look like high/soft state, and can be well explained by multi-color disk model with an innermost temperature of 1.0–1.5 keV, but the innermost radii, 8-21% of Schwarzchild radii, are too small to explain its emission region and does not keep constant. We also detected iron emission lines at 6.8 keV due to highly ionized irons from Swift/XRT, NuSTAR, and Suzaku spectra, and first revealed the presence of photoionized plasma in this source. In this paper, we will discuss the origin of X-ray continuum and iron emission lines, and similarity to the peculiar microquasr V404 Cyg.

E1.4-0033-18 THE BRIGHT AND HOT DISK OF THE LMXB 4U 1957+11

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MIT, Cambridge, Massachusetts, United States 4U 1957+11 is a low mass X-ray binary (LMXB) but, opposed to most other LMXBs, it is in a persistently bright accreting state. It shows one of the cleanest examples of a disk spectrum in the X-ray band, with an extremely small inner disk radius and a disk temperature in the 1.3-1.8 keV range and therefore among the highest detected. The low absorption towards 4U 1957+11 makes disk studies especially rewarding. The spectral shape, together with the low short-term variability, hints towards it being the most rapidly spinning galactic LMXB as long as its mass is over 3 solar masses at a distance greater than 10 kpc. Optical modulation has, however, been used to argue that the mass cannot be greater than 3 solar masses, favoring a neutron star interpretation.

We reassess the historical RXTE data, using recent revisions of the RXTE calibration. We use these observations, along with an assessment of all sky monitor lightcurves, to place more recent pointed observations in their proper context of the overall behavior of the source. These pointed observations include a coordinated XMM + NuSTAR + HST/COS campaign that allows us to probe disk models over a wider bandpass than previously possibly. In particular we can asses the underlying spectral correction factor (the ratio of color to thermal temperature) and test whether the spin results and thus the black hole interpretation of the source can be upheld when taking the UV signature of the disk into account.

E1.4-0034-18 OPTICAL PRECURSORS TO X-RAY BINARY OUTBURSTS

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Disc instability models predict that in quiescence, there should be a slow but prominent brightening of the optical flux between outbursts of black hole X-ray binaries (BHXBs). There is also expected to be an optical precursor to outbursts – a brightening at optical wavelengths of the accretion disc, prior to the X-ray outburst. Tracking the X-ray variations of BHXBs in quiescence is generally not possible, so optical monitoring provides the best means to measure the mass accretion rate variability between outbursts. With our regular Faulkes Telescope / Las Cumbres Observatory (LCO) monitoring we are routinely detecting the optical rise of new X-ray binary outbursts before they are detected by X-ray all-sky monitors.

We present long term optical monitoring of several black hole X-ray binaries, with the Faulkes Telescopes and LCO. We have detected the slow rise between outbursts in the BHXBs GS 1354-64, H1705-250 and Swift J1357.2-0933, and the optical precursor to the bright 2015 outburst of V404 Cyg.

In Swift J1357.2-0933, the quiescent light curve is dominated by high amplitude, short-term (seconds - days) variability spanning 2 mag, with an increasing trend of the mean flux over five years that is steeper than in any other X-ray binary found to date (0.17 mag/yr). Such a steep optical flux rise preceding an outburst is expected according to disk instability models, but the high amplitude variability in quiescence is not. We find that a variable optical/infrared jet spectrum is responsible for the brightening in this source.

We show that it may be possible to predict when new outbursts are likely to occur, by estimating the accumulation of matter in the disc in quiescence from optical monitoring.

Finally, we introduce our new real-time data analysis pipeline, the "X-ray Binary New Early Warning System (XB-NEWS)" which aims to detect and announce new X-ray binary outbursts within a day of first optical detection. This allows us to trigger X-ray and multi-wavelength campaigns during the very early stages of outbursts, to constrain the outburst triggering mechanism.

E1.4-0035-18 INTERPRETING OPTICAL PHOTONS AS CYCLO-SYNCHROTRON EMISSION FROM THE HOT, MAGNETIZED ACCRETION FLOW: A CURIOUS CASE OF BW CIRCINI

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The idea that the hot, moderately bright, advection-dominated accretion flow during a flat, powerlaw dominated spectral state in black hole X-ray binaries can give rise to the low energy infrared/ optical photons has been discussed on several occasions but not convincingly demonstrated using spectral and timing information from multi-wavelength observations with high time resolution. To test this hypothesis, we perform optical (SALT)/X-ray (Swift and INTEGRAL) simultaneous monitoring of the hard X-ray outburst from the black hole X-ray transient BW Circini (= GS 1354-64). During the rising phase of the X-ray outburst, when the source Xray intensity is moderately high, optical/X-ray light curve shows a strong anti-correlation with X-ray photons lagging optical. Optical and X-ray power spectra show quasi-periodic oscillations (QPOs) at a frequency of 18 mHz. Both optical and X-ray auto-correlation width are found similar. Simultaneous fitting of Swift/XRT and INTEGRAL spectra in the range 0.5-1000.0 keV shows non-thermal, power-law-dominated (>90 percent) spectra with a hard power-law index of 1.48 0.03, inner disc temperature of 0.12 0.01 keV and an inner disc radius of 3000 km. All evidence is consistent with the prediction of the cyclo-synchrotron radiation in a non-thermal, hot electron cloud extending to 100 Schwarzschild radii being a major physical process for the origin of optical photons. We also compute the Cyclo-synchrotron luminosity based on observed parameters and found that the observed optical luminosity is 0.21 percent of the X-ray luminosity which is well within the predicted limit of <1-3 percents.

E1.4-0036-18 A MASS ESTIMATIVE FOR THE BLACK HOLE CANDIDATE 1E 1740.7-2942 USING BROAD BAND X-RAY SPECTRUM

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The object 1E 1740.7-2942 is one of the strongest hard X-ray emitters around the Galactic Center region. It was classified as a black hole candidate due to its spectral similarities with Cyg X-1. The lack of information about its counterpart prevents the mass function f(M) of the system from being determined, since it depends on parameters usually better estimated through optical/infrared observations of the companion. In the context of alternative methods, broad band spectrum and the presence of a broadened iron line have opened the possibility of weighting black holes with only X-ray data. In this study, we gather public available data of 1E 1740.7-2942 from 3 different missions to produce a broad band spectrum. NuSTAR data suggest the presence of an iron line and a reflection component. Broad band coverage and thus better fit modeling was achieved including data from XMM and INTEGRAL. Although the observations were not taken simultaneously, their individual fits indicate that the source was in the same spectral state. Preliminarly results point to a black hole mass around 4 solar masses for 1E 1740.7-2942.

E1.4-0037-18 THE EVOLUTION OF GX 339-4 IN THE LOW-HARD STATE AS SEEN BY NUSTAR AND SWIFT

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We analyze eleven NuSTAR and Swift observations of the black hole X-ray binary GX 339–4 in the hard state, six of which were taken during the end of the 2015 outburst, five during a failed outburst in 2013. These observations cover luminosities from 0.5%–5% of the Eddington luminosity. Implementing the most recent version of the reflection model relxillCp, we perform simultaneous spectral fits on both datasets to track the evolution of the properties in the accretion disk including the inner edge radius, the ionization, and temperature of the thermal emission. We also constrain the photon index and electron temperature of the primary source (the "corona"). We observe a maximum truncation radius of 37 Rg in the preferred fit for the 2013 dataset, and a marginal correlation between the level of truncation and luminosity. We also explore a self-consistent model under the framework of coronal Comptonization, and find consistent results regarding the disk truncation in the 2015 data, providing a more physical preferred fit for the 2013 observations.

E1.4-0038-18 A RELATIVISTIC OUTFLOW DETECTED IN THE HARD STATE FROM THE MICROQUASAR GRS 1758-258.

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Outflows are observed from accreting systems on all mass scales in the form of collimated jets and wider angle accretion disk winds. Previous observations have suggested a paradigm wherein the accretion disk wind is strongly suppressed in the hard spectral state and present in the soft spectral state, whereas the jet is observed to behave in the opposite sense. We will present the results of a Suzaku observation of the persistently accreting Galactic microquasar GRS 1758-258 while the source was in the low-hard state (Lx 0.01 LEdd). Analysis of the Suzaku observation reveals the presence of a highly ionized relativistic wind (v 0.1c) originating in the inner regions of the accretion flow. The broad nature of the observed absorption line suggests that it is the signature of a stratified relativistic outflow. This is the highest velocity wind detected from a stellar mass X-ray binary to date, demonstrating the viability of the wind launching mechanism down to luminosities of at least 1% LEdd.

E1.4-0039-18 HIGH ENERGY EMISSION IN BLACK HOLE BINARIES

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In the X/-ray domain, black hole binaries (BHBs) show several and complex spectral behaviors and transitions. Based on INTEGRAL observations, we have now a new view on the high energy emission of black-hole binary. An additional component above 200 keV has been observed in a number of systems, during either hard/intermediate or hard states. The nature of this hardtail is still debated, as also the one observed in the soft state. However, among a number of models, it is usually attributed to the presence of a small fraction of non-thermal electrons in a hot-Comptonising plasma, eventhough the jet nature of this component has not been ruled out. I review on the high energy emission observed by the INTEGRAL telescopes in a few systems and models applied to explain their X/-ray spectra.

E1.4-0040-18 A HIGH-RESOLUTION VIEW OF THE 2015 OUTBURST OF THE BLACK HOLE X-RAY BINARY V404 CYGNI

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The 2015 outburst of the black hole X-ray binary V404 Cygni was the brightest such outburst in over a decade, providing an unparalleled opportunity to study the accretion and ejection processes around an accreting stellar-mass black hole. The exceptionally bright fluxes across the electromagnetic spectrum stimulated intensive observing campaigns at all wavelengths, from the radio to the gamma-ray regime. In this talk I will present the results of our highcadence radio monitoring with the Very Long Baseline Array, detailing the real-time evolution of the jets on timescales as short as minutes. These observations show that the jet is precessing on a timescale no longer than several tens of minutes, most likely due to a precessing inner accretion flow. I will also show how the jet behaviour evolves through the different phases of the outburst, from the initial rapid flaring to the bright ejection event at the peak of the outburst and the re-establishment and fading of the compact jet. Since V404 Cygni is one of the few Xray binaries with a known distance from geometric parallax, we can directly convert measured proper motions into accurate physical parameters, such as jet speeds and Lorentz factors, to determine the energetics of the ejection events. Finally, with such intensive coverage at multiple wavelengths, we can seek to compare the ejection times derived from high-resolution imaging with the contemporaneous behaviour of the accretion flow to determine the events leading to jet ejection.

E1.4-0041-18 SPECTRAL AND TIMING PROPERTIES OF MAXI J1535-571 DURING ITS 2017 OUTBURST

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We present spectral and timing analysis results of the newly-discovered X-ray transient source MAXI J1535-571, which is likely a Galactic black hole binary. It was discovered on 2017 Sep.

02. During the soft/high state, the maximum X-ray flux in 0.3-10 keV band increased by 25 times than that in the quiescent state, which is about 4 Crab. Using the Swift XRT BAT observations, we study accretion flow processes around the black hole from spectral fits with the Two-Component Advective Flow (TCAF) model in XSPEC. Significant emission lines from neutral Fe K and Fe XXV K are observed. Type-C QPOs are also significantly detected in the raising and the declining phases of the outburst. Propagating Oscillatory Shock (POS) model is used to study monotonic evolution of the QPO frequencies during the declining phase of the outburst. This allowed us to have a rough estimation of the evolution of the central Compton cloud region (known as CENtrifugal pressure supported BOundary Layer; CENBOL) by measuring instantaneous locations, strength, velocity etc. of the propagating shock wave. The shock parameters obtained from POS model fit is also found to be consistent with the TCAF model fitted shock parameters. It has been observed that the CENBOL shrinks in the rising phase and expands in the declining phase of the outburst. We also estimate mass of the black hole candidate to be 10 solar masses from our TCAF model fitted spectral fits, suggesting that it is a stellar mass black hole system.

E1.4-0042-18 NEAR INFRARED OBSERVATION OF MAXI J1535-571

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MAXI J1535-571 is a black hole binary candidate discovered by MAXI and Swift at the outburst in September 2017. We performed a series of near infrared observations with IRSF in J, H, and K bands, in which we found significant flux variations on short time scales. We discuss the origin of the infrared emission based on its timing properties, colors, and broad-band SED.

E1.4-0043-18 TIMING BEHAVIORS OF THE BRIGHT NEW BH CANDIDATE MAXI J1535- 571

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We present the X-ray timing results of the new black hole candidate (BHC) MAXI J1535- 571 during its 2017 outburst from Insight-HXMT observations taken from 2017 September 6 until September 23. We find the source exhibits state transition of Low/Hard state (LHS) → Hard Intermediate state (HIMS) → Soft Intermediate state (SIMS). Quasi-periodic oscillations (QPOs) were found in the intermediate states, which seem to be of different types. We present the energy dependence of the QPO amplitude up to 100 keV which was totally unexplored area in timing domain. We find that the phase lag at the type-C QPOs frequency is negative (soft lags) and strongly correlated with the centroid frequency of the QPOs. By assuming a geometrical origin of type-C QPOs, the source is consistent with a high inclination.

E1.4-0044-18 EXPLAINING THE OUTBURSTS OF THE INTERMEDIATE-MASS BH HLX-1 AS A WIND-DRIVEN INSTABILITY

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We model the optical/UV emission of the intermediate-mass black hole HLX-1, using three sets of HST observations (from 2010, 2012, 2013), together with XMM-Newton and Swift data. We quantify the relative contributions of a bluer component, function of X-ray irradiation, and a redder component, constant and likely coming from an old stellar population. By combining optical and X-ray data, in particular around its state transitions, we estimate a BH mass 2 x 104M sun, aspinparametera/M 0.9f or a moderately face–on view, and a peak outburst luminosity 0.3timest

We discuss the discrepancy between the characteristic size inferred from the short X-ray timescale

(R a few 1011 cm) and the characteristic size of their radiated optical emitter (Rsqrt[costheta] 2x1013cm).One ray outburst cycle. We propose that the recurrent outbursts are caused by an accretion rate oscillation driven by term average accretion rate of a few percent of Eddington, just below the upper limit of the low/hard state; aw driven oscillation can trigger transitions to the high/s of tstate, with a recurrence period 1 year (much longer 1 and in the Galactic BHV 404Cyg.

E1.4-0045-18 POSSIBLE IMAGES OF SGR A* IN TWO COMPONENT ADVECTIVE FLOW PARADIGM

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The existence of Two Component Advective Flow around a black hole was proposed earlier and very recently it is proved through time dependent numerical simulation. However, the images, spectra and degree of polarization corresponding to the variation of physical parameters like accretion rate, viscosity and mass are studied in the current context. Self-consistent formation of Keplerian disk around Low Luminosity AGNs like Sgr A* are presented.

E1.4-0046-18 CORONAL PROPERTIES FROM NUSTAR OBSERVATIONS OF AGN AND THEIR IMPLICATIONS

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A significant fraction of the power produced by accretion onto the central black hole of AGN is released in the X-ray band. It is widely accepted that this emission is produced by inverse Compton scattering of UV disc photons by a region of electron plasma known as the corona. However, the detailed conditions in the corona are still poorly constrained.

The recent NuSTAR mission, with significantly greater sensitivity in the hard X-ray band than previous missions, has allowed a step-change in the quality of our observations of the corona. In particular, the Comptonised continuum can now be measured for many sources up to around its high energy cut-off, allowing precise measurements of the coronal temperature and other related parameters.

These measurements suggest that pair production may play an important role in the regulation of coronal temperatures. The increasing sample of sources with high-quality NuSTAR observations allows us to improve the detail and precision of our inferences, such as by considering the prevalence of non-thermal electrons in the plasma.

We will present the latest results from our ongoing campaigns to measure coronal properties with NuSTAR and the significance of these results for the wider accretion process.

E1.4-0047-18 THE ROBOPOL OPTOPOLARIMETRIC BLAZAR MONITORNG PROGRAM

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Optical Synchrotron emission from blazars is significantly polarized and the polarization probes the magnetic field structure in the jet. Rotations of the polarization angle in blazars reveal important information about the evolution of disturbances responsible for blazar flares. The RoboPol program for the polarimetric monitoring of statistically complete samples of blazars was developed in 2013 to systematically study this class of events. RoboPol is a collaboration between the University of Crete, the Max-Planck Institute for Radio Astronomy, Caltech, the Inter-University Centre for Astronomy and Astrophysics in India, and the Nicolaus Copernicus University in Poland. Using a novel polarimeter operating at the 1.3m telescope of the Skinakas Observatory in Crete, it has succeeded in its 4 years of operation in taking optopolarimetric rotations of blazars from novelty status to a well-studied phenomenon that can be used to answer long-standing questions in our theoretical understanding of jets. I will review the RoboPol program and its most important results in the classification of the optopolarimetric properties of blazars, the statistical properties of polarization rotations, and their relation to gamma-ray activity in blazar jets.

E1.4-0048-18 TIME VARIABILITY OF THE CORE-SHIFT EFFECT IN THE BLAZAR 3C454.3

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The so-called core-shift effect in relativistic jets observed at radio wave bands has been widely studied and used for estimating physical parameters such as the magnetic field strength and the particle number density. In this work, we have investigated the time variability of the coreshift effect in the very luminous blazar 3C454.3 (z=0.859). We have analysed multi-frequency (5,8,15,22,43 GHz) Very Long Baseline Array data of 19 epochs from 2005 to 2010. Core-shift measurements have been performed using image plane cross-correlation and visibility plane model-fitting. These measurements allow us to study the time variability of the core-shift in the blazar as well as the time evolution of the spectra. We compare our results with long-term 37 GHz total flux density monitoring observations made at the Metsähovi Radio Observatory searching for correlations. Our preliminary results show that the index kr of the core-shift effect

(rcore ν−1/kr) varies in the range of 0.50 < kr < 1.63 during the observed time period. We suggest that this variability is mainly linked to the occurrence of outbursts. We will discuss the reliability of the core-shift measurements as a proxy for the jet magnetic field strength.

E1.4-0049-18 RECONCILING OBSERVATIONS AND THEORY OF THE OUTBURST OF 3C 279

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Blazars become extremely bright at all frequencies during outburst phases. Multifrequency data of such phases can be modeled through radiation transfer models which in turn allows for testing reconciliation of data and theory of the emission mechanism that is powered by the central supermassive black hole. We have caught the prominent blazar 3C 279 with INTEGRAL in its brightest outburst at high energies. The multifrequency campaign around this detection ranges from IR frequencies to gamma-ray energies (GeV), covering the outburst with public available data from the Small and Moderate Aperture Research Telescope System (SMARTS), the Swift/UVOT, the Swift/XRT, the INTEGRAL/IBIS, and the Fermi-LAT. Eventually also proprietary TeV data of the same outburst by the H.E.S.S. Cherenkov Telescopes were released. We model the outburst with a leptonic and lepto-hadronic model. In this talk I will show the results and how theory and observations can be reconciled. Yet, the modeling predicts extreme conditions in the jet that fail to lead to an exhaustive physical explanation.

E1.4-0050-18 VARIABLE NATURE OF MAGNETICALLY-DRIVEN ULTRA-FAST OUTFLOWS (UFOS) FROM AGN ACCRETION DISKS

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With an increasing number of high-S/N spectroscopic observations of nearby radio-quiet Seyfert galaxies in the past decade, it is becoming more obvious that a sub-class of X-ray winds, known as ultra-fast outflows (UFOs) could be more ubiquitous than ever thought while quite variable in nature. It is suggested that the observed UFOs, especially those detected in Fe K band, may exhibit some likely correlations. For example, in the case of a luminous nearby quasar, PDS 456, and a narrow-line Seyfert 1, IRAS 13224-3809, the observed velocity of the Fe K UFOs (i.e. Fe xxv/xxvi) and its equivalent width (EW) are found to be (both) correlated with the ionizing X-ray flux/luminosity across different epochs. Attributed to their extreme brightness particularly in O/UV band most likely powered by accretion process, it is speculated that strong UV radiation field responsible for producing sufficiently high line-opacity due to bound-bound transition may effectively drive the observed UFOs in these systems. However, a certain optimal ionization condition is necessary in such a scenario to acquire high velocity by avoiding overionization, while the observed UFOs are typically characterized by high ionization parameter.

In this work, it is shown that the action of global magnetic fields, another equally promising launching mechanism, can naturally explain the observed UFO conditions in PDS456 as a case study. By detailed photoionization calculations with xstar code, the MHD-driven disk-wind model predicts that H/He-like Fe are formed at smaller radius where the velocity is higher with higher X-ray luminosity, while the net ionic columns drop due to its higher ionization parameter thus reducing the EW. We successfully fit the 2013-2014 XMM-Newton/NuSTAR campaign spectrum with this model and also show a simulated XARM/micro-calorimeter spectrum. We further demonstrate that the observed multi-epoch correlations of UFOs are well explained within the framework of MHD-driven disk-winds.

The anticipated scientific advances made possible by XARM and Athena in the forthcoming decades will allow us to answer these fundamental questions by exploring AGN winds more throughly.

E1.4-0051-18 THE ORIGIN OF THE BROAD LINE REGION IN ACTIVE GALACTIC NUCLEI

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Broad emission lines are the most characteristic features of AGN but the origin of the material responsible for the observed emission is still hotly debated. Reverberation studies show the predominantly Keplerian motion of the BLR clouds but mixed with the inflow or outflow. I will review various options, paying attention to the division of the lines into Low Ionization Lines and High Ionization Lines. In the case of LIL, I will discuss in detail FRADO (Failed Radiatively Accelerated Dusty Outflow) model which successfully describes the BLR radius - luminosity relation from the first principles. I will briefly mention the issue of the outliers from this relation in the case of highly Eddington sources and at low Eddington ratio tail.

E1.4-0052-18 THE ORIGIN OF THE BROAD LINE REGION IN AGN

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Broad emission lines are the defining property of type 1 AGN. What is the origin of the gas which produces these lines? I will describe our recent study of the vertical structure of a dusty accretion disk atmosphere. The dust opacity leads to an inflated inner disk profile. The illuminated surface of this inflated structure provides a natural source for the broad line emission. I will described various future observations which can be used to test this mechanism.

E1.4-0053-18 HOW UNIVERSAL IS THE BIG BLUE BUMP IN ACTIVE GALACTIC NUCLEI? HOW IMPORTANT IS REPROCESSED LIGHT IN THE OPTICAL?

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Aside from some known minor contributions arising from recombination emission in the Broad Line Region, the optical continuum from quasars and Seyfert 1 galaxies appears to be thermal emission from an optically thick 'surface'. One very successful model for this is an accretion disk. But an additional possible component that has also been considered, is re-processed emission. This is energy which was ultimately produced by accretion, as high energy photons, which were then absorbed and re-emitted further out. Thus this re-processed continuum comes from regions of larger radii and lower temperatures than a plain (self-heated by viscosity) accretion disk.

Reprocessing is already known to produce most of the near-IR continuum observed in most Seyfert 1's and quasars. I will consider several possible observational indicators that reprocessing becomes important, and even dominant, in producing the optical continuum from many AGN. I will discuss the relative strengths of broad emission lines, the near-infrared/optical/UV/Xray continuum spectra, constraints on emission region sizes from microlensing, and also from time delays measured in reverberation experiments. If a substantial fraction of radiation from the inner disk is re-captured by optically thick gas at large radii, the effective temperature should fall off not as r**-3/4 but more gradually, as r**-1/2. A simple calculation of accretion disk-plus-reprocessing which can fit the observations will be presented.

E1.4-0054-18 CONSTRAINT ON AGN CORONA SIZE WITH FULLY RELATIVISTIC MODELING OF 3D CORONA

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The “lamp-post” scenario was usually used to describe AGN corona, in which the corona is assumed to be an infinitesimal point source on the symmetry axis. In some AGNs, especially NLS1s, the broad iron line profile requires extremely compact corona. On the other hand, the corona must be large enough to intercept enough seed photons to be able to produce the observed X-ray continuum and reflection spectrum. One attempt to constrain AGN corona size was made by Dovciak Done 2016, in which the corona size was estimated by conservation of photons during Comptonization process. They found out that for one NLS1 1H 0707-495, the size of the corona must be substantially larger than 1 GM/c2. In that work, the Comptonized spectrum was evaluated assuming lamp-post geometry and the corona size was estimated under the assumption that the emission of the corona is homogeneous. To calculate the spectrum of 3D corona (i.e., the corona is extended and with finite height) self-consistently, we perform a fully relativistic Monte Carlo calculation of energy and polarization spectrum of AGNs of disk-corona geometry, taking into account propagation of null geodesic in Kerr space-time and Compton scattering process. With the calculated spectra, we are able to put constraint on AGN corona size for an AGN sample with simultaneous XMM-Newton X-ray/UV observations.

E1.4-0055-18 THE JET-DISK MODEL FOR SGR A*

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Where does the persistent and flaring emission of the Galactic Center black hole, Sgr A*, originate from? Does it come from an accretion flow or is it produced in a relativistic jet- like outflow? Answering this question is not only important for understanding the plethora of multi-wavelength data available for Sgr A*, it is also crucial for interpreting upcoming VLBI images of the shadow of the event horizon. Using advanced three-dimensional general relativistic magnetohydrodynamics simulations coupled to general relativistic ray tracing simulations, we can now model the dynamics and emission of the plasma around starving black holes in great detail out to several thousand Schwarzschild radii. A crucial parameter is the heating of radiating electrons and we argue that electron-proton coupling is low in the accretion flow and high in the magnetized region of the jets. This makes the jet an important ingredient for the overall appearance of the source. This comprehensive model is able to predict the radio size and appearance, the spectral energy distribution from radio to X-rays, the polarization properties, the variability, and the time lags of Sgr A* surprisingly well.

E1.4-0056-18 THE EVOLVING JET IN THE NEW BLACK HOLE X-RAY BINARY MAXI J1535-571

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MAXI J1535-571 is a recently discovered and very bright Galactic black hole X-ray binary. Here, I will present results from our comprehensive ATCA radio and ALMA millimetre monitoring of this source throughout its outburst. Our multi-frequency coverage show the observed jet spectrum changing rapidly as the source transitioned from the hard state towards the soft state, indicating dramatic changes in the jet over relatively short timescales. Surprisingly, we detect core radio emission throughout the soft state, placing limits on the level of jet quenching in this source. I will also discuss the monitoring of two downstream radio knots/shocks, allowing us to place constraints on their speed and time of their ejection, which can then be linked back to changes in X-ray properties. These radio and millimeter observations provide an unprecedented insight into the changing jet structure, and how the accretion flow may be driving those changes.

E1.4-0057-18 ACCRETION - EJECTION MECHANISM OF MAXI J1836-194 WITH THE TCAF SOLUTION

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MAXI J1836-194 showed its first activity in Aug 2011. It was active for 3 months before it went to quiescent state for 4 months. It renewed its activity again in March 2012 for 2 months. We have analyzed spectral data of 3-25 keV RXTE/PCA for the 2011 outburst and 0.5-10.0 keV Swift/XRT for 2012 outburst with the current fits file of the two component advective flow (TCAF) model in XSPEC. The detailed accretion flow properties of the source during its 2011 outburst has been done from spectral and temporal analysis under TCAF paradigm. Based on the variation of the TCAF model fitted physical flow parameters and nature of observed quasi-periodic oscillations (QPOs), we classified entire outburst into two harder spectral states: hard (HS) and hard-intermediate (HIMS), which are observed in the sequence of HS(Ris.)-> HIMS(Ris.)-> HIMS(Dec.)-> HS(Dec.). We estimated mass of the source from our TCAF model fitted spectral analysis. We also have estimated contribution of jet X-ray fluxes with a newly developed method based on TCAF model. We find that the jet contributes in the X-ray as high as 86% of total intensity during its 2011 outburst. We find jet X-ray (Fouf) correlates with radio flux (FR) as FR F 0.61, which is similar to standard correlation. However, when the correlation is done with total X-ray, we find unusual steep index sim 1.82. This could be due to the surrounding clouds from the excretion disk of the companion Be star. In the correlation plots, we find LR Lx points lie on the jet line for the 2012 outburst and quiescent state indicating observed radio flux is from earlier epoch. Another reason could be that the quiescent and the 2012 outburst is dominated by radiatively inefficient sub-Keplerian flow, the phases are highly jet dominated.

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E1.4-0058-18 DIRECTION OF A JET FROM AN ACCRETING BLACK HOLE

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An important problem of astrophysics is whether a jet from an accreting black hole is aligned with the black hole spin axis or the accretion disk angular momentum vector. An answer to this question can provide important information about the jet triggering mechanism, disk-jet coupling, and the high energy radiation mechanisms in a black hole system. Tidal Disruption Event (TDE) of a star by a supermassive spinning black hole provides a unique astrophyical laboratory to study the jet alignment through the possibility of Lense-Thirring precession of the jet. In this work, we investigate the Swift XRT light curve of the most well sampled jetted TDE, Swift J1644+57. In the thick disk regime of the light curve, we estimate, using a known optimistic method and a new conservative method developed by us, the tilt angle of the jet with respect to the black hole spin axis as a function of the black hole spin parameter. We find that the jet in Swift J1644+57 is more likely to be aligned with the black hole spin axis.

E1.4-0059-18 GLOBAL RADIO VERSUS BOLOMETRIC X-RAY FLUX CORRELATION IN THE BLACK HOLE X-RAY BINARY GX 339-4

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Compact radio jets are ubiquitous in stellar mass black hole binaries in their spectrally hard state. The correlation between the radio emission from the compact jets and X-ray emission from the accretion disk around the black hole, is of major importance in understanding the nature of accretion diskjet coupling in black hole X-ray binaries. Previous works investigating the radio versus X-ray emission correlation properties, used the narrow 3-9 keV or 1-10 keV Xray energy band luminosity as proxy for accretion rate. However, the bulk of X-ray emission in the hard spectral state of black hole X-ray binaries, is emitted around 100 keV. We investigated the global radio versus bolometric X-ray luminosity correlation for the black hole X-ray binary GX 339-4 using RXTE observations. We have found that these correlations show an effect of hysteresis, previously found in the relationship between the X-ray hardness and flux, but not in the radio band. These correlations will provide new insights into the various accretion disk and jet ejection models.

E1.4-0060-18 CORRELATED X-RAY AND OPTICAL VARIABILITY DURING THE 2015 SUPER-EDDINGTON OUTBURST OF V404 CYG

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The 2015 June/July outburst of V404 Cyg was the brightest X-ray transient event ever recorded, but only lasted for barely 2 weeks. During that time V404 Cyg was extensively monitored by INTEGRAL, providing unprecedented soft and hard X-ray (with JEM-X and ISGRI) and optical (with OMC) coverage of this event. A number of dedicated simultaneous observations were also undertaken by NuSTAR and ULTRACAM at high time resolution. Here we give an overview of the remarkable variations that are displayed during the outburst, identifying a number of episodes of correlated X-ray and optical variations which we associate with the inflow of the inner accretion disc, and subsequent ejections of a relativistic jet.

E1.4-0061-18 THE MULTI-WAVELENGTH EMISSION OF X-RAY BINARY JETS POWERED BY INTERNAL SHOCK

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The emission of steady compact jets observed in the hard spectral state of X-ray binaries and in AGN is likely to be powered by internal shocks caused by fluctuations of the outflow velocity. Those fluctuations are likely to originate in the accretion flow. Using the internal shock model ishem, I explore this possible connection between accretion and ejection. The fluctuations of the accretion flow can in principle be traced by the X-ray light curves, while the response of the synchrotron jet can be observed with radio and IR measurements. Under the assumption that the power spectrum of the jet fluctuations is identical to that of the observed X-ray light curve, we calculate the predictions of the model and make comparisons to spectral and timing data from several X-ray binaries. The we find that in GX 339-4 and MAXI J1836- 194 the model provides a good description of the observed radio optical SEDs. In the case of MAXI J1836-192 we model the evolution of the SED in the hard state during an outburst. Our results indicate that in this source, not only the jet power but also the jet time averaged Lorentz factor increases with luminosity. We also find that the quenching of the jet in the soft state might be related to the drop in X-ray variability: the jet could be present in the soft state but undetected due to a very low radiative efficiency associated to very weak velocity fluctuations. The model also predicts a strong, wavelength dependent jet variability that resembles the observed one. In particular, strong sub-second variability is predicted in the infrared and optical bands. In the cas of GX 339-4 complex timing correlations are observed between the IR/optical light curves and the X-rays that we use to probe the fast dynamics of the accretion/ejection connection. In this source also low frequency QPOs have been detected simultaneously in X-ray and IR. The appearance of the IR QPO could be caused by jet precession driven by Lense-Thirring precession of the X-ray accretion flow.

E1.4-0062-18 MAPPING SUPERMASSIVE BLACK HOLE WINDS, FROM THE EVENT HORIZON UP TO GALAXY SCALES

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Powerful winds driven by active galactic nuclei (AGN) are often invoked to play a fundamental role in the evolution of both supermassive black holes (SMBHs) and their host galaxies, possibly quenching star formation and explaining the tight SMBH-galaxy relations. Additional support for this “quasar-mode” feedback came from new X-ray observations of mildly relativistic disk winds, a.k.a. ultrafast outflows, in some ultra-luminous infrared galaxies and their connection with galactic molecular outflows observed in mm and IR wavebands. In particular, the combination of X-ray (Suzaku, NuSTAR), IR (Herschel), and mm (ALMA) observations of IRAS F11119+3257 allowed us to link the SMBH activity to molecular outflows that may quench star formation. Therefore, synergistic observations in X-ray and other wavebands have the power to map AGN winds from the event horizon up to galaxy scales, providing a promising avenue to study the multi-phase SMBH feeding and feedback. Spectroscopic observations suggest that such SMBH winds may be common in local AGN and quasars. However, their origin and characteristics are still not fully understood. Theoretical models and simulations focused on radiation, magnetohydrodynamic (MHD) or a combination of these two processes to investigate the acceleration mechanisms and dynamics of these winds. Revolutionary improvements are expected from upcoming X-ray space observatories, such as Athena and XARM, in synergy with other major spaceand ground-based facilities.

E1.4-0063-18 CAN THE RELATIVISTIC LIGHT BENDING MODEL EXPLAIN X-RAY SPECTRAL VARIATIONS OF SEYFERT GALAXIES?

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Many Seyfert galaxies are known to exhibit Fe-K broad emission line features in their X-ray energy spectra. The observed lines have three distinct features; (1) the line profiles are skewed and show significant low-energy tails, (2) the Fe-K band have low variability, which produces a broad and deep dip in the root-mean-square (rms) spectra, and (3) photons in this band have time lags behind those in the adjacent energy bands with amplitudes of several Rg/c, where Rg is the gravitational radius. The “relativistic light bending model” is proposed to explain these observed features, where a compact X-ray source (lamp post) above an extreme Kerr black hole illuminates the innermost area of the accretion disc. We critically examine the relativistic light bending model by computing the rms spectra and the lag features using a ray-tracing technique, when a lamp post moves vertically on the black hole spin axis. As a result, we found that the observed deep rms dip requires that the iron is extremely overabundant (> 10 solar), whereas the observed lag amplitude is consistent with the normal iron abundance. Furthermore, disappearance of the lag in the high-flux state requires a source height as high as 40Rg, which contradicts the relativistically broad emission line feature. Therefore, we conclude that the relativistic light bending model may not explain the characteristic Fe-K spectral variations in Seyfert galaxies.

E1.4-0064-18 STRONG DISC WINDS TRACED THROUGHOUT OUTBURSTS IN BLACKHOLE X-RAY BINARIES

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Recurring outbursts associated with matter flowing onto compact stellar remnants (such as black holes, neutron stars and white dwarfs) in close binary systems provide constraints on the poorly understood accretion process. Taken as a whole, the light-curves of these outbursts are shaped by the efficiency of angular-momentum (and thus mass) transport in the accretion discs in these systems, which has traditionally been encoded in the α-viscosity parameter. Numerical simulations of the magneto-rotational instability that is believed to be the physical mechanism behind this transport yield values of α of roughly 0.1–0.2, consistent with values inferred from observations of accreting white dwarfs. However, equivalent viscosity parameters have never been estimated for discs around neutron stars or black-holes (i.e., low-mass X-ray binaries) before. We have combined theory, advanced Bayesian statistical techniques, and the observed X-ray light-curves to build an innovative methodology, which for the first time, measures the α-viscosity parameter in low-mass X-ray binary discs. Here we report the results of applying this methodology to the Galactic black-hole low-mass X-ray binary population. We discuss how these results suggest that strong accretion disc winds, with the ability to remove a substantial fraction of the disc mass, must exist in all accretion states throughout outbursts of accreting stellar-mass black-holes.

E1.4-0065-18 MAGNETIC RECONNECTION, PARTICLE ACCELERATION AND VERY HIGH ENERGY EMISSION AROUND BLACK HOLES AND JETS

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Particle acceleration induced by fast magnetic reconnection in the surrounds of black holes and their relativistic jets may help to solve current puzzles specially related to the interpretation of the very high energy (VHE) emission produced in BHBs, AGNs and GRBs. In this talk, we will discuss this process in the framework of these sources, showing our recent results of analytical and three-dimensional numerical MHD simulations with test particles. Our numerical simulations of accretion disk-corona systems reveal the growth of turbulence driven by MHD instabilities that lead to the development of both large scale magnetic loops and magnetic reconnection with fast reconnection rates around 0.13-0.17 VA (where VA is the local Alfven speed). These results are crucial for testing recent theories of particle acceleration and VHE driven by turbulence-induced fast magnetic reconnection around magnetized compact objects (e.g., de Gouveia Dal Pino et al. 2016 and references therein). Furthermore, our numerical simulations of relativistic MHD jets subject to current-driven-kink instability reveal the formation of several compact sites of fast reconnection induced by the kink turbulence (with reconnection rates around 0.15 VA). The injection of thousands of test particles in these reconnection regions of the jet resulted in their acceleration up to energies of 1017 eV, thus demonstrating the ability of this process to accelerate particles and produce the observed VHE in these sources.

E1.4-0066-18 IMAGES OF TWO COMPONENT ADVECTIVE FLOW AROUND BLACK HOLES IN PRESENCE OF OUTFLOWS AND COOLING

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In the literature, several authors have presented images of black holes surrounded by Keplerian disks or simple one component disks. However, successful fitting of the spectral and timing properties suggest that the disks around black hole are of two components, one Keplerian and the other sub-Keplerian. We present images, spectra and energy dependent time lags of Two Component Advective Flow. Hydrodynamical configuration of low angular momentum, sub-keplerian component is generated by the Total Variation Diminishing (TVD) method. To produce the spectra, we incorporate Comptonization via Monte-Carlo technique. The spectral energy distribution, images over various inclination angles on observer plane are obtained by Ray-Tracing process. Variations caused by the self consistent outflows are reported.

E1.4-0067-18 GAMMA-RAY VARIABILITY OF BRIGHT AGNS: IMPLICATIONS ON PROCESSES POWERING THE EMISSION AND JET-CENTRAL-ENGINE CONNECTION

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The X-ray/Ultraviolet/Optical emission from accretion-powered sources shows phenomenological similarities, characterized by a lognormal flux distribution, a linear relation between intrinsic variability and flux (rms-flux), and a (broken) power-law power spectral densities (PSDs). These features have normally been argued to be a result of the multiplicative combination of fluctuations in the accretion disk. Here, we present results from exploration of these properties in gamma-ray emission of four radio-loud Active Galactic Nuclei (AGNs): radio-galaxy NGC 1275 and three blazars - Mrk 421, PKS 1510-089, and B2 1520+31, using continuously sampled light curves between 2008 - 2015 from Fermi-LAT. All the sources, except Mrk 421, display flux spanning 2 orders of magnitude between the extremes with a lognormal profile describing the blazars flux histogram better compared to a Gaussian while none favored for the non-blazar source NGC 1275. The rms-flux relation, however, is linear for all, irrespective of histogram profile while the PSDs are typical of the accretion-powered source, exhibiting a red noise power-law spectrum of slope 1, though there is hint of breaks. The inferred results are consistent with the statistics of magnetic-reconnection powered minijets-in-a-jet model as well as with the statistics of X-ray emission from the whole Solar disk. The results thus suggest magnetic reconnection as the potential process powering the emission, consistent with the non-thermal spectrum observed from these sources. The broad similarity of properties with other accretion-powered sources also suggest that the magnetic reconnection may likely be an imprint of fluctuation in the accretion disk to the jet.

E1.4-0068-18 USING ASTROCHEMISTRY TO PROBE JET PROPERTIES AND ENERGETICS IN GALACTIC BLACK HOLE X-RAY BINARIES

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Relativistic jets launched from accreting black holes in our Galaxy can carry large amounts of energy and matter into their surrounding environment. Identifying where these jets interact with the ISM, and probing the physical conditions at these interaction sites, can provide crucial insight into highly sought-after jet properties, such as the jet power, composition, duty cycles, and the efficiency of jet feedback. Molecular lines observable in the sub-mm frequency bands are excellent diagnostics of shock energetics and ISM excitation in these jet-ISM interaction zones. In this talk, I will present new results from our ALMA observations of a candidate jet-ISM interaction zone near the black hole X-ray binary (BHXB), GRS 1915+105. Through examining the morphological, spectral, and kinematic properties of the molecular emission, we find several lines of evidence that support the presence of a jet-ISM interaction at this site, including a jet-blown cavity in the molecular gas. We also estimate the likelihood of finding such jet-molecular cloud interactions elsewhere in our Galaxy, with the interaction probability per BHXB system being 3%. Our work here demonstrates that astrochemistry can be used as a powerful new tool to identify and probe these jet-ISM interaction zones near accreting black holes in our Galaxy.

E1.4-0069-18 WOBBLING JETS IN ACTIVE SUPER-MASSIVE BLACK HOLES

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Powered by accretion onto super-massive black holes (masses up to 10 billion Solar mass), active galactic nuclei (AGN) are strong emitters of electromagnetic radiation over a range spanning more than 20 decades in energy. About 1 in 10 AGN convert a substantial fraction of accretion energy into highly collimated and relativistic outflows of energetic plasma called "JETS". Many AGN jets do wobble, i.e., show temporal variations in their direction on parsec scales. While the causes of "jet wobbling" are not agreed upon, it is a powerful probe of energy extraction from super-massive black holes. I will present a comparison of jet wobbling with first-principles general relativistic magnetohydrodynamic (GRMHD) simulations.

E1.4-0070-18 SPIN DEPENDENT SPECTRA AND IMAGES OF TWO COMPONENT ADVECTIVE FLOW IN VARIOUS SPECTRAL STATES

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We employ generalized Ray-tracing formulation to compute the spectra and images Two Component Advective Flow. Coupled second order Four dimensional geodesic equations are solved to obtain the images on the plane of the observer. Monte-Carlo technique has been used to generate seed photons. Comptonization has been added to produce the spectrum. Spin dependent image and spectral variations are reported. Time lag maps of accretion disk are presented.

E1.4-0071-18 OBSERVATIONS OF THE SEYFERT 1 AGNS ZW 229.015 AND MRK 493 VISA-VIS THEORETICAL PREDICTIONS

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By using the archival XMM-Newton and Swift data of the nearby Seyfert 1 AGNs Zw 229.015 and Mrk 493, we study both the spectral and temporal properties of the central blackholes in remarkable detail. The energy spectra show soft excess emission (much stronger for Mrk 493) which is consistent with both inverse comptonisation from a cold corona and relativistically blurred reflection close to a black hole. From the time lag estimate between the soft and the hard X-rays, we compute the size of the corona system to be about 20Rg for Zw 229.015. On the other hand, on longer time-scale using the Swift archival data for Zw 229.015, a time delay between the UVW2 and X-ray emissions could not be established with certainty although apparently the source appears to be brighter in UV when softer in X-rays. The UV/X-ray emissions from Mrk 493 show strong correlation that is consistent with the prediction of Comptonisation of seed UV photons in the hot corona.

E1.4-0072-18 ELECTROMAGNETIC FIELDS AND ENERGY EXTRACTION FROM BOOSTED ROTATING BLACK HOLE IMMERSED IN MAGNETIC FIELD

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We have studied electromagnetic fields and processes in the vicinity of the boosted rotating black hole immersed in external magnetic field. The exact solution of the Maxwell equations for the electromagnetic field has been found for the exterior of the boosted rotating black hole. Charged particle motion around the boosted rotating black hole in the presence of external magnetic field have been studied. The presence of the boost velocity will increase the innermost stable circular orbits around rotating black hole. Energetic processes of the energy extraction from the boosted rotating black hole have been also discussed. The exact analytic expression for the efficiency of magnetic Penrose process in the presence of boost velocity has been obtained. It was shown that boost velocity sufficiently increases the efficiency of the magnetic Penrose process.

E1.4-0073-18 LORENTZ FACTORS OF COMPACT JETS IN BLACK HOLE X-RAY BINARIES

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Compact, continuously launched jets in black hole X-ray binaries (BHXBs) produce radio to optical–infrared (OIR) synchrotron emission. These jets are launched in the hard X-ray state, and are quenched in the soft state. They are not spatially resolved except in a few cases using VLBI radio observations. One of the basic properties of these jets is the bulk Lorentz factor, which is notoriously difficult to measure, with to date only weak constraints for a few BHXBs. Here, we adopt simple models to constrain the Lorentz factor of the compact jets in several BHXBs using the amplitude of the jet fade and recovery at infrared wavelengths over state transitions.

The accretion disc tends to dominate the OIR emission throughout BHXB outbursts, but in some sources such as GX 339–4, there is an infrared excess due to synchrotron emission. In other BHXBs this IR excess is very faint or absent. Here, we investigate why some BHXBs have prominent IR excesses and some do not, quantified by the amplitude of the IR quenching or recovery over the transition from/to the hard state. Theoretically, the jet luminosity should correlate with the inclination angle if the emission is strongly beamed. Indeed, we find that some of the sources with the brightest IR excesses compared to their discs are systems with low inclination angle (e.g. 4U 1543–47 and MAXI J1836–194).

In addition, systems with longer orbital periods will produce more OIR disc emission, diluting the jet contribution. We find that the amplitude of the IR fade or recovery over state transitions is expected to be the highest for very low, or very high, inclination BHXBs. For high inclination systems the disc is almost edge-on, which reduces the disc emission but not the jet emission if the jet is not highly beamed, which can lead to relatively bright IR excesses. For intermediate inclination angles (30 – 60 deg), no bright IR excess is expected for any Lorentz factor, and indeed all of the BHXBs with inclination angles within this range do not have prominent IR excesses. Using the amplitude of the IR fade/recovery and the known orbital parameters, we constrain for the first time the Lorentz factor of compact jets in several BHXBs. We find that the very high amplitude IR fade/recovery seen repeatedly in GX 339–4 requires a Lorentz factor greater than 3 and a low inclination angle. These results are strongly supportive of the

IR excess being produced by synchrotron emission in a relativistic outflow, and demonstrate how useful OIR monitoring over state transitions is for studying jet properties.

E1.4-0074-18 THE LONG GAMMA-RAY BURSTS: STANDARD CANDLES OR SOURCES POPULATION INHOMOGENEITY.

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Typically GRBs are subdivided by two classes: long and short separated by t90 = 2 s. Unfortunately, burst duration strongly depends on detector energy band and method used for temporal profile analysis: the same events could had different duration on data of various detectors. For example, 170405A (18:39:48 UT) had t90 = 165 32 s in energy range 15-350 keV on Swift/BAT data but t90 = 81.601 0.923 s in energy band 50-300 keV on Fermi/GBM data. There are several peaks at this burst light curve and last peak was located at more than 50 s from main three-peaks episode and appears only at low energies. This peak is sufficiently slight than first episode: ten times smaller than first peak on Swift/BAT data in energy range 15-100 keV and is absent in energy band 100-350 keV. On Fermi/GBM data in energy band 10- 44 keV its intensity is about only 50 counts/s over background count rate 1200 counts/sec against 2000 counts/s over background count rate 1300 counts/s during first peak. And this peak separation cause difficulties just because of geomagnetic modulation of Fermi/GBM background. Thus Fermi/GBM burst table doesn't contain information about this episode of GRB170405A.

In addition, sufficient amount of GRBs located at high redshift and cosmological correction should be taken into account in event classes' separation due to duration analysis. Thus, GRB110731A (11:09:30 UT) had t90 = 38.8 32.0 s in energy range 15-350 keV on Swift/BAT data but t90 = 7.485 0.923 s in energy band 50-300 keV on Fermi/GBM data. Its z= 2.83 and after cosmological correction t90 1.95 s on Fermi data (short burst) and t90 10.1 s on Swift/BAT data (long event).

Moreover, separation point between short and long GRBs shifted to 1 s on preliminary results of analysis of Swift/BAT events with known z and duration (351 GRBs) and intermediate group of events occurs in range 1 < t90 < 10 s. Last facts can indicate inhomogeneity of long GRBs population. Unfortunately analogous Fermi/GBM subset is insufficient for statistical analysis. It contains only 50 events because of more than 55% of Fermi/GBM bursts has 1-sigma statistical uncertainty in the t90 duration bigger than 10%.

Redshift distribution analysis results should represent GRBs population homogeneity if it's shape similar to one of objects with real uniform distribution in our Metagalaxy. Usually SN1a used as standard candles (for example, for definition of Ω and Λ for our Metagalaxy). But GRBs redshift distribution for subset of events with known z and duration registered by Swift/BAT sufficiently differ: there is deficit of bursts at z 2. It can be caused by long GRBs population inhomogeneity too.

So, results of preliminary analysis of bursts distribution on redshift and duration allows to make conclusion about possibility of use only certain GRBs subsets as "standard candles" ones after completion of advanced events classification. However, the large majority of long GRBs are related to SNe and collapse of massive stars. Thus inhomogeneities of long GRBs population require new theoretical implications to collapse models.

E1.4-0075-18 FREQUENCY DEPENDENT CORE SHIFT EFFECT IN BLAZARS

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Blazars constitute an ambiguous subset of radio-loud Active Galactic Nuclei consisting both BL Lacertae objects with largely featureless optical spectra and flat spectrum radio quasars which have prominent emission lines. Blazars are characterized with luminous core, rapid variability over entire electro-magnetic spectra, high radio to optical polarization, superluminal motion, non thermal emission and a Doppler boosted relativistic jet pointing < 10 deg with the line of sight. We study the core shift effect in the parsec scale jet of blazars which were monitored at five different frequencies ranging from 4.8 GHz - 36.8 GHz using the University of Michigan Radio Astronomical Observatory, the Crimean Astrophysical Observatory, and Metsahovi Radio Observatory for over 40 years. We have developed piecewise Gaussian fit analysis technique to fit each flare, which is used to determine peak amplitude, and their half width. We also calculate time lags between the observation frequencies. We then determine the spectral indices based on peak amplitudes which range from 16.67 to 2.41. From the fitting of time-lag Vs frequency plots, we find equipartition between the magnetic field energy density and the particle energy density. Other jet parameters including core position offset, core radius, mean magnetic field strength at 1 pc and at the core are also estimated following various proposed theoretical models. Based on the statistical trend shown by the estimated core position offset and the core radius, we infer that synchrotron opacity model may not be valid in all cases. The mean magnetic field strength at 1 pc and at the core, are in agreement with previous estimates. We apply the magnetically arrested disk model to estimate black hole spins for these blazars, indicating that the model is consistent with expected accretion mode in such sources. The power law shaped power spectral density is interpreted in terms of multiple shocks or magnetic instabilities. Important objectives met in this study include: the demonstration of the computational efficiency and statistical basis of the piecewise Gaussian fit; consistency with previously reported results; evidence for the core shift dependence on observation frequency and its utility in jet diagnostics in the region close to the resolving limit of very long baseline interferometry observations.

E1.4-0076-18 OFF-EQUATORIAL ACCRETION DISCS - IMITATION BY CIRCLING CHARGED FLUIDS

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Charged fluids circling in strong central gravitational and ambinet magnetic fields, characteristic for compact objects backgrounds, can embody interesting configurations. In contrast to the widely considered neutral fluid structures imitating thick equatorial accretion discs with negligible loss of mass, when the fluid is properly charged, we can find it forming unique toroidal structures 'levitating' above the equatorial plane and also those hovering near the symmetry axis. Along with analytical topological studies of these structures, we can also present an survey of their basic physical characteristics, such as pressure, density and temperature profiles.

E1.4-0077-18 ON THE PROPERTIES OF STANDING AND DISSIPATIVE SHOCKS IN ACCRETION AND WIND FLOWS.

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In the present work, we study the properties of standing and dissipative accretion shocks around a Kerr black hole. We consider accretion flows around a stellar-mass black holes which emit hard X-rays from the post-shock region, also known as Compton cloud and located close to the inner edge of the disc. The radiative loss primarily comes from the thermal and kinetic energy of the flow during its pre-shock to post-apocalyptic transition phase and takes place via Comptonization process. To explain the temporal variation of this radiative loss, we study the dynamical properties of the dissipative shocks as well as the standing shocks in a self-confident way and compare the results. We quantitatively show how the energy loss at the shock affects the location of the shock itself around a rotating black hole. We find that for a suitable range of input parameters, the upper limit of the maximum release of energy at shock could be as high as 90 percent of the total available energy of the inflow matter without violating the Rankine-Hugoniot shock conditions. However, as the energy remove is sIn the present work, we study the properties of standing and dissipative accretion shocks around a Kerr black hole. We consider accretion flows around a stellar-mass black holes which emit hard X-rays from the post-shock region, also known as Compton cloud and located close to the inner edge of the disc. The radiative loss primarily comes from the thermal and kinetic energy of the flow during its pre-shock to post-shock transition phase and takes place via Comptonization process. To explain the temporal variation of this radiative loss, we study the dynamical properties of the dissipative shocks as well as the standing shocks in a self-consistent way and compare the results. We quantitatively show how the energy loss at the shock affects the location of the shock itself around a rotating black hole. We find that for a suitable range of input parameters, the upper limit of the maximum release of energy at shock could be as high as 100 percent of the total available energy of the inflow matter without violating the RankineHugoniot shock conditions. However, as the energy remove is significant, shock moves forward towards the black hole. We also compute the region of the parameter space (Energy vs. Angular momentum) and find that the effective area of parameter space is enhanced significantly as the dissipation is increased. The implication of this could be profound in studying the QPOs observed in several black hole candidates, such as XTE J1550564 and GRO J165540, during their outbursts. The QPOs evolve rapidly and the frequency changes from several mHz to a few tens of Hz in its rising phase. This could be explained with the help of dissipative shock oscillation as the size of the post-shock region varies according to the energy released from it.ignificant, shock moves forward towards the black hole. We also compute the region of the parameter space (Energy vs. Angular momentum) and find that the effective area of parameter space is enhanced significantly as the dissipation is increased. The implication of this could be profound in studying the QPOs observed in several black hole candidates, such as XTE J1550564 and GRO J165540, during their outbursts. The QPOs evolve rapidly and the frequency changes from several mHz to a few tens of Hz in its rising phase. This could be explained with the help of dissipative shock oscillation as the size of the post-shock region varies according to the energy released from it.

E1.4-0079-18 INTERMEDIATE-MASS BLACK HOLES IN DWARF GALAXIES

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Black holes are usually observed to be of stellar-mass or supermassive. By natural extension, there should be a population of Intermediate-Mass Black Holes (IMBHs: with mass between 100 to 106M0) in the Universe; which has started to been observed. An exciting claim has been made recently by Silk, J.(2017, ApJ, 839, L13): that there are IMBHs in essentially all old Dwarf

Galaxies. Early feedback by IMBHs in gas-rich dwarf galaxies at z = 5 8, can potentially solve multiple dwarf galaxy problems (e.g. core-cusp, number) within the Λ-cold-dark-matter cosmology.

I am performing Cosmological Hydrodynamical Simulations to test the case for IMBHs in Dwarf Galaxies. Our simulations employ the 3D TreePM SPH code GADGET3, and include metal cooling, star formation, chemical enrichment, supernova feedback, AGN accretion and feedback (Barai, P.etal.2016, M N RAS, 461, 1548). We are simulating small (2M pc)3 cosmological volumes with periodic boundary conditions, starting from z = 100. Black

Holes of mass 1000M0 are seeded inside halos when they reach a mass of 107M0. The black holes grow by accretion of gas from their surroundings and by merger with other black holes, and consequently eject feedback energy. Currently, I am analyzing the simulation output in post-processing to study the growth of the first IMBHs. We quantify the impact of IMBHs on their host Dwarf Galaxies; especially the effects on star formation in terms of negative or positive feedback.

Our conclusions, based on numerical simulation results, support the phenomenological ideas made by *Silk* (2017). IMBHs at the centers of dwarf galaxies can be a strong source of feedback to quench star-formation and generate outflows. At the same time, these IMBHs form the missing link between stellar-mass and supermassive BHs.

E1.4-0080-18 IS MATTER IN H1743-322 SUPPLIED AT A CONSTANT RATE?

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We study all the RXTE/ASM and MAXI/GSC data received from the transient H 1743-322 till date. The total energy radiated during each outburst shown by the source since 2003 was obtained. The comparison of energy radiated per day of outburst and per day of quiescence during each outburst is carried out. The total energy radiated per day of quiescence during all outbursts are nearly uniform (except in 2004). We speculate why this happens. We conclude that after each outburst, the matter pile-up radius (where matter piles up before being fed in towards the compact object, triggering the outburst) has been getting closer and closer in this particular transient. We also suspect this phenomenon to be a supercycle which started from 2003 and is about to reach its end, leading to a long quiescence before another supercycle begins.

E1.4-0081-18 SYNCHROTRON RADIATION REACTION OF CHARGED PARTICLES AROUND ASTROPHYSICAL BLACK HOLES

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There are convincing evidences that magnetic fields are indeed present in the vicinity of black holes, which imply that in many astrophysically relevant situations, the synchrotron radiation reaction force acting upon charged particles can not be neglected. Depending on the magnitude of the external magnetic field, the radiation-reaction force can considerably shift the stable orbits of particles, which can sufficiently influence the predictions of black hole parameters as well as due to the shifts of observational spectral frequencies. Moreover, the radiation reaction can support the accretion of charged particles from accretion disk towards the black hole. However, it is worth noting that the problem of the radiation reaction in curved spacetime still remains the source of discussion. Generically, the equations of motion are plagued by runaway solutions, so I will present the computational ways to avoid this problem in constructing numerical solutions. I will show, that depending on the orientation of the Lorentz force, the oscillating charged particle either spirals down to the black hole, or stabilizes the circular orbit by decaying its oscillations. The later case leads to an interesting effect of shifting of the particle orbit outwards from the black hole. I will also discuss the astrophysical relevance of the presented approach and provide estimations of the main parameters of the model applied to some particular black hole candidates.

E1.4-0083-18 VERY HIGH ENERGY HADRONIC AND LEPTONIC EMISSION FROM MAGNETIC RECONNECTION EVENTS AROUND BLACK HOLE ACCRETION DISKS: NUMERICAL GRMHD RADIATIVE TRANSFER-PARTICLE SIMULATIONS

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The origin of the very high energy (VHE) emission around black hole sources is still not understood. We here present numerical simulations of the very high energy emission produced in the core region of black hole (BH) accretion disk systems. We first perform general relativistic magnetohydrodynamical (GRMHD) simulations of these systems and then we carry out radiative transfer calculations in order to obtain the density, magnetic, and photon fields of the environment. The obtained photon field is due to electron synchrotron and inverse Compton (IC) radiation, with the synchrotron component being the appropriate target for photo-hadronic interactions. Then, assuming that high energy protons are accelerated by magnetic reconnection in the background magnetic field, we compute photon fluxes stemming from proton interactions with the local photon and magnetic fields (using the CRPropa3 code). From the resulting gamma rays, we obtain the spectral energy distributions, and the IC emission. Finally, we discuss the possible constraints on BH accretion disk system processes based on their emission profiles.

E1.4-0084-18 INTEGRATED MECHANISM THAT BOTH REMOVES ACCRETION DISK ANGULAR MOMENTUM AND DRIVES ASTROPHYSICAL JETS

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A mechanism [1,2] that simultaneously removes accretion disk angular momentum and drives astrophysical jets is proposed.

The mechanism depends on the extreme difference between the governing physics in a weaklyionized, highly collisional accretion disk and the governing physics in the completely-ionized, nearly collisionless region outside the disk. In the completely-ionized exterior region, axisymmetric Hamiltonian mechanics constrain charged particles to move on nested poloidal magnetic flux surfaces. In contrast, fluid elements in the weakly-ionized, highly-collisional accretion disk behave as collisionless meta-particles having an effective charge to mass ratio reduced from than that of an ion by the extremely small disk fractional ionization α. This extremely small charge to mass ratio allows meta-particles to have an effective cyclotron frequency ωc = αqB/m comparable to the Kepler frequency ωK = M G/r3 in which case there is a direct competition between gravitational and magnetic forces.

For meta-particles in a stratum having a critical ionization fraction α, the charge to mass ratio αq/m is such that the meta-particles have zero canonical angular momentum; i.e., the mechanical and magnetic parts of the canonical angular momentum Pϕ = mrvϕ + qrAϕ are equal and opposite. Hamiltonian mechanics shows that these Pϕ = 0 meta-particles experience no centrifugal force and so spiral in towards the central body while conserving canonical angular momentum at Pϕ = 0. Because these inward spiraling meta-particles contain positive charge, their accumulation near the central body produces a radially outward electric field.

This electric field drives an out-of-plane poloidal electric current in the completely-ionized region exterior to the disk. This current and its associated toroidal magnetic field produce J B magnetic forces that drive bi-directional astrophysical jets flowing normal to and away from the disk. The increase in linked toroidal magnetic flux as the jet lengthens is associated with the radial voltage drop at the disk in accordance with Faraday's law.

Bellan, P.M., Monthly Notices Royal Astronomical Society 458, 4400 (2016)

Bellan, P.M., Plasma Physics and Controlled Fusion, Plasma Phys. Control. Fusion 60, 014006 (2018)

E1.4-0086-18 X-RAY SPECTRAL STUDIES OF THE ULTRA-LUMINOUS X-RAY SOURCE M81 X-6

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We present the X-ray spectral studies of the ultra-luminous X-ray source (ULX) M81 X-6 using the Suzaku and XMM-Newton observations performed during 2001 - 2015. We systematically analysed the observed spectra with different physical models including a multi-temperature blackbody model for a thin, steady state, general relativistic accretion disc around a Kerr black hole. Spectral modelling results suggest that the source exhibits three distinct spectral shapes with different luminosity in these observations. Using the relativistic accretion disc model, we attempt to constrain the mass of the black hole, mass accretion rate and spin of the system. Our analysis suggests a maximally rotating black hole for M81 X-6 with a black hole mass of

< 100 solar mass, which is broadly consistent with the scenario that this ULX is a stellar-mass black hole emitting at Eddington or super-Eddington luminosity.

E1.4-0087-18 STUDY OF SUPERMASSIVE BLACK HOLE BINARY EVOLUTION IN EQUILIBRIUM TRIAXIAL GALAXIES USING DIRECT NBODY SIMULATIONS

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Nearly every galaxy in the universe harbor Supermassive Black Hole (SMBH) in its center. During galaxy mergers, dynamical friction drives supermassive black holes to the center of the merger remnant subsequently form a binary. The inspiral of two SMBHs produce gravitational waves (GWs) which can be detected by Laser Interferometer Space Antenna (LISA). In spherical galaxies, binary stalls at the separation of one parsec ejects all of their stars in the loss cone region leading to Final Parsec Problem (FPP). However, triaxial galaxies may avoid FPP during merger providing more loss cone refilling of stars in centrophilic orbit, thus producing coalescence. In this study, initial conditions are generated by using adiabatic squeezing technique for triaxial galaxy model with axis ratio 1:0.85:0.92 using 1000K and 500K number of particles. Starting with spherical Hernquist model with inner density slope γ=1, we then applied the artificial drag to particles velocities along each axis of the model to attain triax- ial shape. Once the initial conditions are generated then their stability were checked for the model by comparing with dehnan density profile with inner density slope γ=1, and scale radius ro=0.5. Direct N-body simulations were then performed on high performance graphic processing unit (GPU) cluster Advanced Computing Center for Research and Education (ACCRE) at Vanderbilt University using the phi-GPU code with 4th order Hermite integration scheme. The SMBH were placed in the xy, yz and xz plane. It was observed that in xy plane the binary separation and semi major axis are decreases more rapidly due to loss of angular momentum. It was also found that the density in the center decreases rapidly due to gravitational slingshot and stars interacting with central SMBH entering into zone of chaos destroying the triaxility in the central region. It is concluded that at axis ratio 1:0.85:0.92 system does not retain its triaxility. Hence, binary coalescence proceeds slowly and FPP persists.

E1.4-0088-18 EFFECTS OF LARGE SCALE STRONG MAGNETIC FIELD IN ADVECTIVE ACCRETION FLOWS AROUND BLACK HOLES: DISC-OUTFLOW COUPLING.

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The outward transfer of the angular momentum of accreting matter leads to the accretion flow and formation of disk around the compact objects. Here, we discuss the importance of large scale strong magnetic field in the removal of angular momentum outward, as well as the possible origin of different kinds of magnetic barrier in advective, geometrically thick, subKeplerian accretion flows around black holes. The origin of this large scale strong magnetic field near the event horizon is due to the advection of the magnetic flux by the accreting gas from the environment, say, the interstellar medium or a companion star, because of flux freezing. In this simplest vertically averaged, 1.5-dimensional disc model, we choose the maximum upper limit of the magnetic field, which the disc around a black hole can sustain. In this circumstances, the accreting gas either decelerates or faces the magnetic barrier near the event horizon by the accumulated magnetic field depending on the geometry. We suggest that these types of flow are the building block to produce jets and outflows in the accreting system. We also find that in some cases, when matter is trying to go back to infinity after knocking the barrier, matter is prevented being escaped by the cumulative action of strong gravity and the magnetic tension, hence by another barrier. In this way, magnetic field can lock the matter in between these two barriers and it might be a possible explanation for the formation of episodic jet.

The most self-consistent approach, in order to understand vertical transport of matter through the magnetic effects, which in turn leads to the radial in-fall of the rest of the matter, is considering the flow to be moving in the vertical direction from the disk plane as well. Such an attempt, in the absence of magnetic effects, was made earlier by Bhattacharya, Ghosh Mukhopadhyay (2010) in the model framework of coupled disk-outflow systems. In such a framework, we can see the energetics of the disk outflow strongly depend on the mass, accretion rate, and spin of the black holes.

Here, we also try to explore the coupled 2.5-dimensional disk-outflow systems in the presence of large-scale magnetic field enabling angular momentum transport, when the magnetic field plays an indispensable role in order to generate vertical flux in the three-dimensional flows.

E1.4-0089-18 OBSERVABLES FOR MASSLESS TEST PARTICLES AROUND KERR-SEN BLACK HOLE SPACETIME IN STRING THEORY

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We study the geodesic motion in the background of the Kerr-Sen black hole which arises in low energy limit of string theory. The nature of the effective potential is discussed in both the radial and latitudinal, directions with a special class of spherical photon orbits along with an expression for the turning point for the radial photons. Few observables for test particles on the angular plane such as the bending of light, perihelion precession for massive test particles and red/blue shift of photons emitted by massive test particles are calculated for a distant observer. The spin and mass parameters for the Kerr-Sen black hole are then estimated theoretically by using the red/blue shift.

E1.4-0090-18 TWO-TEMPERATURE FLOWS AROUND COMPACT OBJECTS

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Two-temperature solutions of rotating flows around black holes is one of the topics in astrophysics which is least understood and worked upon. We address this problem in greater details in the general relativistic regime. The thermodynamics of each constituent species of the relativistic fluid is governed by relativistic equation of state. Cooling has pronounced effect on electrons but negligible effect on protons. On the other hand, various dissipative processes like viscosity affects protons more than the electrons. So, electrons and protons are likely to settle down at two separate temperatures for realistic Coulomb interaction term which controls the energy exchange between these two constituent species of the gas. For inviscid accretion flow, at any given distance from the black hole, we have three unknowns velocity v, electron temperature (Te), proton temperature (Tp) and two constants of motion: generalized Bernoulli parameter and accretion rate. So, for different combinations of v, Te and Tp, we get distinctly different solutions for the same value of Bernoulli parameter and accretion rate. In other words, the solutions are not unique. We found a smart way of fixing this problem by using the principles of second law of thermodynamics. We are able to define the expression of entropy close to the horizon. Since the law of nature is to always prefer a solution of higher entropy, we identify the solution with highest entropy to be the physical one. According to our knowledge no general way of finding the solutions taking into account the degeneracy problem have not been reported so far. This is the first time we have attempted towards obtaining the general picture of the physical solutions in the two-temperature regime.

E1.4-0091-18 THE ORIGIN AND EVOLUTION OF THE MULTI-BAND VARIABILITY IN THE RADIO SOURCE 4C 38.41

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The flat spectrum radio quasar 4C 38.41 showed a significant increase of its radio flux density during the period 2012 March - 2015 August which correlates with gamma-ray flaring activity. Multi-frequency simultaneous VLBI observations were conducted as part of the interferometric monitoring of gamma-ray bright active galactic nuclei (iMOGABA) program and supplemented with additional monitoring observations at various bands across the electromagnetic spectrum. The epochs of the maxima for the two largest gamma-ray flares coincide with the ejection of two respective new VLBI components and the evolution of the physical properties seem to be in agreement with the shock-in-jet model. Derived synchrotron self absorption magnetic fields, of the order of 0.1 mG, do not seem to dramatically change during the flares, and are much smaller, by a factor 10,000, than the estimated equipartition magnetic fields, indicating that the source of the flare may be associated with a particle dominated emitting region. Analysis on the physical properties of the ejected components indicate a semi-parabolic geometry, and magnetic and electron densities seem to fall along the jet in agreement with theoretical predictions.

E1.4-0092-18 LABORATORY EXPERIMENT OF SIMULATED ASTROPHYSICAL JET COLLIDING WITH A GAS CLOUD

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High-speed, highly collimated plasma jets are observed in astrophysical systems having a wide range of length scales; examples are active galactic nuclei (AGNs), young stellar objects (YSOs), and planetary nebulae [1,2]. These jets sometimes have strong interactions with the surrounding gas medium as, for example, the interstellar cloud of the radio galaxy IC 5063 [3]. We present a laboratory experimental study of a simulated astrophysical jet colliding with a gas cloud. The laboratory astrophysical jet is launched from two concentric coplanar electrodes and accelerated by MHD forces to attain a velocity that is a fraction of the Alfvén velocity. A neutral gas cloud is puffed from a side gas tube and is arranged to be in the path of the jet so the jet impacts the target cloud. The changing magnetic field, electron temperature and electron density were measured during the interaction. Adiabatic compression of the density, an increase in the magnetic field and electron heating were observed using comprehensive diagnostics including Thomson scattering, laser interferometry, emission spectroscopy, and a magnetic probe array. Continuum radiation and line emission associated with plasma energy dissipation and cooling indicated that there was a significant radiative energy loss. In addition, the magnetic probes have measured a radially propagating disturbance, tentatively identified as an Alfvén wave, associated with the collision of the jet with the target cloud. This study is also relevant to magnetized target fusion where plasma is adiabatically compressed to achieve fusion-grade density and temperature.

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E1.4-0093-18 GALACTIC PLANE SCANNING SURVEY BY INSIGHT-HXMT

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The Insight-HXMT telescope launched on June 15 2017 is China's first X-ray astronomy satellite. One of the main scientific goal is to scan the Galactic Plane to find new transient sources and to monitor the known variable sources, and to observe X-ray binaries to study the dynamics and emission mechanism in strong gravitational or magnetic fields. We will detail the scanning strategythe data processing pipeline and some interesting results in this report.

E1.4-0094-18 RADIATIVELY DRIVEN RELATIVISTIC JETS IN CURVED SPACE-TIME

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We carry out a general relativistic study of radiatively driven fluid jets around black holes and investigate the effects and significance of radiative acceleration, as well as radiation drag. We apply relativistic equations of motion in curved space-time for the jet, plying through the radiation field of the accretion disc. Radiative moments were computed using the information of curved space-time. Slopes of physical variables at the sonic points are found using L Hôpital's rule and employed Runge-Kutta's 4 th order method to solve equations of motion. The analysis is carried out, using the relativistic equation of state of the jet fluid. The terminal speed of the jet depends on how much thermal energy is converted into jet momentum and how much radiation momentum is deposited on to the jet. Many classes of jet solutions with single sonic points, as well as, radiation driven internal shocks are obtained. Variation of all flow variables along the jet-axis has been studied. Jets with terminal orentz factors up to 3 are obtained for high energy electron-proton jets under intense radiation field. Moderate terminal speed v T 0.5 is obtained for moderately luminous discs. Lepton dominated jets may achieve Lorentz factors up to 10. Variety of jet solutions are obtained, due to the interaction of accretion disc radiation with the out-flowing jet, where the possibility of moderate jets to relativistic jets is possible depending on the intensity of the radiation field and the energetics of the jet. We establish that radiation field is able to induce steady shocks in jets, one of the criteria to explain high energy power law emission observed in spectra of some of the astrophysical objects.

E1.4-0095-18 UPDATES ON THE STELLAR-MASS BLACK HOLE CANDIDATE IN M62

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We present an update to an observational campaign to measure the mass of the black hole candidate in M62. The existence of stellar mass black holes in globular clusters has forced a rethinking of cluster dynamics in recent years. M62-VLA1 was identified as a black hole candidate on the basis of its luminous radio emission with a flat radio spectrum, and a position on the fundamental plane of X-ray and radio luminosity consistent with stellar mass black holes. Spectroscopy with MUSE and HST reveals an F7IV donor star, with 60% of the continuum light originating from the accretion disk. Multiple epochs of spectroscopy reveal variable, double-peaked Hα emission and allow radial velocity measurements to constrain both the orbital period and the mass of the accretor.

E1.4-0096-18 SPECTRAL ANALYSIS OF H 1743-322 IN ITS 2004 OUTBURST USING THE TCAF SOLUTION

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The black hole transient H 1743-322 exhibited several outbursts with different spectral variability since its discovery in 1977. The 2004 outburst was the first stereotypical one after the truly anomalous and intense outburst in 2003. This motivated us to investigate the accretion flow dynamics of this object during its 2004 outburst. We employed spectral analysis in the 2.5-25.0 keV energy range using Two Component Advective Flow (TCAF) solution. We extract spectral fitted parameters like the disk and halo accretion rate, the shock location and also mass, which is intrinsic property to the black hole. The fitting was also done by keeping the normalization constrained in a narrow range, and the new fitted parameters are consistent with the previous case. Thereby the normalization of this object is directly obtained by spectral fitting. We also constrained the mass within a narrower range compared to the previous findings.

E1.4-0097-18 EXPLORING THE EVOLUTION OF INNER DISC RADIUS AND OTHER INTRINSIC PARAMETERS ACROSS THE INTERMEDIATE STATES OF THE BLACK HOLE BINARY GX 339-4 USING X-RAY REFLECTION SPECTROSCOPY

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One of the unsettled issues pertaining to Black Hole x-ray binaries is the origin of state transitions and evolution of various intrinsic physical parameters of the accretion disc during outbursts. In order to explore the same, we analyse several RXTE observations from two different outbursts of the Black Hole binary GX 339-4, and perform a consistent study of the reflected spectrum in its bright intermediate states. We employ the most recent version of the relxill family of relativistic reflection models, and perform simultaneous spectral fits on the observations from each outburst, to probe the evolution of the properties of the accretion disk including the inner disk radius (Rin), ionization parameter (ξ), and the temperature of the inner disk. In order to test the capability of RXTE/PCA in detecting narrow emission lines corresponding to a large disc truncation, several simulations are performed with gaussian and reflection (relxill) models for different cases of Black Hole spin ($a*$) and reflection fraction. Data/Model ratios reveal no evident relativistic broadening in the reflection features with decrease in hardness ratio values, qualitatively suggesting no substantial change in Rin across the bright intermediate states. Our analysis with the relativistic reflection models suggest that, the inner edge of the disk reaches $\sim$ Risco during the bright hard state, and the truncation remains at a value of $1 \sim 5 \times$ Risco throughout the bright horizontal branch across the intermediate states.

E1.4-0098-18 ATOMIC OPACITIES AND THERMAL INSTABILITY IN ACCRETION DISKS

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The radiation pressure instability in geometrically thin, optically thick, Shakura-Sunayev alpha accretion disk causes the instable beaviour of numerous sources like GRS1915 and IGR J17091 microquasars, as well as the HLX-1 intermediate-mass black hole candidate. The thermoviscous instability is determined by local thermal instability, determined by the gap between the viscous heating and radiative cooling.

As the viscous heating depends on pressure and structure of the magnetic field, in the optically thick disk the radiative cooling is inversely proportional to optical thickness, it means that the various processes of interaction between light and matter can shape the stability parameter function and stabilize (or destabilize) the disk.

In our previous models we included only the Thomson type of scattering, being constant value independent on the disk temperature.

In our current work we apply the tabelarized data containing values of atomic opacities connected with the transitions in ionized heavy atoms and investigate their influence on disk instability in both aspects - local and global.

RESEARCH IN ASTROPHYSICS FROM SPACE (E)

ORIGIN OF COSMIC RAYS (E1.5)

E1.5-0001-18 LATEST RESULTS FROM THE AMS EXPERIMENT

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The Alpha Magnetic Spectrometer, AMS, steadily collects data on the International Space Station for 7 years. The AMS data sample corresponds to over 115 billion charged cosmic rays. In this presentation I will review the latest results from the AMS experiment.

E1.5-0002-18 PRECISION MEASUREMENT OF ELECTRON AND POSITRON FLUXES IN PRIMARY COSMIC RAYS WITH THE ALPHA MAGNETIC SPECTROMETER ON THE INTERNATIONAL SPACE STATION

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Precision measurements by the Alpha Magnetic Spectrometer on the International Space Station of the primary cosmic-ray e+, eand (e- + e+) fluxes in the energy range up to 2000 GeV are presented. The electron flux and the positron flux are significantly different in their magnitude and energy dependence, however their behavior is consistent with a contribution from a new source of high energy particle contributing equally to the fluxes of electrons an positrons.

E1.5-0003-18 PRECISION MEASUREMENT OF THE POSITRON FRACTION IN PRIMARY COSMIC RAYS WITH THE ALPHA MAGNETIC SPECTROMETER ON THE INTERNATIONAL SPACE STATION

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A precision measurement by AMS of the positron fraction in primary cosmic rays in the energy range from up to 1000 GeV based on 25 million positron and electron events is presented. This measurement extends the energy range of our previous observation and increases its precision. The new results show that at 290 GeV the positron fraction reaches its maximum. This is consistent with a new source of high energy electrons an positrons.

E1.5-0004-18 ANTIPROTON FLUX AND PROPERTIES OF ELEMENTARY PARTICLE FLUXES IN PRIMARY COSMIC RAYS MEASURED WITH THE ALPHA MAGNETIC SPECTROMETER ON THE INTERNATIONAL SPACE STATION

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The fluxes and flux ratios of charged elementary particles in cosmic rays are presented in the absolute rigidity range from 1 to 1000 GV. In the absolute rigidity range 60 to 500 GV, the antiproton, proton, and positron fluxes are found to have nearly identical rigidity dependence and the electron flux exhibits different rigidity dependence. Below 60 GV, the antiproton-toproton, antiproton-to-positron, and proton-to-positron flux ratios each reaches a maximum. Particular emphasis is made on new observations of the properties of elementary particles in the rigidity range above 500 GV.

E1.5-0005-18 ANTIDEUTERON IN PRIMARY COSMIC RAYS WITH THE ALPHA MAGNETIC SPECTROMETER ON THE INTERNATIONAL SPACE STATION

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Antideuterons and deuterons in Primary Cosmic Rays will be discussed based on over the first 6.5 years of AMS data on the International Space Station

E1.5-0006-18 OBSERVATION OF THE IDENTICAL RIGIDITY DEPENDENCE OF THE PRIMARY COSMIC RAYS HELIUM, CARBON AND OXYGEN WITH THE ALPHA MAGNETIC SPECTROMETER ON THE INTERNATIONAL SPACE STATION

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Precision measurement of the primary cosmic rays fluxes of helium, carbon and oxygen in the rigidity range from 2 GV to 3 TV is presented based on 90 million helium, 8 million carbon and 7 million oxygen nuclei collected by AMS during first 5 years of operation. Unexpectedly, above 60 GV, these three spectra have identical rigidity dependence.They all deviate from a single power law above 200 GV and harden in an identical way.

E1.5-0007-18 MEASUREMENTS OF LIGHT NUCLEAR ISOTOPIC COMPOSITION IN COSMIC RAYS WITH THE ALPHA MAGNETIC SPECTROMETER ON THE INTERNATIONAL SPACE STATION

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The average lifetime of cosmic rays in the Galaxy related with their confinement within the Galactic propagation halo, is a very important parameter to understand comic-ray propagation processes and the cosmic-ray origin. The measurement of the 10Be/9Be secondary isotopes ratio, as 10Be has half-life of 1.39 million years, can be used to constrain the propagation lifetime. The 6Li/7Li ratio, as both isotopes are secondary and stable, is expected to reflect the ratio between the production cross sections and therefore constitutes a good check of the reconstruction method. Measurement of the lithium isotopes ratio (6Li/7Li) as a function of the kinetic energy per nucleon from 0.5 GeV/nucl to 10 GeV/nucl based on data collected by AMS during the first 5 years of operation is presented. Prospects for measurement of the beryllium and boron isotopic ratios with AMS-02 will be presented.

E1.5-0008-18 PRECISION MEASUREMENTS OF 3HE-TO-4HE RATIO AND INDIVIDUAL 3HE AND 4HE FLUXES IN COSMIC RAYS WITH THE ALPHA MAGNETIC SPECTROMETER ON THE INTERNATIONAL SPACE STATION.

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The spectral shape of the secondary isotopes in cosmic rays is completely determined by the source spectrum of the parent elements and by the propagation process. In particular, 3He in cosmic rays is believed to result from the interaction of primary 4He with the interstellar medium, providing a powerful tool to constrain the parameters of the galactic cosmic rays propagation models. A precise measurement of the helium isotopes ratio (3He/4He) and the individual 3He and 4He fluxes in the kinetic energy per nucleon range from 1.0 GeV/nucl to 10 GeV/nucl based on data collected by AMS during the first 5 years of operation are presented.

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The nitrogen flux in cosmic rays is expected to contain both primary and secondary components, so the knowledge of their relative contributions is important in understanding the origin, acceleration, and propagation of cosmic rays. A precise measurement of the nitrogen flux with rigidity from 2 GV to 3 TV based on 2 million nuclei collected by AMS during first 5 years of operation is presented.

E1.5-0010-18 PRECISION MEASUREMENT OF SECONDARY-TO-PRIMARY COSMIC RAYS FLUX RATIOS WITH THE ALPHA MAGNETIC SPECTROMETER ON THE INTERNATIONAL SPACE STATION.

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Precision measurement of Secondary-to-Primary Cosmic Rays Flux Ratios Li/He, Be/He, B/He, Li/C, Be/C, B/C, Li/O, Be/O, and B/O is presented based on 5.4 million secondary nuclei and more than 100 million primary nuclei collected by AMS during the first 5 years of operation. Remarkably, above 200 GV, the secondary cosmic rays harden more than the primary cosmic rays. This observation is important for the study of the origin of the hardening in cosmic ray fluxes and for the global understanding of the origin, acceleration and propagation of cosmic rays.

E1.5-0011-18 OBSERVATION OF NEW PROPERTIES OF SECONDARY COSMIC RAYS LITHIUM, BERYLLIUM, AND BORON BY THE ALPHA MAGNETIC SPECTROMETER ON THE INTERNATIONAL SPACE STATION

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We report on the observation of new properties of secondary cosmic rays, Li, Be, and B, measured in the rigidity range 1.9 GV to 3.3 TV with a total of 5.4 million nuclei collected by AMS during the first 5 years of operation. Unexpectedly, the Li and B fluxes have an identical rigidity dependence above 7 GV and all three fluxes have an identical rigidity dependence above 30 GV with the Li/Be flux ratio of 2.0 ± 0.1. The three fluxes deviate from a single power law above 200 GV in an identical way.

E1.5-0012-18 THE LESSON OF PAMELA

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PAMELA is a medium-sized space experiment for the detection of cosmic rays that took data for 10 years from 2006 to 2016. Composed of a magnetic spectrometer and several auxiliary detectors it has been completely realized, at a very reasonable cost, by the collaboration: its different parts at Physics Departments in Italy, Russia, Sweden and Germany and finally the integration in the clean rooms of INFN at Rome Tor Vergata University. The reduced dimensions of the instrument required high performance of the individual detectors to obtain high-precision measurements over a range of energy from tens of MeV/n to 1 TeV/n. In ten years of data taking in space, the experiment PAMELA has shown very interesting features in cosmic rays, namely in the fluxes of protons, helium, electrons, that might change our basic vision of the mechanisms of production, acceleration and propagation of cosmic rays in the Galaxy. In particular, remarkable and stimulating have been the measurements of cosmic antiproton and positron fluxes that have allowed the nature of dark matter to be probed in a new way, suggesting new ideas and setting strong constraints to the models. The continuous particle detection allowed for a constant monitoring of the solar activity and detailed study of the solar modulation for a long period, giving important improvements to the comprehension of the heliosphere mechanisms. PAMELA also measured the radiation environment around the Earth, and discovered an antiproton radiation belt.

E1.5-0013-18 OBSERVATION OF COMPLEX TIME STRUCTURES IN THE COSMIC-RAY ELECTRON AND POSITRON FLUXES WITH THE ALPHA MAGNETIC SPECTROMETER ON THE INTERNATIONAL SPACE STATION

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High-statistics, precision measurements of the time and energy dependence of the primary cosmic-ray electron flux and positron flux over 79 Bartels Rotations from May 2011 to May 2017 in the energy range from 1 to 50 GeV are presented. For the first time, the charge-sign dependent modulation during solar maximum can be investigated in detail by leptons alone. Based on 23.5 million events the observation of short-term structures on the time scale of months coincident in both the electron flux and the positron flux is reported. These structures are not visible in the positron/electron flux ratio. The precision measurements across the solar polarity reversal show that the ratio exhibits a smooth transition from one value to another. The midpoint of the transition shows an energy dependent delay relative to the reversal. Unfolding the time-dependent solar modulation will constrain the physics of cosmic rays outside the solar system.

E1.5-0014-18 ANISOTROPY IN THE ARRIVAL DIRECTIONS OF PRIMARY COSMIC RAYS MEASURED WITH THE ALPHA MAGNETIC SPECTROMETER ON THE INTERNATIONAL SPACE STATION

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The features observed by AMS in high energy cosmic rays e+, e-, p, He,. are new phenomena, which may be connected to the presence of new astrophysical sources. Possible anisotropies in the arrival directions of cosmic rays therefore provide crucial information to understand their origin. Based on a sample collected during the first 6 years of AMS operation on the ISS, a measurement of the anisotropy in the arrival directions of primary cosmic rays will be presented.

E1.5-0015-18 NEW RESULTS OF VERY-LOW ENERGY ANTIPROTON SPECTRUM AND ANTIDEUTERON SEARCH IN BESS-POLAR II

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High-precision measurement of the cosmic-ray antiproton spectrum and sensitive search for cosmological antihelium has been published from BESS-Polar II (Balloon-borne Experiment with a Superconducting Spectrometer) for core study of the early Universe using elementary particle measurements. With a thin plastic scintillator middle-TOF (MTOF) hodoscope that is installed on the lower surface of the magnet bore to measure low-energy particles that cannot reach the lower-TOF, new absolute spectrum of the cosmic-ray antiproton in the range 0.1 to 0.8 GeV and the antiproton/proton ratio calculated with upper-middle TOF trigger events would be reported. We also report the result of a new search for antideuterons with unprecedented sensitivity using BESS-Polar II data that is more than ten times the statistics of the most sensitive reported search from BESS97 in near solar minimum conditions. The low-energy antiproton spectrum and the search for antideuteron probe possible exotic sources, such as dark-matter candidates.

E1.5-0016-18 ON THE ACCELERATION AND TRANSPORT OF GALACTIC COSMIC RAYS

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I will review recent developments on the subject of acceleration and transport of Galactic Cosmic Rays. Recent observations, and the data collected by PAMELA and AMS02 in particular, have revealed a number of unexpected features in the spectra of both primary and secondary Cosmic Rays. These findings seem to challenge the standard description of Cosmic Ray propagation through the Galaxy and also impact our theories on the origin of these particles.

I will discuss how at least some, if not all, of the presumed anomalies allow for an explanation based on non-linear effects associated with CR transport, and more generally what they suggest about the origin and propagation of Galactic Cosmic Rays.

E1.5-0017-18 DAMPE AND ITS LATEST RESULTS

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Dark Matter Particle Explorer (DAMPE), the first Chinese astronomical satellite, was launched into a Sun-synchronous orbit at an altitude of about 500 km on 17 December 2015. DAMPE is a high-energy particle detector optimized for observations of cosmic ray electrons and gammarays up to about 10 TeV. In this talk I'll introduce the on-orbit performance of the detector, the calibration, and the latest results on cosmic rays and gamma-rays of DAMPE.

E1.5-0018-18 STUDIES ON COSMIC-RAY ELEMENTAL COMPOSITION WITH DAMPE MISSION

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Since December 17th, 2015, the DAMPE (DArk Matter Particle Explorer) detector is orbiting at the altitude of 500 km and collecting data smoothly. The main goal of the mission includes the indirect search of Dark Matter, by looking for signatures in the electron and photon spectra with energies up to 10 TeV, and in general the study of cosmic charged and gamma radiation in space. The large effective area and calorimeter depth (32 radiation lengths), in particular, enable DAMPE to study the elemental composition of cosmic rays and to measure their fluxes in the energy range from 20 GeV up to hundreds of TeV, thus providing insight on their origin and propagation mechanisms. Here the analysis progress in the study of the Helium and heavier components in cosmic rays will be presented and discussed.

E1.5-0019-18 ANALYSIS OF COSMIC RAY PROTON SPECTRUM WITH THE DARK MATTER PARTICLE EXPLORER

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Precise measurements of the energy spectra of cosmic rays are very important for understanding such fundamental questions as the origin, acceleration, and propagation of cosmic rays. The Dark Matter Particle Explorer (DAMPE), a satellite-borne high-energy particle detector, is able to measure nuclear cosmic rays to kinetic energies up to hundreds of TeV and is expected to advance significantly such studies. The DAMPE mission was launched on December 17th, 2015, and all detectors operate smoothly for over two years. In this talk the preliminary analysis of the proton component of Galactic cosmic rays will be reported.

E1.5-0020-18 COSMIC RAY ENERGETICS AND MASS (CREAM) LAUNCH AND ON-ORBIT PERFORMANCE

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The CREAM experiment was launched on a SpaceX Falcon 9 rocket to the International Space Station (ISS) from NASA's Kennedy Space Center on August 14, 2017. The instrument was successfully installed and activated on the ISS Japanese Experiment Module Exposed Facility as an attached payload on August 22, 2017. The CREAM instrument was initially developed to measure cosmic ray elemental spectra using a series of ultra-long-duration balloon flights. The balloon-borne CREAM experiment was flown seven times between 2004 and 2016 over Antarctica accumulating 191 days of flight time, the longest known exposure for a single balloon project. Building on the success of the balloon flights, the payload was transformed for accommodation on the ISS. This version of CREAM, aka ISS-CREAM, is configured with redundant and complementary particle detectors capable of precise measurements of elemental spectra for $Z = 1 - 26$ nuclei, as well as electrons. The four layers of its finely segmented Silicon Charge Detector provide precise charge measurements, and its ionization calorimeter provides energy measurements. In addition, scintillator-based Top and Bottom Counting Detectors and Boronated Scintillator Detector distinguish electrons from nuclei. At least an order of magnitude increase in data collecting power is expected by utilizing the ISS to reach the highest energies practical with direct measurements. On-orbit performance of the instrument and preliminary results from the ongoing analysis will be presented.

E1.5-0021-18 SUPERNOVA REMNANTS AS ACCELERATORS OF VERY HIGH ENERGY COSMIC RAYS

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Cosmic ray acceleration by astrophysical shocks in supernova remnants of different types is discussed. Results of numerical modeling for young and middle-age supernova remnants and acceleration in interstellar bubbles created by powerful stellar winds of supernova progenitors are presented. Non-thermal electromagnetic and neutrino emission produced by accelerated particles in supernova remnants is compared with the available data of radio, X-ray, gammaray and neutrino astronomy.

E1.5-0022-18 THE CALORIMETRIC ELECTRON TELESCOPE (CALET) ON THE INTERNATIONAL SPACE STATION

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The CALorimetric Electron Telescope (CALET) space experiment, which has been developed by Japan in collaboration with Italy and the United States, is a high-energy astroparticle physics mission installed on the International Space Station (ISS). The primary goals of the CALET mission include investigating possible nearby sources of high-energy electrons, studying the details of galactic particle propagation and searching for dark matter signatures. During a two-year mission, extendable to five years, the CALET experiment measures the flux of cosmicray electrons (including positrons) to 20 TeV, gamma-rays to 10 TeV and nuclei with Z=1 to 40 up to 1,000 TeV. The instrument consists of two layers of segmented plastic scintillators for the cosmic-ray charge identification (CHD), a 3 radiation length thick tungsten-scintillating fiber imaging calorimeter (IMC) and a 27 radiation length thick lead-tungstate calorimeter (TASC). CALET has sufficient depth, imaging capabilities and excellent energy resolution to allow for a clear separation between hadrons and electrons and between charged particles and gamma rays. The instrument was launched on August 19, 2015 to the ISS with HTV-5 (H-II Transfer Vehicle 5) and installed on the Japanese Experiment Module-Exposed Facility (JEM-EF) on August 25 .

Since the start of operation in mid-October, 2015, a continuous observation has being kept mainly by triggering high energy (>10 GeV) showers without any major interruption. The number of the triggered events over 10 GeV is nearly 20 million per month. By using the data obtained during the first two-years, we will have a summary of the CALET observations: 1) Electron+Positron energy spectrum, 2) Proton and Nuclei spectrum, 3) Gamma-ray observation, with results of the performance study on orbit. We also present the results of observations of the electromagnetic counterparts to LIGO-VIRGO gravitational wave events and high-energy counterparts to GRB events measured with the CALET Gamma-ray Burst Monitor (CGBM).

E1.5-0023-18 MEASUREMENT OF COSMIC-RAY ELECTRON AND POSITRON SPECTRUM FROM CALET ON THE ISS

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The CALET (CALorimetric Electron Telescope), launched to the International Space Station (ISS) in August 2015 and accumulating scientific data since October 2015, is an all-calorimetric instrument with total vertical thickness of 30 radiation lengths and fine imaging capability, designed to achieve large proton rejection and excellent energy resolution well into the TeV energy region. CALET will allow for the detailed search for various spectral structures of highenergy electron cosmic rays, perhaps providing the first experimental evidence of the presence of a nearby astrophysical cosmic-ray source.

Electron spectrum analysis starts with detailed detector calibrations covering from detector alignment to energy determination, followed by electron event selection and flux normalization. Special care was taken to identify electrons in the presence of a large hadron background. Possible source of systematic errors are carefully surveyed, and associated uncertainties are estimated for each contribution. As a result, electron + positron spectrum is obtained including the TeV energy range.

In this contribution, we will present electron and positron spectrum measured by CALET with an emphasis on a detailed analysis of the systematic uncertainties.

E1.5-0024-18 MEASUREMENTS OF COSMIC-RAY CARBON AND OXYGEN NUCLEI SPECTRA WITH CALET

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The Calorimetric Electron Telescope (CALET) was installed onboard the International Space Station in August 2015 and since October 2015 it is collecting data with smooth and continuous operations. The instrument consists of two layers of segmented plastic scintillators to identify the charge of individual elements from proton to iron, a thin imaging tungsten-scintillating fiber calorimeter providing accurate particle tracking and complementary charge measurement, and a thick total absorption calorimeter made of lead-tungstate crystal logs. In addition to high precision measurements of the electron spectrum up to several TeV, CALET can measure the individual spectra and elemental composition of cosmic-ray nuclei from few tens of GeV to the PeV scale, which is of fundamental importance to shed light on the mechanism of acceleration and propagation of cosmic rays in the galaxy. In this paper, preliminary measurements of the energy spectra of carbon and oxygen and their ratio will be presented.

E1.5-0025-18 PROPAGATION OF COSMIC RAYS IN COLLECTIVE AND NONDIFFUSIVE REGIMES

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Advanced measurements of cosmic ray (CR) spectra have revealed vast gaps in our knowledge of how they propagate through the ISM and Heliosphere. The propagation is thought to be a diffusion controlled by particle scattering on the hydromagnetic turbulence present in the medium. Although the limitations of the diffusive approximation are apparent in many cases, ways to overcome them are not, which hinders the interpretation of observed spectra. One glaring flaw arises with increasing particle energy. As the particle mean free path (m.f.p.) typically also increases, the diffusive approximation breaks down whenever the m.f.p. exceeds some scale of the problem. The particle transport must be ballistic on that size. These two very simple propagation regimes, diffusive and ballistic, proved challenging to connect. The corresponding transition (transdiffusion) region in the energy spectrum is not small, while the two transport models are very different. The transdiffusive propagation is best approached using Fokker-Plank equation, from which the ballistic and diffusive propagation regimes both derive. By finding an exact solution of this equation, the issue of applicability of either quickly resolves.

Particle propagation dramatically deviates from both diffusive and ballistic regimes when their concentration is sufficient to enhance the turbulence level in the ambient medium. The enhancement is caused by instabilities that particles drive while escaping their acceleration sites, such as supernova remnants. The resulting propagation may technically be considered diffusive, but it is a nonlinear diffusion, spreading particles very differently than test particles. Most importantly, enhanced scattering on the self-excited turbulence leads to reduced particle transport. This effect is also energy-dependent, implicating another transition (break) in the particle energy spectrum. The latter phenomenon is essential whenever the pressure of energetic particles near a source exceeds the ambient magnetic pressure. Since they are similar under average ISM conditions, the particle pressure automatically exceeds the magnetic pressure by orders of magnitude near sources that contribute to the galactic CR population.

E1.5-0026-18 A RANKING OF PRODUCTION CROSS-SECTIONS FOR LIGHT COSMIC RAYS: LI, BE, B, C, AND N.

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The precision of the new generation of cosmic-ray (CR) experiments, such as AMS-02, PAMELA, CALET, and ISS-CREAM, is now reaching the percent level in a wide energy range from GeV/n (per nucleon) to multi-TeV/n. A precise understanding of cosmic-rays production and propagation as well as stringent constraints on dark matter are guaranty results from a precise interpretation of the measured fluxes. Meanwhile, a major obstacle in doing so is the current uncertainty in the isotopic production cross sections which is often as high as 20-50% or even larger in some channels. This embarrassing situation is gaining momentum in the astrophysics community which call for a dedicated experimental effort. I will first illustrate the impact of the current cross-section models on the interpretation of the data. Measuring the all set of cross-sections needed is of course a huge work that requires an incremental approach. In a recent work my collaborators and I aim at providing the community with the ranking of the cross sections contributing to the production of the most astrophysically important isotopes of Li, Be, B, C, and N. I will present this ranking and give an evaluation of the beam time necessary to reach a 3% precision in the production cross-sections pertinent to the AMS-02 experiment. This first roadmap may become a starting point in the planning of new measurement campaigns that could be carried out in several nuclear and/or particle physics facilities around the world.

E1.5-0027-18 COSMIC-RAY ELECTRON FLUX FROM 1GEV TO 10 GEV WITH LOW-ENERGY TRIGGER IN THE CALET EXPERIMENT

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The Calorimetric Electron Telescope (CALET) was installed on the International Space Station (ISS) in August 2015 and began to collect data in October 2015. CALET has multiple event trigger modes for measuring high-energy particles and gamma rays, and the effective observations have been successfully performed by scheduling these trigger modes according to the conditions of ISS position and orbital information. The cosmic-ray (CR) electrons (electrons

+ positrons) in the energy region from 10 GeV to 20 TeV, that may provide a possible signature of high-energy electron acceleration at nearby CR origin, have been measured by using a high-energy shower trigger mode. In addition, a low-energy (LE) shower trigger mode working at the polar region can measure the low-energy CR electrons in an energy range of 1 GeV to 10 GeV. By using this LE shower trigger, stable and continuous observations of the low-energy CR electrons have been accomplished for about 2.5 years that is comparable to one quarter of the period of the solar activity cycle.

In this study, we have analyzed flight data obtained by the LE shower trigger for 812 days from October 12, 2015 to December 31, 2017. Using a physics analysis consisting of seven event selections, including a track reconstruction utilizing the Kalman filter method and an electron identification based on the lateral energy-deposit distribution in the TASC first layer with respect to the shower axis, we succeeded to keep electron efficiency of about 50% at 1GeV and that of 70% or more above 2 GeV while removing more than 99% of protons. In this presentation we will show the variations of the energy spectrum of CR electrons in an energy range of 1 GeV to 10 GeV observed by CALET from October 2015 to December 2017, and also discuss the physics implications of the solar modulation of CR electrons.

E1.5-0028-18 MEASUREMENTS OF HEAVY COSMIC-RAY NUCLEI SPECTRA FROM CALET ON THE ISS

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The CALorimetric Electron Telescope, CALET, was launched in August 2015 and has been measuring high-energy cosmic rays on the International Space Station since October 2015. In addition to the high-precision measurements of the all electron spectrum, CALET also performs the precise measurements of the energy spectra of elements from proton to iron, the relative abundances and the secondary-to-primary ratios to the highest energies ever directly observed in space. These will allow for the investigation of the details of their origin and propagation in the galaxy. The CALET instrument consists of two layers of segmented plastic scintillators to identify the individual elements from Z=1 to 40, a fine-grained imaging calorimeter to obtained complementary charge and tracking information, and a total absorption calorimeter to measure the energy with a total 30 radiation lengths and 1.3 nuclear interaction lengths.We will present the details of heavy nuclei (Z>8) analysis including the particle identification capabilities and the analysis of the systematic uncertainties.

E1.5-0029-18 STATUS OF CALET ULTRA HEAVY COSMIC RAY ANALYSIS

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The CALorimetric Electron Telescope (CALET) is a Japanese-Italian-US astroparticle observatory operating on the International Space Station (ISS). CALET was launched on August 19, 2015 and continues to return excellent data. The main calorimeter (CAL) was designed to measure the highest energy cosmic ray electrons from 1 GeV to 20 TeV, but it also measures cosmic-ray (CR) nuclei up to 1,000 TeV and gamma-rays above 10 GeV. The energy spectra of the more abundant CR nuclei through 26Fe are measured with the CAL, which also has the dynamic range to measure the abundances of CR nuclei from 1H to 40Zr. CALET has a ultraheavy cosmic-ray (UHCR) trigger based on the two scintillator layers of the charge detector (CHD) module and the four top scintillating fiber planes of the imaging calorimeter (IMC) module that provides an expanded geometric acceptance. Rigidity cutoffs from the earth's geomagnetic field can be used to select higher energy events from this trigger that can be resolved without an energy measurement from the bottom total absorption calorimeter (TASC) module, such that in its approved 5 year mission on the ISS CALET will collect a UHCR data set with statistics comparable to that achieved with the first flight of the SuperTIGER balloon-borne instrument in a similar energy range. Preliminary results of the CALET UHCR data analy- sis show reasonable agreement with SuperTIGER relative abundances of even charge UHCR nuclei, and progress has been made in resolving the odd charge UHCR nuclei as well. The CALET space-based measurements have the benefit that they do not require the corrections for atmospheric interactions that those of SuperTIGER do. They also complement the lower energy space-based UHCR measurements by ACE-CRIS.

E1.5-0030-18 PRELIMINARY RESULTS ON THE MEASUREMENT OF THE PROTON SPECTRUM WITH CALET ON THE ISS

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The CALorimetric Electron Telescope CALET, located in the JEM-EF external platform of the International Space Station, is collecting science data continuously since mid October 2015. More than 500 million triggers generated by high-energy charged particles and photons of cosmic origin have been recorded to date. CALET is an international space mission led by JAXA with the participation of the Italian Space Agency ASI and NASA. In addition to its primary goal of carrying out direct measurements to explore the electron spectrum in the poorly known energy region above 1 TeV, CALET is investigating the cosmic-ray hadronic component with highprecision measurements of the energy spectra, relative abundances and secondary-to-primary ratios of elements from proton to iron and above (up to atomic number Z=40). Equipped with a thick (30 X0, 1.3 ΛI) calorimeter, including a finely segmented 3 X0 pre-shower section with excellent imaging capabilities followed by a 27 X0 total absorption homogeneous calorimeter, and with two independent sub-systems to identify the charge of the incident particle, CALET provides an excellent energy and angular resolution and electron/proton discrimination of order 10−5. CALET observations extend the range of previous proton measurements in the multi-TeV region confirming a deviation of the proton differential spectrum from a simple power-law, as previously reported by CREAM, PAMELA and AMS-02. In this paper, preliminary results on the proton spectrum as well as details of the analysis will be presented.

E1.5-0031-18 ACCELERATION OF COSMIC RAYS IN SUPERNOVA REMNANT SHOCKS: MASS TO CHARGE SELECTIVITY

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The high precision spectrometry of galactic cosmic rays (CR), e.g. the Pamela experiment [1], accurately determined an approximately 0.1 difference between the rigidity spectral indices of protons and Helium ions. Similar deviations have been indicated earlier by other experiments [2] and confirmed by the recent high-fidelity AMS-02 measurements [3]. These findings may shed light on the long standing problem of CR origin. While the CR particles are believed to be accelerated in supernova remnant (SNR) shocks via diffusive shock acceleration (DSA), it is still not understood how different CR elements are extracted from the supernova environments and injected into the DSA. The similarity of He/p, C/p, and O/p rigidity spectra demonstrated by AMS-02 has provided new evidence that injection is a mass-to-charge dependent process. In oder to investigate the elemental selectivity of the injection mechanism and determine the injection efficiency of ion species with different charge-to-mass ratio, A/Z, we performed fully self-consistent hybrid simulations. Our results confirm the earlier theoretical predictions that the efficiency of injection depends on the shock Mach number, M and its increase with A/Z saturates at a level that growth with M. Moreover, they show that for high A/Z the injecton efficiency decreases. By convolving the time-dependent injection rates of p and He, obtained from the simulations, with a decreasing shock strength over the active life of SNRs, we generate the integrated SNR spectra for p and He. These spectra are consistent with the AMS-02 and Pamela data. In particular they correctly predict the decrease in p/He ratio with increasing rigidity at exactly the rate measured in the experiments for > 10 GV. Only at lower rigidities,

;S 10 GV, the difference between the data and our predictions becomes noticeable. Whether this deviation comes from the propagation through the interstellar medium or solar modulation, remains unclear. Except for this uncertainty, the suggested mechanism for A/Z-dependence of the injection fully explains the measured p/He ratio.

[1] O. Adriani, et al., Science 332, 69 (2011)

[2] A.D. Panov, et al., Bul. Russian Academy of Sciences: Physics, 73, 564 (2009) [3] M. Aguilar, et al. (AMS Collaboration), Phys. Rev. Lett., 115, 251101 (2015)

E1.5-0032-18 A MULTI-MESSENGER APPROACH TO THE SEARCH FOR THE ORIGIN OF THE POSITRON EXCESS IN COSMIC RAYS

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Pulsed TeV gamma-ray measurements from Crab with the MAGIC experiment and gravitational wave detection with the Earth interferometers (LIGO-Virgo detectors) in the last three years represent two major steps forward for the understanding of young and middle-aged pulsar physics and energy losses at the moment the advanced versions of these last experiments will be operational. Middle-aged pulsars were proposed among the most plausible astrophysical sources of electrons and positrons that may explain the positron excess observed in cosmic rays with respect to the secondary component. It will be shown here that the role of supernova fallback matter on pulsars and circumpulsar disk formation may reconcile within only one scenario cosmic-ray particle observations and electromagnetic and gravitational wave measurements from disks around these compact objects. As a matter of fact, the second generation space interferometers are expected to allow for the detection of circumpulsar disk precession.

E1.5-0033-18 RESULTS OF THE "NUCLEON" SPACE EXPERIMENT AND EXTENSION OF GALACTIC COSMIC RAYS RESEARCH BY THE "NUCLEON 2" AND THE "HIGH ENERGY RAYS OBSERVATORY" PLANNED EXPERIMENTS

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In this work results of the "NUCLEON" space observatory for two and a half exposure years: energy spectra and charge composition of cosmic ray nuclei in the energy range of 2-500 TeV are presented. Current status of the "NUCLEON 2" project for charge and isotopic composition research of ultra heavy cosmic ray nuclei (launching in 2021-2022) and "High Energy Rays Observatory" project for cosmic ray nuclei research up to 1017eV byaheavycalorimeter(launchingafter2025)isal

E1.5-0034-18 A NEW UNIVERSAL COSMIC RAY KNEE NEAR THE MAGNETIC RIGIDITY 10 TV IN THE DATA OF NUCLEON SPACE OBSERVATORY

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Data from the NUCLEON space observatory indicates the existence of a universal cosmic ray “knee”, which is observed in different groups of nuclei (protons, helium, heavy nuclei) near a magnetic rigidity of about 10-20 TV. The knee is estimated to be statistically significant. The position in the magnetic rigidity scale and changes of the spectral indices of the spectra of different nuclei groups are reported. New cosmic-ray knee is similar to the famous cosmic-ray knee near the energy 3 PeV per particle and may be related to a limit of acceleration energy of some sort of cosmic ray source. The location of the knee near the same magnetic rigidity 10 TV points out to such a nature of this spectral break.

E1.5-0035-18 SECONDARY TO PRIMARY RATIOS OF COSMIC RAY NUCLEI IN THE NUCLEON EXPERIMENT

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The NUCLEON satellite experiment is aimed at direct measurement of the energy spectra of cosmic ray nuclei and the chemical composition (Z=130) in the energy range of 2-500 TeV. Energy measurements are performed by two different methods (ionization calorimeter and the new Kinematic Lightweight Energy Meter (KLEM) technique). Ratios of secondary to primary nuclei (B/C, N/O, subFe/Fe) are presented. The behavior of the ratios is discussed.

E1.5-0036-18 ORIGIN OF COSMIC RAY METALS: CORE COLLAPSE AND TYPE IA SUPERNOVAE, PLUS BINARY NEUTRON STAR KILONOVAE

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Analyses of recent cosmic ray abundance measurements from H to U now allow us to quantitatively define the nucleosynthetic and grain-sputtering injection contributions to the elemental abundance enrichment of cosmic rays accelerated in core collapse supernovae in superbubbles. Moreover, they also enable us to address the contributions of Type 1a supernovae and the newly observed binary neutron star merger kilonovae.

E1.5-0037-18 GALPROP CODE FOR GALACTIC COSMIC RAY PROPAGATION AND ASSOCIATED PHOTON EMISSIONS

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Last decade is marked with many breakthroughs in astrophysics of cosmic rays, and more are expected in the nearest future. Their proper interpretation is impossible without a welldeveloped propagation code. The GALPROP project celebrates its 22nd anniversary this year. This project is devoted to the development of a self-consistent model for CR propagation in the Galaxy and associated diffuse emissions (radio, microwave, X-rays, gamma-rays). The project stimulated independent studies of the interstellar radiation field, distribution of the interstellar gas (H2, H I, H II), synchrotron emission and the Galactic magnetic field, and isotopic production cross sections. Version 56 that have many new capabilities has recently become public. I will talk about recent updates to the code and results. As always, the latest release is available through the WebRun, a service to the scientific community enabling easy use of the GALPROP code via web browsers.

E1.5-0038-18 NASA'S SCIENTIFIC BALLOONING PROGRAM

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I will talk about progress in NASA's scientific ballooning program and opportunities it will provide in the near future.

E1.5-0039-18 GALACTIC COSMIC RAY ENERGY SPECTRA FOR HEAVY ELEMENTS (NEON TO ZINC) FROM 0.8 TO 10 GEV/NUC AND A SEARCH FOR MICROQUASAR SPECTRAL FEATURES WITH THE SUPERTIGER INSTRUMENT

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SuperTIGER (Trans-Iron Galactic Element Recorder) is a large-area balloon-borne instrument built to measure the galactic cosmic-ray (GCR) abundances of elements from Z=10 (Ne) through Z=56 (Ba) at energies from 0.8 to sim 10 GeV/nuc. SuperTIGER was launched from Antarctica and flew for a record-breaking 55 days, from December 8, 2012 to February 1, 2013. We will report on the status of SuperTIGER energy calibration, using the instrument's aerogel and acrylic Cherenkov detector signals, and on instrumental and atmospheric corrections to obtain cosmic ray energy spectra for abundant elements (e.g. Zle30). Heinz and Sunyaev (2002) suggested that microquasar jets observed in GRS 1915+105 and GRO J1655-40 may be observable as near monoenergetic peaks in heavy ions in the 3-10 GeV/nuc energy range. The large area and long flight duration of SuperTIGER is particularly suited to looking for these microquasar signatures with good statistics. We will compare our SuperTIGER spectra (extrapolated to the top of the atmosphere) with ACE/CRIS spectra from the same time period, and with spectra from a solar modulated GCR model, in order to search for features that may be produced by microquasar jets. We will also compare SuperTIGER spectra with those of the earlier TIGER experiment, using data from its 2001-2002 Antarctic flight.

E1.5-0040-18 SUPERTIGER ABUNDANCES OF GALACTIC COSMIC-RAYS FOR THE CHARGE INTERVAL Z=41-56

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On December 8, 2012 the SuperTIGER (Trans-Iron Galactic Element Recorder) instrument was launched from Williams Field, Antarctica on a long-duration balloon flight lasting 55 days and maintaining a mean altitude of 125,000 feet. SuperTIGER made measurements of the relative abundances of Galactic cosmic-ray nuclei from Neon to Zirconium (charges Z=10-40) with high statistical precision and well resolved individual element peaks. SuperTIGER also made exploratory measurements of the relative abundances up to Barium (Z=56). Although the statistics are low for elements heavier than Zirconium (Z=40), we will show how the relative abundances of charges Z=40-56 compare to those reported by HEAO3-HNE during 1979-81. The relative abundances of elements Zirconium through Neodymium (Z=40-60) are of particular interest because they are formed both by supernova explosions and by binary neutron star mergers. A well resolved measurement of this range of elements can show us how much the composition of the Galactic cosmic-rays is affected by contributions from both of these possible sources. SuperTIGER 2 was originally scheduled for a 2017-18 Austral summer launch from Williams Field, Antartica. The 2017-18 campaign was cancelled, however, due to consistently unfavorable weather. A fully integrated SuperTIGER 2 will remain in Antarctica in anticipation of a possible rescheduled flight during the Austral summer of 2018-19. As solar minimum should persist through next season, we estimate that SuperTIGER 2 will experience a 50% increase in the particles collected per unit time as compared to SuperTIGER 1. With the combined data sets of SuperTIGER 1 and 2, we will improve the statistics of our relative abundance measurements of the Z=30-56 range.

E1.5-0041-18 CONSTRAINTS ON GALACTIC COSMIC-RAY ORIGINS FROM ELEMENTAL COMPOSITION MEASUREMENTS

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Constraints on galactic cosmic-ray origins from elemental composition measurements

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We present measurements of the abundances of ultra-heavy (Z>29) cosmic rays made by the

CRIS instrument on NASA's ACE satellite. The data set corresponds to >7000 days of data collection beginning December 4, 1997 through January 10, 2018. The charge resolution shows essentially complete separation of charges in the Z>28 range. We have detected more than 1100 events over the charge range of Z=30-40. Our measurements show that the ordering of refractory and volatile elements with atomic mass is greatly improved when compared to a mix of massive star outflow and SN ejecta with normal interstellar material (ISM), rather than with pure ISM. In addition, the refractory and volatile elements have similar slopes and refractory elements are preferentially accelerated by a factor of 4. The measured abundances support a model in which cosmic-ray source material is a mix of material from massive star outflow and ejecta and normal ISM. This research is supported by NASA under Grant NNX13AH66G.

E1.5-0042-18 THE GAPS EXPERIMENT TO SEARCH FOR DARK MATTER USING LOWENERGY ANTIMATTER

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The General Antiparticle Spectrometer (GAPS) is designed to carry out a sensitive dark matter search by measuring low-energy cosmic ray antiparticles. GAPS will open a new window to explore a wide range of dark matter models and masses in a complementary manner to existing direct, indirect and collider searches. At low energies the secondary antideuteron flux is very low, and well-motivated, beyond the standard model theories predict a detectable flux of antideuterons significantly above this level. GAPS will also conduct a low-energy antiproton search. Combined, these observations will provide stringent constraints on dark matter, and provide the best limits to date on primordial black hole evaporation on Galactic length scales.

GAPS is planned to fly on a long-duration balloon over Antarctica in the austral summer of 2020. The primary detector is a one cubic meter central volume containing planes of Si(Li) detectors. This volume is surrounded by a time-of-flight system to both trigger the Si(Li) detector and better reconstruct particle tracks. After slowing down in the Si(Li) target, an incident antiparticle is captured and autoionizes the shell electrons to form an excited exotic atom. This atom de-excites via characteristic X-ray transitions before producing a pion/proton star when the antiparticle annihilates with a portion of the nucleus of the atom. This unique event topology will give GAPS the nearly background-free detection capability that is critical in a rare-event search.

This presentation will address the motivation for this low-energy antiparticle search, discuss the current status of the GAPS experiment and give an update on the design of the payload.

E1.5-0043-18 GALACTIC COSMIC RAY OBSERVATIONS FROM VOYAGERS 1 AND 2

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Voyager 1 crossed into interstellar space on 25 August 2012 at 121.6 AU from the Sun. At the time of the conference, it will have collected nearly 6 years of low-energy galactic cosmic ray (GCR) data from the nearby interstellar medium. We will report the latest results on topics ranging from the radial gradient of GCRs just outside the heliosphere to energy spectra and composition of the arriving cosmic rays. Voyager 2 is still in the inner heliosheath but appears to be rapidly approaching the heliopause. We will show observations that yield rough estimates of when it might cross into interstellar space.

This research was supported by NASA Grant NNN12AA01C.

E1.5-0044-18 SOLAR MODULATION, FORBUSH DECREASES AND SOLAR ENERGETIC PARTICLES WITH AMS

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The Alpha Magnetic Spectrometer (AMS), on the International Space Station (ISS) since May 2011, has acquired the largest number of particles ever measured in space by a single experiment, performing the most precise measurement of galactic cosmic rays (GCR) to-date. The detailed time variation of multiple particle species fluxes measured in the first years of operations, during the ascending phase of solar cycle 24 and reversal of the Sun's magnetic field polarity (from negative $A < 0$ to positive $A > 0$). For all particles, the high energy spectrum remains stable versus time, while the low-energy range is strongly modulated by the solar activity. In addition, AMS measured several Forbush decreases (FD) and solar energetic particles (SEP) associated with the short term solar activity. AMS data allows us to study the time evolution of the rigidity dependence of these type of events for multiple particle species. Selected FD and SEP events observed by AMS, since the beginning of its mission, will be presented.

E1.5-0045-18 HELMOD MODEL AND COSMIC RAY PROPAGATION IN THE HELIOSPHERE

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HelMod is a 2-D Monte Carlo capable to describes the transport of Galactic cosmic rays through the heliosphere down to and at several distances from Earth. The model includes the symmetric and antisymmetric part of the diffusion tensor, thus, properly treating particle drift effects. The model was been tuned in order to fit the data observed outside the ecliptic plane at several distances from the Earth and, also, the spectra observed near the Earth during high and low solar activity periods. HelMod was proved to reproduce light and heavy cosmic rays observed during solar cycle 23-24 by several detectors, for instance, PAMELA, BESS and AMS-02. A new set of local interstellar spectra were obtained in conjunction with GALPROP model.

E1.5-0046-18 NEW SELF-CONSISTENT LOCAL INTERSTELLAR SPECTRA FOR ELECTRONS, POSITRONS, PROTONS, HELIUM AND CARBON

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The observations made by the Voyager 1 spacecraft outside the dominant modulating influence of the heliosphere allows the comparison of computed galactic spectra with in situ experimental data at lower energies (less than 100 MeV/nuc). Using a galactic propagation model, such as the GALPROP code, galactic spectra can be computed and taken as local interstellar spectra (LIS's). By implementing the GALPROP code we set out to simultaneously reproduce the cosmic ray electron, proton, Helium and Carbon observations made by Voyager 1 beyond the heliopause. These LIS's are also compared to the observations made by the PAMELA space detector at the Earth using a comprehensive 3D solar modulation model. Using these models and observations we can also infer a positron LIS and present a set of self-consistent LIS's for the energy range of 3 MeV/nuc to 100 GeV/nuc.

E1.5-0047-18 THE HEAVY NUCLEI EXPLORER

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The HNX (Heavy Nuclei eXplorer) is a new mission to measure the abundances of ultra-heavy galactic cosmic ray (UHGCR) nuclei, that will be proposed as a NASA Small Explorer (SMEX) at the next opportunity (expected early 2019) by NASA Goddard Space Flight Center, University of California, Berkeley, Washington University in St. Louis, the Jet Propulsion Laboratory, the University of Minnesota, Pennsylvania State University and the Northern Kentucky University. The planned effort builds on very successful proposals in 2001 and 2014, that, unfortunately, did not result in a flight selection. HNX will complement and extend measurements by TIGER/SuperTIGER, ACE, and HEAO and will investigate the nature of the reservoirs of nuclei at the cosmic-ray sources, the mechanisms by which nuclei are removed from the reservoirs and injected into the cosmic accelerators, and the GCR acceleration mechanism. HNX will measure, for the first time, the abundance of every individual element in the periodic table from carbon through the actinides, providing the first fully resolved measurement of many of these elements. These measurements are especially timely and interesting to the broader astrophysics community in light of the recent detection of a binary neutron star merger in gravitational radiation, gamma-rays and radio. HNX will record several thousand UHGCR nuclei with atomic number Z30, including about 50 actinides. This will enable sensitive tests of the relative importance to the nucleosyntheis of UH elements of R and S neutron capture processes and the relative contributions of supernovae and binary neutron star mergers. To measure UHGCR with unprecedented statistics and individual element resolution over its full measurement range, HNX will use two large instruments, the Extremely-heavy Cosmic-ray Composition Observer (ECCO) using sophisticated glass detectors and the Cosmic-ray TransIron Galactic Element Recorder (CosmicTIGER) using electronic detectors evolved from the SuperTIGER (Super Trans-Iron Galactic Element Recorder) long-duration balloon instrument. HNX will be accommodated in the SpaceX DragonLab orbiting laboratory that will also return it to Earth for post-flight processing of the ECCO detectors. The scientific motivations of HNX and details of the planned mission and instruments will be discussed, including the results of CERN accelerator tests.

E1.5-0048-18 THREE-DIMENSIONAL MODELS OF THE INTERSTELLAR MEDIUM FOR THE PROPAGATION OF COSMIC RAYS AND THEIR NON-THERMAL INTERSTELLAR EMISSIONS

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High-energy gamma rays of interstellar origin are produced by the interaction of cosmic-ray (CR) particles with the diffuse gas and radiation fields in the Galaxy. The main features of this emission are well-understood and are reproduced by existing CR propagation models employing 2D Galactocentric cylindrically symmetrical geometry. However, the high-quality data from instruments like the Fermi Large Area Telescope reveal significant deviations from the model predictions on few to tens of degree scales indicating the need to include the details of the Galactic spiral structure and thus require 3D spatial modelling. In this contribution the propagation of CRs and generation of high-energy interstellar emissions from the Galaxy are calculated using the latest release of the GALPROP code employing 3D spatial models for the CR source, interstellar gas, and interstellar radiation field (ISRF) densities. The interstellar emission models that include arms and bulges for the CR source and ISRF densities provide plausible physical interpretations for features found in the residual maps from high-energy gamma-ray data analysis. The 3D models for the CR and interstellar medium densities provide a more realistic basis for interpretation of the direct CR measurements and for their non-thermal interstellar emissions including the directions toward the inner Galaxy and about the Galactic centre.

E1.5-0049-18 COSMIC-RAY SOURCES AS GAMMA-RAY SOURCES

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Galactic cosmic rays are accelerated in sources situated in the disc of the Galaxy, and thereafter move along spiral trajectories, scatter on magnetic inhomogeneities, and consequently diffuse through the interstellar medium and leak away into the intergalactic medium. This process of diffusion essentially erases almost all traces of the direction to their origins. Thus the expectation from the early years of cosmic-ray astrophysics was that gamma-ray astronomy would help in identifying the sources: The cosmic rays subsequent to acceleration to high energies would interact with matter in the source regions, produce neutral pions, which decay and generate gamma rays. Observation of such gamma rays would point directly towards the sources of cosmic rays. This expectation of identifying the sources of cosmic rays is only partially fulfilled - gamma-ray astronomy in recent decades has been able to identify a very large number of sources in the Galaxy, but it has not been possible to unequivocally identify them as the sources of cosmic rays that have been observed. In this paper we identify the amount of material that cosmic rays traverse in the source regions, as this has a direct bearing on their gamma-ray emissivity and spectra. To this end we make use of all the available data on cosmic rays, especially the recent results on the spectra and composition measured with great energy resolution and statistical significance by the Alpha Magnetic Spectrometer aboard the International Space Station. The analysis shows that a significant amount of material is indeed traversed by cosmic rays in the source regions allowing these regions to function as gamma-ray sources.

E1.5-0050-18 ORIGIN OF COSMIC RAYS IN LIGHT OF 10 YEARS OF FERMILAT MISSION

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The Large Area Telescope (LAT) on board the Fermi Gamma-ray Space Telescope has continuously taken data data since 2008. In 10 years of the mission, the Fermi-LAT team has provided gamma-ray measurements from 10 MeV to 2 TeV as well as the flux and dipole anisotropy of electrons, positrons and protons from GeV to multi TeV energies. I will review the main results on the origin of cosmic rays that the LAT team has published using gamma-ray, electron and positron and preliminary proton data. My presentation will include evidence of the acceleration of protons in Supernova Remnants (SNRs) through the measurement of hadronic gamma-ray emission and the detection of the gamma-ray emission from the Fermi Bubbles, molecular clouds and star forming galaxies. Finally, I will show possible interpretations for the electron and positron flux in terms of SNRs, Pulsar Wind Nebulae and secondary production.

E1.5-0051-18 RECENT RESULTS FROM THE HAWC GAMMA-RAY OBSERVATORY

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The High Altitude Water Cherenkov (HAWC) Gamma-ray Observatory in the high mountains of Mexico was completed in March of 2015 and is now giving us a new view of the TeV sky. HAWC is 15 times more sensitive than the previous generation of wide-field EAS gamma-ray instruments and is able to detect the Crab nebula at >5 with each daily transit. Unlike Imaging Atmospheric Cherenkov Telescopes (IACTs), HAWC operates 24hrs/day with over a 95% ontime and observes the entire overhead sky (8sr over the course of the day). This talk will present recent results showing our updated sky catalog, including our view of the sky above 50 TeV and first observations of the jets of a micro-quasar. We will also show recent results on how our observation of nearby middle-aged pulsars impact our understanding of their contribution to the positron flux at earth.

E1.5-0052-18 HAWC OBSERVATIONS ON TWO NEARBY PULSAR WIND NEBULAE CONSTRAIN THE ORIGIN OF LOCAL POSITRONS

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Nearby electron and positron accelerators, especially Pulsar Wind Nebulae, have been proposed as potential origins of the local positron excess above 10 GeV. The HAWC Gamma-Ray Observatory has reported the discovery of TeV gamma-ray emission extending several degrees around two nearby middle-aged pulsars Geminga and B0656+14, suggesting ultra-relativistic electrons and positrons accelerated in our backyard. By performing morphological studies, we determine the diffusion of electrons and positrons in the interstellar medium around the two pulsars. We will present the morphological and spectral studies on these two TeV gamma-ray sources and the derived positron contribution at Earth.

E1.5-0053-18 THE VHE GAMMA-RAY SKY VIEWED WITH H.E.S.S.

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In the 15 years since its construction, the H.E.S.S. gamma-ray observatory has allowed the study of the VHE gamma-ray sky at resolutions and sensitivities which were never before possible. During this period H.E.S.S. has discovered a rich zoo of both galactic and extra galactic source classes, made measurements of the galactic cosmic ray spectrum and placed limits on fundamental physical processes.

We will present a summary of the latest H.E.S.S. results for these source classes, describing the most interesting new observations and their physical interpretation. Additionally we will detail the latest upgrades and improvements to the H.E.S.S. hardware and data analyses and the future science prospects for the experiment.

E1.5-0054-18 GALACTIC GAMMA-RAY ASTROPHYSICS WITH VERITAS

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The Galaxy carries a small but quite significant population of highly energetic denizens: supernova remnants with fast shocks, pulsars with powerful winds, intensely-interacting binary systems built from a compact object and a massive star. All of these environments conspire to generate nonthermal populations of particles, and radiation produced by these particles is gradually revealing the methods by which Nature accelerates cosmic rays, as well as the ways in which those cosmic rays escape and diffuse into the interstellar medium. In this talk, we discuss advances in our understanding of these environments and processes provided by recent results from VERITAS, an array of ground-based imaging air-Cherenkov telescopes located at the Whipple Observatory in southern Arizona and sensitive to gamma rays in the energy range from 85 GeV to > 30 TeV. These results include studies of cosmic-ray acceleration in the supernova remnants Cassiopeia A and IC 443, as well as the remarkable Fall 2017 periastron passage of VER J2032+4127, the binary system containing PSR J2032+4127 and the Be star MT91 213 with a 50-year period.

E1.5-0055-18 THE ALPACA EXPERIMENT: OVERVIEW AND CURRENT STATUS

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ALPACA (Andes Large area PArticle detector for Cosmic ray physics and Astronomy) is a highaltitude air-shower experiment at 4,740m of Mt. Chacaltaya near La Paz, Bolivia. ALPACA aims at observing 10 TeV gamma rays in the southern hemisphere with 100elucidate sub-PeV high-energy astrophysics. ALPACA consists of a 83,000m2 surface air-shower array to measure energies and arrival directions of air showers, and a 5,400m2 underground muon detector array to discriminate gamma-ray and cosmic-ray primaries based on the muon content of air showers. A 1/10-scale prototype array is currently being constructed and data taking will be started in mid 2018. The overview and current status of the project will be presented in the talk.

E1.5-0056-18 TUNKA ADVANCED INSTRUMENT FOR COSMIC RAYS AND GAMMA ASTRONOMY

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We present the current status of high-energy cosmic-ray physics and gamma-ray astronomy at the Tunka Astrophysical Center. This complex is located in the Tunka valley, about 50 km from the Baikal lake. At present, three arrays of the complex to study charged cosmicrays are operated: Tunka-133, Tunka-REX and Tunka-Grande. Their measurement of energy spectrum and mass composition is important in order to understand the acceleration limit of the Galactic cosmic-ray sources and the transition from Galactic to extragalactic sources. Most of the ongoing efforts are focused on the construction of the first stage of the gamma-ray observatory TAIGA. TAIGA (Tunka Advanced Instrument for cosmic ray physics and Gamma Astronomy) is designed for the study of gamma-rays and charged cosmicrays in the energy range of 1013 eV - 1018 eV. The TAIGA prototype will consist of 100 wide angle timing Cherenkov stations (TAIGA-HiSCORE) and three IACTs deployed over an area of 1 km^2. The installation of the array will be finished in 2019 while data-taking already proceeds during the commissioning phase. The combined reconstruction of energy, direction, and core position of the imaging and non-imaging detectors allow to increase the distance between the IACTs up to 600 -800 m, therefore reducing the costs dramatically. The low investments together with the high sensitivity for energies 30-50 TeV make this pioneering technique very attractive for exploring the galactic PeVatrons and cosmic rays. In addition to the Cherenkov light detectors we intend to deploy a muon detectors over an area of 1 km^2 with a total area of muon detectors of about 1000 m2. The results of the fist season of common operation of IACT with 40 stations of TAIGA-HiSCORE will be presented

E1.5-0057-18 PROBING COSMIC-RAY PHYSICS IN STARBURST GALAXIES WITH FUTURE HIGH-ENERGY MISSIONS

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Cosmic ray feedback on a galaxy's interstellar medium (ISM) can substantially influence the galaxy's formation and evolution. Cosmic rays ionize and heat the ISM, regulating star formation. Cosmic-ray transport can also result in galactic winds that will drive material out of galaxy disks and enrich the intergalactic medium. In order to assess the influence of cosmic ray feedback (relative to other types of feedback) in driving the conditions for galaxy formation and evolution, we need to better understand the complex interplay among cosmic rays, galaxy magnetic fields, and the ISM (the CR-B-ISM relationship) in a variety of interstellar environments.

The sole means for probing cosmic-ray physics in other galaxies is through the byproducts of their interactions with gas and radiation in their environments, including the broadband nonthermal diffuse spectrum observable from hard X-rays to TeV gamma rays. Observations of nearby galaxies by Fermi in the GeV band and Imaging Atmospheric Cherenkov Telescopes in the TeV band have resulted in the first detections of non-AGN galaxies outside of the Milky Way. Recent NuSTAR observations of starburst galaxies such as NGC 253 and M82 enable the most sensitive search to date for their diffuse inverse Compton emission in the hard X-ray band (10-30 keV). Such extremely deep observations are made with very long exposures and are currently only available for very nearby galaxies; however, they provide a glimpse of what we may expect from next-generation facilities. In this talk, I will discuss the latest results from high-energy observations of nearby star-forming galaxies, including the connection between the gamma-ray, radio, and far-infrared emission. I will discuss the implications of these results for these galaxies' cosmic ray populations. Finally, I will set the stage for next generation high-energy facilities, including (but not limited to) HEX-P, FORCE, AMEGO, CTA, and IceCube-Gen2.

E1.5-0058-18 CHERENKOV TELESCOPE ARRAY: OVERVIEW AND GALACTIC SCIENCE PROGRAM

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See https://www.cta-observatory.org/consortium_authors/authors_2018_07.html for full author list

The Cherenkov Telescope Array (CTA) will be the next-generation gamma-ray observatory, investigating gamma-ray and cosmic ray astrophysics at energies from 20 GeV to more than 300 TeV. The observatory, consisting of large arrays of imaging atmospheric Cherenkov telescopes in both the southern and northern hemispheres, will provide full-sky coverage and will achieve a wider energy range and a significantly improved sensitivity compared to existing instruments such as H.E.S.S., MAGIC and VERITAS.

The development of CTA is being carried out by a worldwide consortium of scientists from 32 countries. This talk will provide an overview of CTA and will review the scientific motivation for CTA, with a focus on the key science projects that relate to the study of Galactic sources of very high-energy emission and to the long-standing question on the origin of cosmic rays.

E1.5-0059-18 RECENT RESULTS FROM THE PIERRE AUGER OBSERVATORY

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I will review recent results from the Pierre Auger Observatory, especially studies of the anisotropy of the highest energy cosmic rays.

E1.5-0060-18 RESULTS FROM THE TELESCOPE ARRAY EXPERIMENT

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We present recent results on the spectrum, composition and anisotropy of VHE and UHE cosmic rays based on data from the Telescope Array (TA) and Telescope Array Low Energy Extension (TALE) experiments. TA and TALE are hybrid air-fluorescence/Cherenkov and surface array experiments covering the energy range from 1015.2 to greater than 1020 eV with overlapping techniques. New results on spectral features including the first and second knee, ankle and GZK cutoff will be presented as well as updates on the hybrid composition measurements using the Xmax technique above 1018.2 eV. A new analysis of energy spectrum anisotropy above 1019.2 eV around the previously reported hot spot near Ursa Major will also be presented. We also report on the status of the TAx4 project currently under construction.

E1.5-0061-18 ON THE ACCELERATION OF ULTRA HIGH ENERGY COSMIC RAYS AT RICH CLUSTER ACCRETION SHOCKS - PROGRESS, PROBLEMS AND PROPOSED TESTS

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Longstanding, proposed sites for the acceleration of Ultra High Energy Cosmic Rays are accretion shocks surrounding nearby, rich clusters of galaxies. These can form with large Mach numbers and subject a seed population of PeV cosmic rays that escape normal galaxies to diffusive shock acceleration. This explanation probably requires the highest energy particles to be medium to heavy nuclei and the intergalactic propagation to be quite rapid. We will outline the modern basis of this model in the context of recent observations of this particles and supernova remnants, address some difficulties that these observations may present and propose some observational tests. Special attention will be paid to the associated luminosity densities of the various cosmic ray populations.

E1.5-0062-18 HIGH ENERGY INTERACTIONS OF COSMIC RAYS

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I'll review the state of the art concerning modelling of high energy cosmic ray interactions. A special attention will be devoted to novel theoretical approaches employed in models-generators of hadronic interactions and to the impact of experimental data from the Large Hadron Collider (LHC). In relation to studies of ultra-high energy cosmic rays (UHECRs), the differences between models' predictions for basic characteristics of UHECR-induced extensive air showers in the atmosphere will be analysed and traced down to the differences in the respective interaction treatments. Possibilities to discriminate between the alternative approaches, based on LHC and UHECR data, will be demonstrated and the relation to UHECR primary composition will be outlined. Finally, in relation to direct studies of charged cosmic rays, potential improvements of the treatment of cosmic ray interactions at low and intermediate energies will be discussed.

E1.5-0063-18 PRELIMINARY RESULTS OF THE TUS ORBITAL DETECTOR OF ULTRAHIGH ENERGY COSMIC RAYS

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The first orbital detector of ultra-high energy cosmic rays (UHECR) TUS was launched on board the Lomonosov satellite on April 28, 2016. The detector is a UV telescope with a mirrorconcentrator of 2 m2 area and a photodetector composed of 256 photo multiplier tubes for measuring fluorescent radiation of extensive air showers (EAS) produced in the atmosphere by UHECR particles. The field of view of the detector is 80 80 km^2 at sea level providing an instant exposure comparable with that of the largest ground-based arrays (Pierre Auger Observatory and the Telescope Array). We report preliminary results of a search for EAS-like events in the TUS data and their analysis, including a strong UHECR candidate registered on October 3, 2016. We also present a rich variety of atmospheric phenomena measured during the mission, among them UV background and airglow, anthropogenic radiation, aurora lights, lightning discharges and transient luminous events, meteors. The experience of the TUS detector gives unique data on the transient UV radiation from the atmosphere and proves the capability of EAS measurements from space. This is an important step for future UHECR orbital missions like KLYPVE-EUSO.

E1.5-0064-18 RESULTS FROM THE THIRD FLIGHT OF THE ANTARCTIC IMPULSIVE TRANSIENT ANTENNA (ANITA) PAYLOAD

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ANITA is a long-duration balloon payload which searches for impulsive radio signals in the 200-1200MHz band arising from the Askaryan effect in neutrino interactions in the Antarctic ice sheets, and via air-shower radio signals from cosmic-ray-like events in the atmosphere above the ice. Because of the wide synoptic view of Antarctic ice that is obtained from stratospheric balloon altitudes, ANITA has a very large instantaneous acceptance for neutrino signals. We report here on results of the third flight of ANITA, taking place in December 2014-January 2015. We also present preliminary performance results from the fourth ANITA flight, which flew in the last weeks of 2016, and for which the data was retrieved in early 2017.

E1.5-0065-18 POEMMA: PROBE OF MULTI-MESSENGER ASTROPHYSICS

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The Probe Of Multi-Messenger Astrophysics (POEMMA) mission is being designed to identify the sources of the most extreme particles ever observed, the ultra-high energy cosmic rays (UHECRs), and to discover cosmic neutrinos above 10 PeV. POEMMA will consist of two satellites, flying in loose formation, each with a wide field-of-view UV photodetector, using an innovative Schmidt camera, optimized to observe both air fluorescence and air Cherenkov signals from UHECRs and neutrinos. POEMMA will measure the spectrum, composition, and sky distribution of the UHECRs above 10 EeV and the Cherenkov signals from upward-moving air showers induced from tau neutrino interactions in the Earth. POEMMA's goal is to obtain orders of magnitude higher sensitivity to the highest energy cosmic messengers compared to what is achieved by ground-based experiments in order to identify the most energetic cosmic accelerators in the universe, study the acceleration mechanism(s), and probe particle interactions at energies well-above those achieved by man-made accelerators.

E1.5-0066-18 THE JEM-EUSO PROGRAM TO STUDY ULTRA-HIGH ENERGY COSMIC RAYS FROM SPACE.

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The origin and nature of Ultra-High Energy Cosmic Rays (UHECRs) remains as one of the still unsolved problems in the current scenario of Astroparticle Physics. To give an answer to these questions is rather challenging because of the extremely low flux of a few per km^2 per century at extreme energies such as $E > 5 \times 1019$ eV and beyond. In order to obtain a significant statistics in the data, very large arrays of surface telescopes on ground are required (like Auger and Telescope Array, operating in Argentina and Utah, respectively). A complementary way to tackle the problem is to employ wide-field telescopes to look down from space onto the night sky to detect UV photons emitted from air showers generated by UHECRs in the atmosphere. The observation of UHECRs from space offers several advantages such as large exposure, uniform observation of both celestial hemispheres, uniform detector response. The main objective of the JEM-EUSO program (Extreme Universe Space Observatory) is the realization of a space mission devoted to the scientific research of cosmic rays of highest energies. In order to make a proof-of-principle of the UHECR observation from space, to meet the science requirements and the constraints (mass, power, hardness) of space-borne detectors, and to raise the technological level of the instrumentation to be employed in a space mission, different test experiments using fluorescence detectors systems have been developed and performed by the JEM-EUSO Collaboration. These systems have been extensively tested and calibrated in different phases: the installation of a ground based telescope at the Telescope Array site (EUSO-TA, operating since 2013) and a first Stratospheric Balloon flight from Canada (EUSO-Balloon, 2014). A second generation of greatly improved detectors has been developed, the first on a Super Pressure Balloon (EUSO-SPB) which flew from New Zealand in Spring 2017, the second - Mini-EUSO - a small telescope to be placed on the Russian Module of the International Space Station (ISS) in late 2018 - early 2019. A second Super Pressure Balloon flight (EUSO-SPB2) is planned to be launched in 2021 from New Zealand. Scientific, technical and programmatic aspects will be discussed also in the context of future missions like K-EUSO (in Russia) and POEMMA (in USA).

E1.5-0067-18 USING THE SQUARE KILOMETRE ARRAY TO DETECT HIGH ENERGY COSMIC PARTICLES

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SKA High Energy Cosmic Particles Focus Group

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The Square Kilometre Array (SKA) will be a giant array of radio telescopes to be built in Australia and Southern Africa over the next ten years. The SKA's High Energy Cosmic Particles Focus Group aims to use this instrument to study cosmic ray interactions in the atmosphere above the detector with 'ultimate precision', and use the Moon as a 20 million km² target for the highest-energy flux.

This contribution describes these two proposed experiments. It gives an update on the current status of the SKA, and describes the efforts of the HECP Focus Group to harness its power to detect sub-microsecond cosmic ray pulses. The ultimate aim is to use the SKA to study air shower physics with high-precision near-field interferometry, the cosmic-ray composition near the knee, and perform directional studies in the highest-energy regime, above 1019 eV.

E1.5-0068-18 A VISION FOR THE FUTURE OF MULTIMESSENGER ASTRONOMY WITH NEUTRINOS: THE ICECUBE GEN2 OBSERVATORY

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Neutrinos are ideal astronomical messengers that bring information across vast cosmological distances. Neutral, they are not deflected by galactic and intergalactic magnetic fields. Weakly interacting, they are not diffused by interstellar matter nor photon fields nor even by thick shrouds of material surrounding the exotic, high energy astrophysical particle accelerators where they are produced. They arrive at the observer in pristine form. Catching these ghostly particles, however, is an enterprise: cubic kilometers of target material must be instrumented to yield a handful of events per year. The IceCube detector has turned a billion tons of ice at the South Pole into a neutrino telescope. In 2013, IceCube reported the discovery of a flux of neutrinos of astrophysical origin consistent with isotropic sources, establishing the existence of hadron accelerators and the detectability of the neutrino flux from them. In 2017, the new real-time alerting system of IceCube released an ATEL following the appearance of a high-energy neutrino event in the detector. Follow up observations confirm emission of high energy gamma rays from the blazar TXS0506+056. This latter event marks the beginning of neutrino multimessenger astronomy. The IceCube collaboration plans to deploy additional instrumentation to expand the science achievable by this unique observatory. In the near term, the addition of 7 infill strings with advanced photodetectors will extend IceCube's sensitivity to GeV atmospheric neutrinos. The sheer tonnage of this upgraded detector will allow the detection of an unprecedented number of tau neutrinos created in transit through the Earth by the phenomenon of neutrino oscillations and will enable measurements of the tau mixing parameters to greater precision than any planned astrophysical or accelerator based detector. Further in the future will be the IceCube Gen2 Observatory, a revolutionary new observatory which will combine optical and radio detection techniques to detect neutrinos spanning ten decades in energy and presenting an order of magnitude more neutrino effective area at high energies.

E1.5-0069-18 MEASUREMENT OF COSMOGENIC NEUTRINOS WITH THE ARIANNA EXPERIMENT

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The detection of cosmogenic neutrinos offers the potential to reveal the sources of ultra-high energy cosmic rays. Cosmogenic neutrinos are expected to be produced via the GZK effect during the propagation of cosmic rays or by the interaction of cosmic rays with surrounding media directly at the source. In particular, a coincident detection of neutrinos and recently discovered gravitational waves signals from neutron star mergers offers a unique opportunity to directly probe a cosmic-ray source.

The ARIANNA detector aims to detect neutrinos with energies above 1016 eV with a surface array of a thousand independent radio detector stations in Antarctica. Radio signals are produced via the Askaryan effect from particle cascades generated in the ice by interactions of these neutrinos. The Antarctic ice is transparent to MHz - GHz radio signals which allows for a cost-effective instrumentation of large volumes. A pilot array of 10 stations is currently operating successfully at the Moore's Bay site (Ross Ice Shelf) in Antarctica. In addition, one station was installed at the South Pole to test the suitability of this site. We will report on the current status of the ARIANNA detector. Furthermore, we will present techniques to reconstruct neutrino properties from our radio measurements which we probe experimentally by the detection of the more abundant cosmic-ray air showers.

E1.5-0070-18 PHAESTOS: USING GALACTIC MAGNETIC TOMOGRAPHY TO ENABLE CHARGE PARTICLE ASTRONOMY AND ELECTROMAGNETICALLY PROBE COSMIC-RAY COMPOSITION AT THE HIGHEST ENERGIES

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The sources of the highest-energy particles in the Universe remain an unresolved mystery. The reason is that charged-particle astronomy is severely complicated by magnetic deflections. I will discuss the PHAESTOS project - a radically new approach to charged-particle astronomy: constructing a 3-dimensional map of the Galactic magnetic field through optopolarimetric magnetic tomography, and backtracking the paths that UHECR traverse through the Galaxy before reaching us, to improve agreement between their (corrected) arrival directions and the location of their sources on the sky. Effectively, this technique aims to improve the charged-particle point-spread-function by a factor of several, boosting the sensitivity to individual sources by a similar factor, and allowing us to probe the cosmic-ray composition at the highest energies without reference to the development of extensive air showers in the atmosphere. This approach is becoming possible for the first time thanks to two experimental breakthroughs: the unparalleled wealth of stellar distances that the Gaia mission is in the process of providing; and recent advances in optopolarimetry of point sources that make possible systematic large-area surveys of stars. This technique would act multiplicatively on the return from current and future cosmic-ray observatories, groundand space-based.

E1.5-0071-18 ULTRA HIGH ENERGY COSMIC RAYS BY LIGHT NUCLEI IN NEAREST UNIVERSE: THE CONFIRMED CEN A, M 82, NGC 253 IMPRINT.

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Ultra High Energy Cosmic Rays UHECR had probed (by the Virgo absence, the best candidate source of galaxy cluster inside a 40 Mpc GZK volumes) to be screened at least from Virgo 20 Mpc volumes: that hint forced us ten years (2008) ago to claim and to point toward light nuclei as the main currier: consistently only Cen A AGN (at 2 Mpc distance) was and it still shines as a main clustered region in UHECR south sky. Only a few years later (2014-2015) this result on composition for UHECR had been achieved independently by AUGER via air shower morphology composition models. Last years (2014-2015) we noted that also NGC 253 in AUGER and M82 in Telescope Array anisotropy, (both nearby star bust galaxy or AGN) were crowding UHECR events, confirming the local UHECR understanding by sources as Cen A, M82, NGC 253. Most of these results had been achieved once again later and shown only recently, 2018, by AUGER collaboration. We claim therefore that there is a new reading key for UHECR and also CR. Additional new views for the tens EeV dipole anisotropy will be shown for the first time. References: 1) Daniele Fargion, Graziano Ucci, Pietro Oliva, Pier Giorgio De Sanctis Lucentini, The meaning of the UHECR Hot Spots: A Light Nuclei Nearby Astronomy; EPJ Web Conf. 99, 08002; Conference: C14-08-18.1 Proceedings, (2015).

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E1.5-0072-18 COSMIC RAY ORIGIN: WHY COSMIC RAY PHENOMENON IS UNIVERSAL IN THE UNIVERSE?

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Usually, when are talking on the origin of Cosmic Rays (or Astroparticles), have in view protons, nucleus of different Z, electrons, gamma-quants, and neutrino of high and very high energy generated in our Galaxy and in different astrophysical objects in the Universe, outside the Galaxy. Moreover, during many years energetic particles generated on the Sun were called as Solar Cosmic Rays (SCR), but now increased the tendency to rename this phenomenon as Solar Energetic Particles (SEP) event. We will show that SEP, energetic particles generated in magnetospheres of the Earth, Jupiter, Saturn and other planets, in interplanetary space, and in atmospheres of stars have the same nature as Galactic and Intergalactic CR: they are all runaway particles from the MaxwellBoltzmann distribution of background plasma where they were generated. Energy of these run-away particles is much higher than average energy of background thermal particles. We will show in our report that the energy of all these run-away particles have the same general nature: it is always transfer energy from the Macro-objects and Macroprocesses directly to charged particles. This transfer energy is formatted in dynamic plasma with frozen in magnetic fields: really magnetic fields 'glues' thermal background particles in Macro-objects and Macro-processes involved milliards thermal particles. Through magnetic fields run-away particles can interact not only with thermal background particles (and loose energy), but also directly with Macro-objects and Macro-processes with very high macro-energy (many order higher than energy of run-away particle). We come to conclusion that main cause of origin of all types of Cosmic Rays in the Universe is the transform energy from Macroworld directly to Micro-world through frozen in magnetic fields in plasmas. At the stage when in early Universe were formatted small density plasmas objects with magnetic fields, where formatted also Cosmic Rays of different types. We consider also the problem of formatting energy spectrum of different types of CR.

E1.5-0074-18 SOLUTION OF INVERSE PROBLEM FOR TRANSPORT OF ULTRA-HIGH ENERGY COSMIC RAYS IN THE INTERGALACTIC SPACE: DETERMINATION OF SOURCE SPECTRUM AND COMPOSITION

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The inverse problem of cosmic ray transport of ultra-high energy cosmic rays is considered. The source spectrum and composition is derived based on the Auger data on energy spectrum, energy dependence of mean logarithm of atomic mass number and its variance. The regularization procedure for considered ill-posed problem and the statistical analysis of experimental data are employed.

E1.5-0075-18 ANOMALIES IN POSITRON AND ANTIPROTON SPECTRA OF GALACTIC COSMIC RAYS: POSSIBLE EXPLANATIONS

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The unexpected energy spectrum of the positron/electron ratio is interpreted astrophysically, with a possible exception of the 100-300 GeV range. The data indicate that this ratio, after a decline between 0.5-8 GeV, rises steadily with a trend towards saturation at 200-400GeV. These observations (except for the trend) appear to be in conflict with the diffusive shock acceleration (DSA) mechanism, operating in a single supernova remnant (SNR) shock. We argue that positron/electron ratio can still be explained by the DSA if positrons are accelerated in a subset of SNR shocks which: (i) propagate in clumpy gas media, and (ii) are modified by accelerated CR protons. The protons penetrate into the dense gas clumps upstream to produce (secondary) positrons and, charge the clumps positively. The induced electric field expels positrons into the upstream plasma where they are shock-accelerated. Since the shock is modified, these positrons develop a harder spectrum than that of the CR electrons accelerated in other SNRs. Mixing these populations explains the increase in the positron/electron ratio at $E>8$ GeV. It decreases at $E<8$ GeV because of a subshock weakening which also results from the shock modification. Contrary to the expelled positrons, most of electrons are left unaccelerated inside the clumps. Antiprotons, generated at the cloud edges are not retained in the cloud, contrary to the light electrons. Scenarios for the 100-300 GeV AMS-02 fraction exceeding the model prediction, including, but not limited to, possible dark matter contribution, are also discussed.

E1.5-0076-18 NEW INSIGHTS IN THE PROPAGATION MODELS IN THE LIGHT OF AMS02 SECONDARY FLUXES.

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Yoann Génolini, Pasquale D. Serpico, Mathieu Boudaud, Sami Caroff, Vivian Poulin, Laurent Derome, Julien Lavalle, David Maurin, Vincent Poireau, Sylvie Rosier, Pierre Salati and Manuela Vecchi.

Secondary to primary ratios, freshly published by AMS-02 are decisive for the understanding of Galactic cosmic-rays propagation mechanisms. In turn, the propagation models are a crucial ingredient for testing astrophysical scenarios as well as indirect dark matter searches. Focusing on the boron to carbon ratio (B/C) at high-energy we find indications (decisive evidence, in Bayesian terms) in favor of a diffusive propagation origin for the broken power-law spectra found in protons (p) and helium nuclei (He). I will show that this result is robust with respect to currently estimated uncertainties in the cross sections, and in the presence of a small component of primary boron, expected because of spallation at acceleration sites. At lower energies, around 1GeV/nuc, several effects are competing. I will discuss the different models allowed by the data, and the emerging indications which call for refinements of the standard cosmic-rays production and diffusion models. Theoretical uncertainties and limitations affecting the interpretation of the data will be highlighted.

E1.5-0077-18 COSMIC RAYS AND ASSOCIATED MULTIFREQUENCY OBSERVATIONS OF THE INTERSTELLAR EMISSION

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The interactions of cosmic rays with the interstellar medium and magnetic field produce diffuse emissions that span the electromagnetic spectrum from radio to gamma rays. Observations of this diffuse emission are an invaluable tool for understanding densities and spectra of CRs in different places of our Galaxy.

We present our results on cosmic-ray properties by combining multi-frequency observations of the interstellar emission, from radio to gamma rays, and latest cosmic-ray direct measurements with propagation models.

E1.5-0078-18 ARE RUNAWAY O-STAR BOW SHOCKS CAPABLE OF ACCELERATING COSMIC RAYS?

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In the long-standing quest to understand the origin of cosmic rays and how they can acquire their enormous energies, particle acceleration by shock waves is thought to play a central role. Massive runaway stars moving supersonically through the interstellar medium (ISM) are known to produce bow shocks detected through their associated infrared (IR) emission, and it has been speculated that these bow shocks can accelerate particles to very high energies, even producing cosmic rays. Here, we present preliminary results of our Chandra observations of the field centered on the runaway star AE Aur and its well characterized bow shock. Previous XMMNewton observations revealed an X-ray "blob", located near the well-known IR arc, possibly a nonthermal source consistent with models of inverse Compton scattering of dust IR photons by electrons accelerated within the bow shock. The previous conclusions for AE Aur were based on relatively poor spatial coincidence between the X-ray "blob" and the IR arc. In contrast, our Chandra data, while confirming the XMM-Newton results, neither show a spatial coincidence with the bow shock, nor confirm a non-thermal spectrum. We conclude that in the AE Aur case, there is no observational evidence for cosmic-ray (electron) acceleration by the shock.

E1.5-0079-18 COSMIC-RAY ACCELERATION IN ETA CARINAE

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Galactic cosmic-rays are likely produced through Fermi acceleration processed in supernova remnant shocks and other exotic sources. Identifying the different contributors to cosmic ray acceleration in galaxies is fundamental to understand galactic processes, how Fermi acceleration works in various environments, and the feed-back between cosmic-ray acceleration, galactic magnetic fields and the dynamics of the interstellar medium. Variable sources are interesting targets to study particle shock acceleration as the correlated observations in various energy bands provide key signatures of the physical processes at play and allow to understand how particle acceleration takes place and the luminosity of the source in the different particle species. Particle acceleration in stellar wind collision can be particularly well studied in η Carinae, the most luminous massive colliding wind binary system of our Galaxy and the first one to have been detected at very high energies without hosting a compact object. Most of the shock power is released on both sides of the wind collision zone downstream of the wind-collision region.

The photon-photon opacity could also be estimated as < 10−2, excluding a significant effect on the observed GeV spectrum. γ-ray observations can probe the magnetic field and shock acceleration in details. The quality of the current data below 100 MeV and above 1 GeV does not yet provide enough information to test hydrodynamical models including detailed radiation transfer (inverse-Compton, pion emission, photo-absorption). eAstrogam and CTA will provide a wealth of information and allow to test the conditions and the physics of the shocks at a high level of details. η Carinae could yield to 1048−49 erg of cosmic-ray acceleration, a number close to the expectation for an average supernova remnant.

E1.5-0081-18 INTENSE ELECTROMAGNETIC WAVE EMISSION IN RELATIVISTIC MAGNETIZED SHOCKS

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The origin of high energy cosmic rays (>1015.5eV) has not been fully understood, and the acceleration mechanism is still controversial. Recently Chen et al. (2002) proposed the particle acceleration by the large-amplitude Alfvén waves at gamma-ray bursts as a model of the generation of ultra-high energy cosmic rays (>1018eV), based on the wakefield acceleration (WFA) mechanism which was initially proposed by Tajima and Dowson (PRL, 1979) in the context of laser-plasma interactions in the laboratory. The WFA in laboratory is induced by an intense laser pulse (or transverse electromagnetic waves) propagating in a plasma. The mechanism may also operate in relativistic shocks in nature because it is known that large-amplitude electromagnetic precursor waves are excited by synchrotron maser instability (SMI) driven by the particles reflected off the shock-compressed magnetic field in relativistic shocks (Hoshino and Arons, 1991). In fact, Hoshino (2008) demonstrated the generation of the non-thermal electrons by the wakefield induced by the ponderomotive force of the electromagnetic precursor waves in relativistic magnetized shocks by means of 1D PIC simulation.

In multidimensional systems, it is well known that Weibel instability (WI) develops in the transition region of weakly magnetized shocks. Previous PIC simulation studies in multiple dimensions indeed showed that the shock transition is dominated by the WI at low magnetization. Since both WI and SMI are excited from the same free energy source in the same region and the growth rate of the WI is larger than that of the SMI at low magnetization, it was believed that the WI dominates over the SMI and the precursor wave emission could be shut off in multidimensional shocks.

Recently, by using 2D PIC simulations, we have shown that the SMI can coexist with the WI and that the precursor wave emission continues to persist to the Weibel-dominated regime (Iwamoto et al. 2017). We also showed that the wave power is sufficient enough to induce wakefield for a wide range of magnetization parameter. However, the WFA did not operate in our previous simulation in pair plasmas because the finite mass ration between positive and negative charges is essential for the WFA. To investigate the feasibility of the WFA in relativistic shocks, we carried out 2D simulations in ion-electron plasmas. We found that the wakefield is indeed induced in the upstream. In this presentation, we discuss the acceleration mechanism.

E1.5-0082-18 THE STRONG SURFATRON ACCELERATION OF RELATIVISTIC ELECTRONS BY ELECTROMAGNETIC WAVE PACKET IN CLOSEST INTERSTELLAR CLOUDS

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The Cherenkov resonant interaction between an electromagnetic wave packet and relativistic electrons in the space plasma based on digital calculations is investigated. The strong surfatron acceleration of electrons (having their initial energies about GeV) up to energies at the cosmic rays knee in the particles energy spectrum is considered. The electric field amplitude in the central area of the wave packet must be above the threshold value. Thereby, if Cherenkov resonance conditions are met, it becomes possible for the wave packet to capture electrons in the surfing acceleration mode. The research is carried out by numerically solving second order nonlinear, nonstationary equations for the wave packet phase on the particle's trajectory at the packet carrying frequency. For small enough difference between the component of particle velocity along the wave packet direction of propagation and the wave phase velocity, the numerical calculations reveal that the trapping of relativistic electrons in strong surfatron acceleration occurs immediately for a wide enough range of favorable initial wave phase values at the particle's trajectory. It has been demonstrated that the combination of ranges of the particle's initial parameters corresponding to the capturing in surfatron acceleration mode is large enough, so the possibility for important practical applications become real. The temporal dynamics of momentum components and velocities for accelerated particles, the particularities of their trajectories, taking into account the possibility of cyclotron rotation at the initial stage and the phase plane structure for digitally solved nonlinear equation are considered for selected initial sets of parameters. Simulation results allow us to draw conclusions about the possibility of ultrarelativistic surfatron acceleration of electrons in space plasma by an electromagnetic waves packet in the closest plasma interstellar clouds up to 'knee' energy. It is obvious that such strong acceleration may cause large enough variations of the cosmic rays spectrum observed in the solar system.

E1.5-0083-18 PRODUCTION OF ULTRA-HIGH-ENERGY PARTICLES IN THE VICINITY OF SUPERMASSIVE BLACK HOLES.

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Origin and mechanism of production of ultra-high-energy (UHE) particles with energies above 1020 eV in cosmic rays detected by several cosmic ray observatories still remain the subject of discussion. It is generally believed that the sources of such particles should be of extragalactic origin. I will show that UHE particles can be produced in the dynamical environment and close vicinity of supermassive black holes (SMBH) located at the centers of galaxies by extracting out the rotational energy of the central SMBH within a neutron beta-decay. Assuming the presence of astrophysically relevant magnetic fields and taking into account the back-reaction force of individual charged particles, we put constraints on the mass of SMBH and magnetic fields in its vicinity to produce UHE particles within the model. From this, it follows that these are more likely protons, which may escape from SMBH, while Sgr A* at the Galactic center cannot serve as a source of such UHE particles, mainly due to its relatively low mass.

E1.5-0086-18 ENERGY SPECTRA OF ABUNDANT COSMIC-RAY NUCLEI IN THE NUCLEON EXPERIMENT

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The NUCLEON satellite experiment is aimed to directly measure the energy spectra of cosmicray nuclei and the chemical composition (Z=130) in the energy range of 2-500 TeV. Energy measurements are performed by two different methods (ionization calorimeter and the new Kinematic Lightweight Energy Meter (KLEM) technique). Energy spectra of different abundant nuclei are presented. Spectral peculiarities are found and discussed.

E1.5-0087-18 THE NUCLEON-2 MISSION CURRENT STATUS

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The NUCLEON-2 experiment is aimed at the investigation of isotope and charge composition of medium, heavy and ultra-heavy ions (Z < 82) in the 300 MeV/N - 1 GeV/N energy range. The concept design of HICRS for the NUCLEON-2 satellite cosmic ray experiment is presented. The performed simulation confirms the isotope resolution algorithms and techniques.

E1.5-0088-18 THE HERO (HIGH ENERGY RAY OBSERVATORY) CURRENT STATUS

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Current status and preliminary design of the High-Energy Ray Observatory (HERO) are presented. The HERO is planned to be launched onboard a heavy satellite. This experiment is based on the application of a deep and wide aperture ionization calorimeter. The effective geometrical factor of the observatory is at least 9-16 m2∗sr, dependingonthetypeof particles.U nderthelongexpo

E1.5-0089-18 ION BEAM TEST RESULT OF THE PROTOTYPE SILICON DETECTOR SYSTEM FOR HERD PROJECT

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HERD(High Energy Cosmic Radiation Detection) facility is one of the Cosmic Lighthouse Programs onboard China's Space Station. The main science objectives of HERD are indirect dark matter particles search, cosmic ray spectrum and composition measurements and high energy gamma-ray observations. The Silicon TracKer (STK) inherited from DAMPE is one of the main payloads of HERD. A new readout electronics system based on ASIC-IDE1162 is developed for charge measurement of STK. Here, we present the performance measurements and the preliminary ion beam test results.

E1.5-0090-18 STATUS AND TRIGGER EFFICIENCY OF THE TOP AND BOTTOM COUNTING DETECTORS OF THE ISS-CREAM EXPERIMENT ON THE INTERNATIONAL SPACE STATION

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The Cosmic Ray Energetics And Mass (CREAM) instrument on the International Space Station (ISS) is designed to study the origin, acceleration and propagation mechanism of high energy cosmic rays. The ISS-CREAM detector was launched on the 14th of August 2017 to the ISS aboard the SpaceX-12 Dragon spacecraft. The Top Counting Detector (TCD) and Bottom Counting Detector (BCD) are parts of the detector suite of the ISS-CREAM instrument and they are designed to separate electrons and protons for studying electron and gamma-ray physics. The TCD/BCD separate electrons from protons using differences in shapes between electromagnetic and hadronic showers. In addition, the TCD/BCD provide a redundant trigger to that from the calorimeter and a low energy trigger to the ISS-CREAM instrument. We can trigger on cosmic ray events from He to high-Z nuclei. At the ISS, the TCD/BCD status is stable, and the pedestal values are almost the same as those measured in ground tests. In this presentation, we will present the status and trigger efficiency of the TCD/BCD on the ISS.

E1.5-0091-18 SEARCH AND STUDY OF EXTENSIVE AIR SHOWER EVENTS WITH THE TUS SPACE EXPERIMENT.

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The TUS experiment is designed to investigate the ultra high energy cosmic rays (UHECR) at energy 100 EeV from the space orbit by the UV radiation measurement of extensive air showers (EAS). It is the first orbital telescope aimed for such measurements and is taking data since April 28, 2016. TUS detector consists of a modular Fresnel mirror and a photo receiver matrix with a field of view 4.5° and the number of PMT pixels 16x16. The DAQ electronics has a main mode of operation with 0.8 µs temporal resolution and a 200 µs duration of measured waveforms. Spatial resolution in the atmosphere is 5 km with a total field of view of about 80x80 km^2. The TUS apparatus structure, methods of UHECR on-line selection and off-line data analysis are described. A few UHECR EAS candidates were found. Preliminary results of their investigation and comparison with the corresponding Monte-Carlo events are presented.

E1.5-0092-18 THE CHARGES SHARING AND RECONSTRUCTION STUDY OF THE DAMPE SILICON TUNGSTEN TRACKER

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The DArk Matter Particle Explorer (DAMPE) is one of the four satellites within the Strategic Pioneer Research Program in Space Science of the Chinese Academy of Science (CAS). The Silicon-Tungsten Tracker (STK), which is composed of 768 singled-sided silicon microstrip detectors, is one of the four subdetectors in DAMPE, providing track reconstruction and charge identification for relativistic charged particles. The charges sharing effect of STK was studied by charges-injection, SPICE simulation, test beam data and on-orbit data analysis. Based on this charges sharing effect, the on-orbit STK charge spectrum was reconstructed and shown.

E1.5-0093-18 ON PAIRED EVENTS OBSERVED BY YAKUTSK EAS ARRAY

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The ultra-high energy cosmic ray database of Yakutsk extensive air shower array is analyzed. Attention is drawn to showers from particles with energy greater than 5 EeV coming one after another at intervals less than 20 hours and having approximately the same energy and arrival direction ("doublets"). The significant excess of the number of such events over the random distribution is found. The mass compositions and arrival directions of doublets are analyzed. Possible mechanisms for the origin of such doublets are discussed.

E1.5-0094-18 SEARCH DARK MATTER OF THE GALAXY

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We analyzed distribution particles in celestial sphere by data Yakutsk array at energy E 8×1018 eV. It is consider arrival directions of extensive air shower (EAS) or particles with zenith angles $\vartheta<60°$ and cores located inside the array perimeter. We consider primary particles with energies

E 5.7×1018 eV. Energy of particles determined by registration Cherenkov light with accuracy's 30% and angles 5-7°. We have found correlation arrival directions of ultrahigh energy E<4×1019

eV particles with the positions of pulsars and anisotropy of arrival directions of these particles from side of the galactic plane by Yakutsk array data and Telescope array data at energy E>5.7×1019 eV at high galactic latitudes. 0ur analyses of data show that observed cosmic rays up to 4×1019 eV are galactic and above this energy most likely extragalactic. Detectors which registered particles each had area 2 m2 and they are situated at area S<10 km^2 and we choice EAS (extensive air showers) inside this area 10 km^2 and at energy above E>1018 eV.

E1.5-0095-18 MINI-EUSO: A MISSION ON THE INTERNATIONAL SPACE STATION FOR THE STUDY OF TERRESTRIAL AND COSMIC UV EMISSION

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The Mini-EUSO space experiment ("UV atmosphere" in Russian Space Program) aims to perform observations of the UV-light night emission from Earth.

The scientific goal of the experiment is to map the earth in the UV range (300 - 400 nm) with a spatial resolution of 6.11 km and a temporal resolution of 2.5 s, offering the opportunity to study a variety of atmospheric events such as transient luminous events (TLEs) and meteors, as well as searching for strange quark matter and bioluminescence.

The mission is approved by the Italian Space Agency and the Russian Space Agency. Launch is foreseen between Autumn 2018 and beginning 2019.

The Mini-EUSO instrument is a UV telescope to be placed inside the International Space Station (ISS), looking down on the Earth from a nadir-facing, UV-transparent window in the Russian Zvezda module.

The instrument comprises a compact telescope with a large field of view, based on an optical system employing two Fresnel lenses for increased light collection. The light is focused onto an array of photo-multipliers and the resulting signal is converted into digital, processed and stored via the electronics subsystems on-board. The instrument is designed and built by the members of the JEM-EUSO collaboration.

In this paper, scientific, technical and programmatic aspects of this project will be described.

E1.5-0096-18 A BALLOON EXPERIMENT FOR THE ULTRAHIGH ENERGY COSMIC RAYS COMPOSITION STUDY IN ANTARCTICA DURING POLAR NIGHT

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A new balloon experiment with small optical detector for registration of the Vavilov-Cherenkov radiation and the fluorescence light from the extensive air showers with energies 5 ∗ 1018 –

5 1019eV is proposed. The flights are planned in the polar night period at an altitude up to 30km above snow covered surface of Antarctica. Scientific novelty of this project is in the methodology

of the extensive air showers registration over a large area up to 600km^2, that allows to measure the two optical components of the shower - Vavilov-Cherenkov radiation and fluorescence light by the same sensitive element of the detector simultaneously. To obtain the most reliable data about the energy spectrum and mass composition of primary cosmic rays in the energy region 5 1018 5 1019eV is especially important in connection with the planned orbital experiments.

E1.5-0099-18 ARRRAY IN SATELLITES AND BALLOONS TO DETECT UHECR AND UHE UPGOING TAU NEUTRINO SKIMMING AIRSHOWERS, OFFERING ALSO STATIONS FOR INFRARED COSMIC RADIATION INTERFEROMETRY.

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The discover of UHECR and UHE neutrino it is widely approched in ground and underground (respectively) detector. However the Ultra High Energy Cosmic Ray (UHECR) and UHE neutrino tau may shine in Space too. Indeed there are several experiment like Jem-EUSO searching for the upgoing view of luminescent UHECR trail in air at night. We propsed since 1999-2002 to reveal UHE tau neutrino by their induced tau airshower upgoing the horizons. The same UHECR might be tested at different angles as skimming airshower and blazing at Earth boundaries observable by mountains, balloons or satellites. The UHECR composition reflects into the angular distribution and their corresponding slanth depth, offering a filter and a spetroscopy of UHECR events. We suggested the ISS with several detector elements in its extreme edges as a main location for such an array detector. However also nano satellite cooperative and in array flight possibly along ISS may test wide area airshower signals by their gamma, X, radio correlated triggered signals. Rate for future array in Space and in ISS will be shown in detail. Also a new Cherenkov optical array telescope geometry detector, ideal for crown detection in space, will be shown for the first time. The UHECR filtered sinals at different angle and different slanth depth might better calibrate the UHECR composition, while the upgoing air shower below the Earth horizons and its polarization will probe for the first time tau airshower (tens PeV-EeV) existence. The same satellite or ISS element array system may be also used for an interferometric radio detection of Cosmic Background leading to highest angular resolution of cosmic millimeter Big Bang radiation.
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E1.5-0100-18 SUBARU OBSERVATIONS OF H-ALPHA FILAMENTS OF THE CYGNUS LOOP AND TYCHO'S SUPERNOVA REMNANTS

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We present high-resolution long-slit spectroscopy of a Balmer-dominated shock in the northeastern limb of the Cygnus Loop with the Subaru HDS (Katsuda et al. 2016, ApJ, 819, L32). By setting the slit angle along the shock normal, we investigate variations of the flux and profile of the H-alpha line from preshock to postshock regions with a spatial resolution of about 4e15 cm. The H-alpha line profile can be represented by a narrow (28.9 +/- 0.7 km/s) Gaussian in a diffuse region ahead of the shock, i.e., a photoionization precursor, and narrow (33.1 +/0.2 km/s) plus broad (130–230 km/s) Gaussians at the shock itself. We find that the width of the narrow component abruptly increases up to 33.1 +/- 0.2 km/s, or 38.8 +/- 0.4 km/s if we eliminate projected emission originating from the photoionization precursor, in an unresolved thin layer (4e15 cm at a distance of 540 pc) at the shock. We show that the sudden broadening can be best explained by heating via damping of Alfven waves in a thin cosmic-ray precursor, although other possibilities are not fully ruled out.

We also recently performed spectrally resolved polarimetry of Tycho's knot g with Subaru FOCAS. Our observation is similar to the pioneering work by Sparks et al., 2015, ApJL, 815, L9 who measured 2% polarization at the H-alpha filament (narrow component) in the northwestern limb of SN 1006. Given that the cosmic-ray acceleration efficiency at Tycho's knot g appears to be higher than that in the northwestern limb of SN 1006, we expect a higher polarization in Tycho's knot g (Shimoda et al. 2015, MNRAS, 473, 1349). We will present our preliminary results.

E1.5-0101-18 AN INVESTIGATION OF THE INTERSTELLAR ENVIRONMENT OF SUPERNOVA REMNANT CTB 87

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We present a new millimeter CO-line observation towards supernova remnant (SNR) CTB 87, which was regarded purely as a pulsar wind nebula (PWN), and an optical investigation of a coincident surrounding superbubble. The CO observation shows that the SNR delineated by the radio emission is projectively covered by a molecular cloud (MC) complex at VLSR = 60

54km s−1. Both the symmetric axis of the radio emission and the trailing X-ray PWN

appear projectively to be along a gap between two molecular gas patches at 58- 57km s−1. Asymmetric broad profiles of 12CO lines peaked at 58km s−1 are found at the eastern and southwestern edges of the radio emission. This very probably represents a kinematic evidence of the SNR-MC interaction. We also find that a superbubble, 371 in radius, appears to surround the SNR from HI 21cm (VLSR 61- 68km s−1), WISE mid-IR, and optical extinction data.

We build a multi-band photometric stellar sample of stars within the superbubble region and find 82 OB star candidates. The likely peak distance in the stars' distribution seems consistent with the distance previously suggested for CTB 87. We suggest the arc-like radio emission is mainly the relic of the part of blastwave that propagates into the MC complex and is now in a radiative stage while the other part of blastwave has been expanding into the low-density region in the superbubble. This scenario naturally explains the lack of the X-ray emission related to the ejecta and blastwave. The SNR-MC interaction also favours a p-p hadronic contribution to the gamma-ray emission from the CTB 87 region, as the GeV-TeV gamma-ray spectrum could be well fitted with the molecular gas density estimated in this work (~ 80cm−3).

E1.5-0102-18 MEASUREMENT OF LOW-ENERGY COSMIC RAYS IN SUPERNOVA REMNANTS VIA NEUTRAL IRON LINE

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Supernova remnants (SNRs) have been prime candidates for Galactic cosmic-ray accelerators. Gamma-ray observations have revealed that protons and/or electrons are accelerated to energies up to 100 TeV in SNRs. In diffusive shock acceleration, suprathermal particles (low-energy cosmic rays; LECRs) are accelerated to relativistic energy through multiple crossings of the shock front. Thus, the energy spectra and fluxes of the LECRs in SNRs provide a key link to generation of the GeV and TeV cosmic rays in SNRs. However, there has been very few observation of LECRs below the MeV band due to the lack of an effective probe to investigate them. When LECRs collide with interstellar gas, they ionize neutral iron atoms and emit the neutral iron line at 6.4 keV. We have started a campaign to search for the 6.4 keV line in SNRs with the Suzaku archive data. We have already discovered the line emission from more than 10 SNRs [1-3]. The spectra and morphologies suggest that the 6.4 keV line is produced by interactions between LECR protons and the adjacent cold gas. The proton energy density is estimated to be 10–100 eV/cc, which is more than 10 times higher than that in the ambient interstellar medium. In this presentation, we also discuss an association between the 6.4 keV line and gamma rays.

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E1.5-0103-18 DISCOVERY OF A 6.4 KEV EMISSION LINE IN THE SUPERNOVA REMNANT IC 443: FLUORESCENCE INDUCED BY LOW-ENERGY COSMIC RAYS?

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IC 443 is a middle-aged supernova remnant (SNR) in our galaxy. A gamma-ray spectrum of IC 443 shows a pion-decay signature, which means that cosmic-ray protons are accelerated in the SNR (Ackermann et al. 2013, Sci, 339, 807). Since pion production requires cosmic-ray protons with > 280 MeV, gamma-ray observations cannot constrain low-energy cosmic rays (LECRs). Observations of H+ absorption lines revealed that the ionization rate of H2 is large in IC 443 (Indriolo et al. 2010, ApJ, 724, 1357). This suggests that a large amount of LECRs are produced. However, H+ observations cannot provide the information on energy density of LECRs. When LECRs collide with the surrounding interstellar material, they ionize the neutral iron in it and emit a fluorescent X-ray at 6.4 keV (Tatischeff et al. 2012, A&A, 546, 24). Since IC 443 interacts with molecular clouds, accelerated particles can collide with them to produce the 6.4 keV line. Analyzing the Suzaku archive data of IC 443, we discovered the

6.4 keV line with a significance level of 3 σ. We measured the spatial intensity distribution of the 6.4 keV line and found that the high-intensity region contains the site where the large ionization rate was observed. The 6.4 keV line would be produced by LECRs with the energy density of 10 – 100 eV/cc for protons and 0.01 – 0.1 eV/cc for electrons.

E1.5-0104-18 A STUDY OF FERMI-LAT GEV GAMMA-RAY EMISSION TOWARD THE MAGNETAR-HARBORING SUPERNOVA REMNANT KESTEVEN 73 AND ITS MOLECULAR ENVIRONMENT

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We report our independent GeV γ-ray study of the young shell-type supernova remnant (SNR) Kes 73, which harbors a central magnetar, and CO-line millimeter observations toward the SNR. Using 7.6 years of Fermi-LAT observation data, we detected an extended γ-ray source ("source A") with centroid on the west of the SNR, with a significance of 21 in 0.1-300 GeV and an error circle of 5 4 in angular radius. The γ-ray spectrum cannot be reproduced by a pure leptonic emission or a pure emission from the magnetar, and thus a hadronic emission component is needed. The CO-line observations reveal a molecular cloud (MC) at VLSR 90 km/s, which demonstrates morphological correspondence with the western boundary of the SNR brightened in multiwavelength. The 12CO (J=2-1)/12CO (J=1-0) ratio in the left (blue) wing 85-88 km/s is prominently elevated to 1.1 along the northwestern boundary, providing kinematic evidence of the SNR-MC interaction. This SNR-MC association yields a kinematic distance 9 kpc to Kes 73. The MC is shown to be capable of accounting for the hadronic γ-ray emission component. The γ-ray spectrum can be interpreted with a pure hadronic emission or a magnetar+hadronic hybrid emission. In the case of pure hadronic emission, the spectral index of the protons is 2.4, very similar to that of the radio-emitting electrons, essentially consistent with the diffusive shock acceleration theory. In the case of magnetar+hadronic hybrid emission, a magnetic field decay rate >~ 1036 erg/s is needed to power the magnetar's curvature radiation.

E1.5-0105-18 THE MONSTER NEXT DOOR: FERMI-LAT OBSERVATIONS OF SUPERNOVA REMNANT N132D IN THE LARGE MAGELLANIC CLOUD

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Supernova remnant (SNR) N132D, located in the Large Magellanic Cloud, represents a unique opportunity for the study of gamma-ray emission from shock-accelerated cosmic rays (CRs) in another galaxy since it stands as the first and only extra-galactic SNR detected in gamma-rays. N132D is one of the brightest SNRs in the local Universe in the X-ray, infrared and radio bands, and it has also been detected in TeV energy gamma-rays. N132D's apparent interaction with a giant molecular cloud strongly favors the scenario where the gamma-ray emission results from CR hadrons interacting with dense ambient media. We report on the detection of N132D with the Fermi-LAT, and by characterizing its emission in the MeV-GeV band, as well as constraining the non-thermal contribution to the X-ray spectrum using Chandra observations, we build a very complete picture of the properties of the system and its progenitor, ultimately helping us better understand CR acceleration in SNRs.

E1.5-0106-18 INTERGALACTIC HADRONIC CASCADE MODEL OF BLAZAR EMISSION: BASIC IDEAS, SIGNATURES AND DIFFICULTIES

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Blazars can emit extremely high energy protons and nuclei. If the extragalactic magnetic field in voids of the large scale structure is small enough, gamma-rays from intergalactic electromagnetic cascades initiated by these primary protons or nuclei contribute to observable emission of these sources. Using a novel, fast and precise enough hybrid approach, we discuss in details the observability of these cascade gamma-rays. Assuming a realistic emission model of blazar 1ES 0229+200, we calculate its observable spectrum, accounting for the effect of magnetic fields around the source and in large scale structure between the source and the observer on the spectrum. We show that the observable spectrum shape is mainly determined by the size of the first void. Furthermore, we show that under the above-mentioned assumptions the model of [W. Essey et al., Phys. Rev. Lett., 104, 141102 (2010)] is excluded with statistical significance $Z>7\sigma$. This conclusion is stable with respect to the major astrophysical uncertainties of the model. The details of these calculations are available in our paper [AA, 603, A59 (2017), Sect. 2, Sect. 4 and Sect. 5].

E1.5-0107-18 THE NAKED ORION: A MYSTERIOUS GAMMA-RAY EMISSION MAYBE DUE TO COSMIC RAY ACCELERATION.

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The Orion region is expected to emit a large amount of diffuse gamma-ray radiation because of the large amount of interstellar medium in its surroundings. We modelled the AGILE data from that region through a template that quantifies the gamma-ray diffuse emission expected from atomic and molecular hydrogen, together with an isotropic contribution. In the excess map, appears an "arc-like" gamma-ray emission with high significance in the high-longitude part of Orion A, confirming previous results from Fermi-LAT. However, we do not think that this emission is correlated with some inaccuracy in the relation between H2 and CO fraction. We think that this emission could be due to Cosmic Ray acceleration in the Termination Shock of k-Orionis wind. Here we present a preliminary spectrum from the excess region and some preliminary attempts of CR acceleration models

E1.5-0108-18 MORPHOLOGICAL STUDY OF THE MSH 15-52 PULSAR WIND NEBULA IN VHE GAMMA-RAYS WITH H.E.S.S.

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Pulsar wind nebulae (PWNe) are magnetised ultra-relativistic particle clouds around neutron stars. They are considered as plausible sources of the primary cosmic-ray positron component observed above 10 GeV. They have also been proposed as candidates instigating a hadronic Galactic cosmic-ray component at energies above the spectral "knee". In this contribution, we aim to shed light on the mechanisms of the transport of accelerated particles from the PWN into the surroundings of the host supernova remnant (SNR) and ultimately into the interstellar medium, by studying in greater detail the morphology of the very-high-energy (VHE) gammaray emission of a PWN.

The composite SNR MSH 15-52 encloses the bright X-ray PWN of PSR B1509-58. In 2005,

H.E.S.S. discovered extended VHE gamma-ray emission coincident with this PWN. We study its gamma-ray morphology with additional H.E.S.S. observations, by modelling the synchrotronemitting particles using an X-ray template and by making assumptions on the magnetic field within. We find a distinct VHE emission component extending beyond the X-ray nebula, and examine the energy dependence of its shape. We discuss the consequences of this morphology for lepton transport from the PWN and explore the possibility and implications of a hadronic gamma-ray emission component, thus probing the validity of PWNe as cosmic ray sources in the Milky Way.

RESEARCH IN ASTROPHYSICS FROM SPACE (E)

SPECTRAL MEETS TIMING: A GLOBAL APPROACH TO ACCRETION ONTO COMPACT OBJECTS (E1.6)

E1.6-0001-18 X-RAY REVERBERATION IN ACCRETING BLACK HOLE SYSTEMS

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Accreting black hole (BH) systems are characterized by strong, aperiodic variability on a wide range of time scales. The variable primary X-ray radiation interacts with any surrounding matter, including the accretion disc. Short light travel time delays are expected between the primary and the reprocessed emission in the disc. These, so-called "X-ray reverberation lags" can be used to map the geometry of the very inner regions of the accretion flow. I will review recent studies of X-ray reverberation lags in accreting BH systems, discussing the analogies between X-ray reverberation lags in active galactic nuclei (AGN) and in BH X-ray binaries (BHXRB), and showing how the latter give indirect evidence of evolving disc geometry during the outburst.

E1.6-0002-18 MAPPING CORONAL GEOMETRY WITH BROADBAND NOISE CONTINUUM LAGS

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Hard continuum lags have been observed in the broadband noise X-ray variability of accreting black holes since the late 1980s. Since they are seen in the power-law emission which dominates the hard spectral states, they should provide information about the corona or hot flow which produces that continuum. However, previous models for the hard lags either require scattering on very large scales (thousands of gravitational radii) or propagation of mass accretion fluctuations through a hot flow which is substantially radially-extended. Both explanations are inconsistent with the breadth of the iron line and the reverberation lags seen at high Fourier frequencies, which suggest relatively compact coronae (< 20 gravitational radii). We show how this problem can be resolved when the mass-accretion fluctuations propagate through the seed-photon producing disk before reaching (and heating) a compact central corona. The resulting coronal cooling followed by heating predicts the correct frequency and energy-dependent behaviour for the lags, both within the power-law and between the power-law and the disk blackbody emission. The continuum lags model can be combined with reverberation models to provide physically self-consistent explanations of the lags over a large range in time-scale, which can strongly constrain the coronal geometry.

E1.6-0003-18 SPECTRAL-TIMING MODELING OF RELATIVISTIC X-RAY REFLECTION FROM BLACK HOLES

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X-ray spectroscopy and timing analysis have been proven to be powerful tools in the study of accreting sources for over three decades; yet, their development and implementation remains largely independent. The synergy between these two techniques offers a potentially transformative new view to the physics of accretion in the strong gravity regime. Here we discuss the theoretical challenges in constructing an unified model for time-dependent relativistic Xray reflection in accreting compact objects. The self-consistently merging the best spectral and timing reflection models allow us to make accurate predictions for observables such as flux-energy, lag-frequency, lag-energy spectra simultaneously. By modeling the response of the accretion disk to an external and variable source of X-rays, we explore the effects of local ionization and ionization gradients in the disk; study impact of geometry and location of the corona; and determine the role of disk's density and vertical extension. We briefly discuss current observational problems that can be addressed by these models in the context of accreting black holes.

E1.6-0004-18 MULTI-TIMESCALE X-RAY REVERBERATION MAPPING OF ACCRETING BLACK HOLES

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Accreting black holes show reflection features in their X-ray spectrum, including an iron Kα line, which result from reprocessing of hard X-ray continuum photons illuminating the accretion disk. Measuring the reverberation lag caused by the differences in path length between direct and reflected emission, and the spectral distortions to the iron line caused by rapid orbital motion and gravitational redshift provides a powerful tool to probe the innermost regions around the black hole. Previous reverberation studies have largely ignored spectral variability of the illuminating continuum. We studied the effect of a pivoting continuum power-law which causes non-linear changes in the shape of the reflection spectrum, and developed an analytic description of the complex cross spectrum as a function of both energy and frequency. I will present our application of this new reverberation model to RXTE data from the black hole X-ray binary Cygnus X-1. We are able to jointly fit the time-averaged X-ray spectrum and the real and imaginary parts of the cross spectrum as a function of energy for a range of Fourier frequencies, thus utilising vastly more information than traditional spectral fitting. I will demonstrate we need to properly account for the continuum variability in order to correctly characterise the parameters of the system such as mass of the central object and inner radius and inclination of the accretion disc.

E1.6-0005-18 X-RAY REVERBERATION MAPPING IN ACTIVE GALACTIC NUCLEI

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Accreting supermassive black holes can produce more electromagnetic and kinetic luminosities than the combined stellar luminosity of an entire galaxy. Most of the power output from an Active Galactic Nucleus is released close to the black hole, and therefore studying the inner accretion flow–at the intersection of inflow and outflow–is essential for understanding how black holes grow and how they affect their surrounding environments. In this talk, I will present a new results from X-ray reverberation mapping, which allows us to map the gas falling on to black holes and measure the effects of strongly curved spacetime close to the event horizon. I will present the results on several new campaigns aimed at probing the X-ray emitting corona and inner accretion disc in local Seyfert galaxies.

E1.6-0006-18 REVEALING THE STRUCTURE OF BLACK HOLE CORONAE, JETS AND ACCRETION DISCS THROUGH X-RAY REVERBERATION

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From the reflection and reverberation of X-rays from the innermost regions of AGN accretion discs, a three-dimensional picture is starting to emerge of the structure of the disc and the corona producing the intense X-ray emission, as well of how the launching sites of jets may be connected to the corona and inner disc.

Spectral timing analysis of AGN observed by the great X-ray observatories, compared to the predictions of general relativistic ray tracing simulations, reveals not only the mechanisms of variability in the X-ray emission, but enables the structure of the corona and accretion disc to be mapped. We discover how the corona evolves on long and short timescales, giving rise to orders of magnitude variation in luminosity as well as the processes the corona can undergo during transient events, most notably the collimation and ejection of portions of the corona during X-ray flares, reminiscent of the aborted launching of a jet.

The latest X-ray reverberation studies are revealing, for the first time, structure within the corona including a persistent collimated core akin to the base of a jet, even in radio-quiet sources, alongside a second component associated with the accretion disc itself.

This gives us important insight into the small-scale processes close to the event horizon that enable supermassive black holes to power some of the most luminous objects in the Universe, launch vast jets at close to the speed of light and play their important feedback role in the formation of structure in the Universe.

E1.6-0007-18 MODELLING THE X-RAY FRMS VARIABILITY SPECTRUM OF ACTIVE GALACTIC NUCLEI

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Active Galactic Nuclei(AGN) are the centre of interest because of their complex broadband electromagnetic spectra and extreme variability ranging from radio, optical/Ultra-Violet (UV) to gamma-ray at the time-scales from a few minutes to hundreds of years depending upon the physical processes they are governed by. In order to understand the complex nature of AGN Xray variability, we developed the fractional root-mean-squared (FRMS) spectral model in ISIS (Interactive Spectral Interpretation System). This technique needs event file as input, derive the observed FRMS spectrum and then it calculates the model FRMS spectrum by varying the specified parameter of a user-defined energy spectral model. We have derived and modelled the FRMS variability spectra of different types of AGN and probed the underlying physical processes responsible for the observed X-ray variability of Seyfert galaxies. In this talk, I would like to present results of the X-ray variability spectral modelling for a number of AGN.

E1.6-0008-18 PROBING THE INNER ACCRETION REGION WITH A 2 MS OBSERVATION ON A NEARBY AND HIGHLY VARIABLE AGN

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The fast timing properties of accreting black hole light curves allow us to probe the direct vicinity of black holes, the region most affected by strong gravity. We present an extensive X-ray variability analysis from a new 1.5 mega-second XMM-Newton VLP observation (plus 500 ks archival = 2Ms) of the highly variable Seyfert 1 galaxy, IRAS 13224-3809. This is the longest observation taken to date on a nearby variable AGN. This long observation has revealed complex underlying variability processes, displaying the first non-linear rms-flux relation in any accreting source. We will show modelling of the coronal and reverberation delays using GR ray tracing models. This allows us to build up the most detailed picture to date of the inner X-ray emitting regions of AGN. We discuss the implication of these results for accreting sources across the mass range.

E1.6-0008-18 BREAKING THE SPECTRAL DEGENERACIES OF BLACK HOLE BINARIES WITH FAST TIMING DATA

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The spectra of black hole binaries in the low/hard state are complex, with evidence for multiple different Comptonisation regions contributing to the hard X-rays, in addition to a cool disc component. However, it is difficult to constrain the shapes of these components uniquely using spectral data alone. Using observations of Cygnus X-1, we show that additional information from fast variability can break this degeneracy. Specifically, we use the observed variability power spectra to reconstruct the energy spectra of the variability on timescales of roughly 10 s, 1 s and 0.1 s. The two longer timescale spectra have similar shapes, but the fastest component is dramatically harder, and has strong curvature indicating that its seed photons are not from the cool disc. We discuss these results in the context of propagating fluctuations through a hot flow, where the outer regions are cooler and optically thick, so that they shield the inner region from the disc.

E1.6-0009-18 TIME DEPENDENT SPECTRUM OF AN X-RAY IRRADIATED ACCRETION DISC WITH STOCHASTIC PERTURBATIONS

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The X-rays emitted by the inner regions of the accretion disk induce structural changes in the outer regions of the disk. We study here how the effective temperature and hence the corresponding spectrum of the disk is altered by stochastic perturbations in the outer regions and thereby try to study the long term variability which has been observed in some X-ray binaries. We use a time dependent global hydrodynamic code to study the variations in the effective temperature of the disk in response to sinusoidal accretion rate perturbations introduced at different radii and with different time periods. To quantify the results, we calculate the root mean square effective temperature at different radii and the root mean square flux at differ- ent frequencies. From our calculations of the time-lags in accretion rate, effective temperature and the different frequencies, we find that the time-lags in presence of X-ray irradiation is significantly smaller than the expected viscous time-scale.

E1.6-0010-18 TOMOGRAPHIC MAPPING OF ACCRETING BLACK HOLES USING X-RAY QUASI-PERIODIC OSCILLATIONS

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Accreting stellar-mass black holes often show a quasi-periodic oscillation (QPO) in their X-ray flux with a period that slowly drifts from 10s to 0.05s. The physical origin of the QPO has long been debated, but is often attributed to Lense-Thirring precession, a General Relativistic effect causing the inner accretion flow to precess as the spinning black hole twists up the surrounding space-time. A distinctive prediction of the precession model is that the iron fluorescence line, produced as part of a 'reflection' spectrum by disk irradiation, should rock between redand blue-shifted as the receding and approaching sides of the disk are respectively illuminated by the precessing inner accretion flow. Our recent XMM-Newton and NuSTAR observations in which the centroid energy of the iron line in H 1743-322 varies systematically over the 4 s QPO cycle, confirm this prediction and thus provide strong evidence in favour of the precession model. Here I will focus on the tomographic mapping techniques that this result has enabled. This entails developing a physical model for the QPO phase-dependent reflection spectrum and fitting to the observed QPO phase-resolved spectra. I will present results for our campaign on H 1743-322 and also for NICER observations of the recently discovered source, MAXI J1535-571. I will present results of modelling that additionally takes into account thermal reprocessing, which exploits the very high count rates achieved by NICER in the soft X-ray band.

E1.6-0011-18 NICER SPECTRAL-TIMING STUDIES OF A LOW-FREQUENCY QPO IN THE SOFT-INTERMEDIATE STATE OF MAXI J1535-571

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We present the discovery and preliminary spectral-timing analysis of a low-frequency QPO feature in observations of MAXI J1535-571 in the soft-intermediate state, obtained by the Neutron Star Interior Composition Explorer (NICER). The feature is relatively broad and weak, with a weak harmonic and additional low-amplitude broadband noise. These characteristics likely make it a weak Type B QPO, like one previously identified in the soft-intermediate state of the transient black hole X-ray binary XTE J1550-564. The lag-energy spectrum of the QPO shows soft lags of about 50 ms with an inflected spectral shape, flattening above 4 keV. Preliminary QPO-phase-resolved spectral analysis suggests that the inflected lag-energy spectrum is due to the disk blackbody component lagging the Comptonized power-law emission by 27% of a QPO cycle. This large phase shift has similar amplitude but opposite sign to that seen in Rossi X-ray Timing Explorer data for the Type B QPO from the transient black hole X-ray binary GX 339-4. We suggest that the Type B QPOs from these systems may have the same origin, in the form of a precessing jet-like corona illuminating the disk, with the different lag signs depending on the observer inclination angle.

E1.6-0012-18 ADVANCES IN PHASE RESOLVING QUASI-PERIODIC OSCILLATIONS WITH NICER

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The X-ray emission of accreting, stellar-mass black holes is variable on a wide range of timescales and often shows quasi-periodic oscillations, or QPOs. Discovered decades ago, the origin of these QPO remains an open question to this day. In the most promising QPO model, the inner accretion flow precesses due to relativistic frame dragging. In addition to X-ray variability, such geometric changes should cause distinct spectral variations with the QPO phase. Phaseresolving the QPO for spectral analysis is therefore an important step towards understanding its physical origin. In this talk, I will discuss how the recently deployed NICER mission, with its CCD-like energy resolution and soft response, has impacted such QPO studies. After introducing different phase-resolving methods, I will compare their results and the improvements brought on by NICER, by presenting a case-study of the QPO in NICER observations the recently discovered accreting black hole MAXI J1535-571.

E1.6-0013-18 THE LENSE-THIRRING PRECESSION MODEL FOR THE LOW-FREQUENCY QPO IN ACCRETING BLACK HOLES

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The Lense-Thirring precession model is a promising model for the low-frequency QPO in accreting black hole systems. It combines the standard geometry of the accreting two-phase plasma, with a geometrical scenario producing a periodic variability of the X-ray emission.

I am going to present results of Monte Carlo simulations of generation of hard X-ray emission in the scenario of precessing inner hot plasma torus with an outer cold disk. The soft photons from the disk are inverse-Compton upscattered in the hot torus, to produce the hard X-rays. Photon propagation from the system to the observer includes relativistic effects. Changes of the viewing conditions and possibly the plasma temperature during the precession cause the variability of the observed emission.

E1.6-0014-18 A REVIEW ON HIGH-FREQUENCY QUASI-PERIODIC OSCILLATIONS: PAST, PRESENT AND FUTURE

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X-ray observations of both Black Holes and Neutron Stars in Low-mass X-ray binaries have shown quasi-periodic oscillations (QPOs) with frequencies as low as Milli-hertz, and as high as 1300 Hz. The highest frequencies we observe are thought to be due to the motion of gas a few gravitational radii from the compact object. In this talk I will review what we know about the so-called kHz QPOs in neutron stars and the high-frequency QPOs in black hole systems, what are the current theoretical models which better describe the data, and how new spectral/timing approaches could help us understand this extreme phenomena.

E1.6-0015-18 BICOHERENCE OF QUASI-PERIODIC OSCILLATIONS FROM GX 339-4

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Quasi-periodic oscillations (QPOs) are features that appear as narrow peaks in the power spectrum of X-ray binaries. While QPOs have been observed in many sources, the manner in which they are produced is under debate. The bicoherence, a measure of coupling between the phases of different Fourier frequencies, can be used to differentiate between models that produce very similar features in their power spectra. We analyse several observations of RXTE/PCA archival data of the black hole binary GX 339-4 which show QPOs. We find that these QPOs show different patterns in their bicoherence plots, suggesting that they are produced by different physical processes.

E1.6-0016-18 THE SPECTRAL AND TIMING PROPERTIES OF THE KHZ QPOS IN 4U 1636-53

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Combined spectral-timing techniques are the key to understand the variability, environment and internal composition of neutron-stars in X-ray binary systems. We analyzed all the available RXTE observations of the neutron-star low-mass X-ray binary 4U 1636-53 and studied the rms fractional amplitude of its pair of kilohertz quasi-periodic oscillations (QPOs) as a function of energy and frequency. By combining the observations with the QPOs within chosen frequency ranges we produced frequency-resolved fractional rms amplitude spectra. By selecting lightcurves in different energy bands we created energy-resolved relations of the fractional rms amplitude vs. frequency of the kHz QPOs. We also studied the relation between the frequency of the kHz QPOs and the physical parameters that describe the energy spectrum of 4U 163653. We obtained results that, for the first time, show the connection between the spectral parameters and the dynamical and radiative properties of the kHz QPOs. We discuss the implications of our findings on our understanding of the mechanism that produces the kHz QPOs. Our results demonstrate that a simultaneous description of the time and energy domains is needed to reveal the origin of the kHz QPOs.

E1.6-0017-18 QUASI-PERIODIC OSCILLATIONS FROM POST-SHOCK ACCRETION COLUMN OF STRONGLY MAGNETIZED ACCRETING WHITE DWARFS

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Polars are a set of strongly magnetized accreting white dwarfs which does not form any accretion disk due to its extended magnetosphere. Quasi-periodic oscillations (QPOs) with frequency about a Hz are detected in many optical observations of a few polars. In these binary systems, the high-frequency QPOs are thought to be generated due to the variation in emitted radiation from the post-shock accretion column. Thermal bremsstrahlung is a significant process to generate Xray radiation from this post-shock region. Local thermal instability due to the efficient cooling from the highly dense region is believed as the primary region behind the temporal variability. We study the structure and the dynamical properties of the post-shock accretion column including the effects of bremsstrahlung and cyclotron radiation. We find that the presence of significant cyclotron emission in optical band reduces the overall variability of the post-shock region. These characteristics of the post-shock region are consistent with the observed properties of V834 Cen and in general with Cataclysmic Variable sources that exhibit QPO frequency of about a Hz.

E1.6-0018-18 SOFT BAND SPECTRAL-TIMING OF KHZ QPOS

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The fastest variability signals that may be observed from the accretion process, kilohertz quasiperiodic oscillations (kHz QPOs) have long been recognized as an important probe of the accretion process. A firm theoretical understanding of how these QPOs are generated, however, remains elusive. Measurements of the energy dependent QPO amplitude and time lag may provide some constraints, especially at low photon energies, where proposed models give diverging predictions. In this contribution we present new results from NICER, which, for the first time, observed kHz QPOs down to 1 keV. Extending spectral-timing analysis of these QPOs to the soft band, we discuss our results in the context of QPO emission models.

E1.6-0019-18 NONLINEAR TIMING TECHNIQUES

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I will give a review of nonlinear timing techniques, such as the bispectrum and the time skewness. These techniques can be used to break degeneracies between models that produce identical power spectra. In particular, they can determine whether rise times or decay times are faster in light curves, and determine the symmetry of the flux distribution on a variety of timescales.

E1.6-0020-18 (BAYESIAN) INFERENCE FOR X-RAY TIMING

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Fourier techniques have been incredibly successful in describing variability of X-ray binaries (XRBs) and Active Galactic Nuclei (AGN). The detection and characterization of both broadband noise components and quasi-periodic oscillations as well as their behavior in the context of spectral changes during XRB outbursts has become an important tool for studying the physical processes of accretion and ejection in these systems. In this talk, I will review state-of-the-art techniques for characterizing variability in compact objects and show how these methods help us understand the causes of the observed variability and how we may use it to probe fundamental physics. Despite numerous successes, however, it has also become clear that many scientific questions cannot be answered with traditional timing methods alone. I will therefore also present recent advances to modeling variability with generative models, some in the time domain like CARMA as well as machine learning approaches like Hidden Markov Models, and discuss where these methods might lead us in the future.

E1.6-0021-18 X-RAY REFLECTION COMPONENTS WITH INTRINSIC ABSORPTION

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X-ray reflection spectra are the result of competition between absorption, scattering and emission. They are usually identified through their emission and scattering properties, although photoelectric absorption edges are clearly present. Absorption lines should also occur, particularly when the reflector is viewed at high inclination. This may be relevant to the detection of blueshifted iron absorption lines in some accreting black hole spectra. The absorption may occur in the outer, possibly more highly ionized, layer of the bright approaching side of the inner accretion disc. Intrinsic disc absorption must be either quantified or eliminated before a genuine outflow can be claimed. For this purpose, we investigate 2 Ms of X-ray data from the highly variable AGN IRAS13224-3809, which shows variable blueshifted absorption lines.

E1.6-0022-18 A NICER LOOK AT X-RAY BINARIES

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NICER is the new premier X-ray timing instrument onboard the International Space Station, having been installed in the summer of 2017. NICER offers an order of magnitude better time fidelity than any predecessor X-ray instrument. For spectra, NICER provides CCD-like energy resolution and sensitivity to soft X-rays, low background, and large collecting area, all with negligible pileup for even Crab-bright sources. NICER is poised to make leading contributions to fundamental topics in the X-ray binary field including constraining neutron-star equation of state, measuring black-hole spins, discerning accretion flow structure using quasi-periodic oscillations (QPO), and mapping disk-coronal geometry. I will present some of NICER's first results on black hole microquasar and neutron star systems which showcase the power of NICER for X-ray spectral-timing investigations.

E1.6-0023-18 A NEW ERA FOR SPECTRAL-TIMING AT OPTICAL WAVELENGTHS

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From supermassive black holes at the centre of galaxies, to young-stellar objects still in the star-forming process, accreting systems on all scales are now known to display very similar phenomenology when comparing their spectral/timing properties. However, it was not until the spectral/timing methods and techniques adopted from accreting stellar-mass black holes and neutron stars were applied to accreting white dwarfs and young-stellar objects that these clear similarities were quantified. Since accreting white dwarfs and young-stellar objects display intrinsically longer accretion-induced timescales and emit most of their accretion-driven radiation at optical/UV wavelengths, applying the well-known spectral/timing methods (bicoherence, fourier-lags, bispectrum) has faced new challenges. In this talk I will discuss these challenges and how they have been overcome to allow us to compare the spectral/timing properties across accreting systems on all mass and size scales. This global spectral/timing analysis approach demonstrated how all accreting systems display the same phenomenological similarities when compared to each other, and more importantly how these remarkably similar properties seem to suggest a common physical mechanism to accretion on all scales.

E1.6-0024-18 STROBE-X: X-RAY TIMING AND SPECTROSCOPY ON DYNAMICAL TIMESCALES FROM MICROSECONDS TO YEARS

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We describe a probe-class mission concept that provides an unprecedented view of the X-ray sky, performing timing and 0.2-30 keV spectroscopy over timescales from microseconds to years. The Spectroscopic Time-Resolving Observatory for Broadband Energy X-rays (STROBE-X) comprises three primary instruments. The first uses an array of lightweight optics (3-m focal length) that concentrate incident photons onto solid state detectors with CCD-level (85-130 eV) energy resolution, 100 ns time resolution, and low background rates to cover the 0.2-12 keV band. This technology is scaled up from NICER, with enhanced optics to take advantage of the longer focal length of STROBE-X. The second uses large-area collimated silicon drift detectors, developed for ESA's LOFT, to cover the 2-30 keV band. These two instruments each provide an order of magnitude improvement in effective area compared with its predecessor (NICER and RXTE, respectively). Finally, a sensitive sky monitor triggers pointed observations, provides high duty cycle, high time resolution, high spectral resolution monitoring of the X-ray sky with 20 times the sensitivity of the RXTE ASM, and enables multi-wavelength and multi-messenger studies on a continuous, rather than scanning basis. We describe the mission concept including updated instrument and mission designs resulting from the GSFC IDL and MDL studies.

The STROBE-X concept study is supported by NASA.

E1.6-0025-18 SPECTRAL-TIMING STUDIES OF X-RAY BINARIES AND AGNS WITH ATHENA

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I wish to review the expected capabilities of Athena for observing bright (up to Crab) X-ray sources with the onboard calorimeter XIFU, i.e. at an unprecedented high (<10 eV) energy resolution and throughput. I will then present some examples of spectral-timing studies that will allow to probe winds and accretion flows in X-ray binaries and AGN with unprecedented details.

E1.6-0026-18 THE X-RAY / UV / OPTICAL VARIABILITY OF AGN

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The origin on the UV and optical variability in AGN has long been unknown. I will discuss the results of recent multiwaveband monitoring campaigns. On long timescales (year) there are optical variations which are not correlated with the X-rays and are probably caused by accretion rate variations in the disc. However on short timescales (hours-weeks) the X-ray variations are correlated with, and lead, the UV/optical variations, implying that reprocessing of X-rays is the origin of the variations. By measuring the lags as a function of wavelength we are able to map out the structure of the surrounding reprocessing material. We find that the accretion disc can account for some of the reprocessed emission but the observed size is larger than expected theoretically. There is also evidence for a second reprocessor at a larger distance, probably the broad line region gas. There is considerable variation between AGN, particularly with regard to the X-ray to UV lag which may be affected by absorption and scattering in an inflated inner disc.

E1.6-0027-18 LINKING TEMPORAL SCALES AND STATE TRANSITIONS OF THE BLACK HOLE BINARY GX 339-4

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Low-Mass X-ray Binaries are known to undergo spectral transitions and exhibit a number of distinct spectral states, which are usually depicted as tracks, tracing in an anticlockwise direction, a characteristic q-shape on a hardness intensity diagram (HID). While a number of spectral states and transitions are discussed in the literature, the two most prominent states, of which there is universal agreement, are the Low/Hard (LHS) and the High/Soft states (HSS). The spectral nature of these states is typically understood in terms of changes in the size of the accretion disk. In this work we extract temporal scales and link these to the different state transitions of the source GX 339-4 by constructing a luminosity variability diagram (LVD). This new diagram can be compared directly with a traditional HID.

E1.6-0028-18 SPECTRAL ANALYSIS WITH THE TCAF MODEL: A GLOBAL UNDERSTANDING OF BOTH SPECTRAL AND TEMPORAL PROPERTIES OF BLACK HOLES

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There are many theoretical and phenomenological models in the literature which try to explain physics of accretion around black holes (BHs). Some of these models assume ad-hoc additional components to explain different timing and spectral aspects of black hole candidates (BHCs) which no necessarily follow from physical equations. Chakrabarti and his collaborators, on the other hand claim in the last two decades that the spectral and timing properties of BHCs must not be treated separately since variation of these properties happens due to variation of matter accretion from two component (Keplerian and sub-Keplerian) of flows, and the Compton cloud parameters only. Recently after the inclusion of two component advective flow (TCAF) solution into HEASARC's spectral analysis software package XSPEC as an additive table model, we found that TCAF is quite capable of describing the underlying accretion flow dynamics around BHs with spectral fitted physical parameters. Properties of different spectral states and their transitions during an outburst of a transient BHC are more clear. A strong correlation between spectral and timing properties could also be seen in Accretion Rate Ratio Intensity Diagram (ARRID), where transitions between different spectral

states are prominent. One can also predict frequencies of the dominating type-C quasi-periodic oscillations (QPOs), which is a temporal phenomena from TCAF model fitted shock parameters. Estimation of the most probable mass ranges of BHCs and X-ray contributions from jets/outflow (if present) could also be done from spectral fits with the TCAF model. This gives us a confidence that we are in the verge of understanding accretion processes most accurately than ever before.

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E1.6-0029-18 UNIFIED SPECTRAL AND TIMING MODEL OF SEYFERT 1 GALAXIES OBSERVED WITH NUSTAR AND XMM/SUZAKU

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NuSTAR satellite was launched in 2012 and high-quality energy spectra of Seyfert 1 galaxies above 10 keV have been made available for the first time. In this paper, we analyze archival data of the NuSTAR and XMM/Suzaku simultaneous observations of particularly variable Seyfert 1 galaxies, MCG-6-30-15, NGC 4593, NGC 1365, Swift J2127.4+5654 and MCG-5-2316. Our aim is to construct a unified spectral and timing model that explains spectral variations in 0.2-78 keV with minimum free parameters. Consequently, we were successful to explain observed spectral variations of all the five sources at timescales below 1 day with only two independently variable parameters; partial covering fraction and normalization of the power-law component. In this model, the continuum is composed of disk-black body component, cut-off power-law component, and thin-thermal plasma component, if any. The central X-ray source is fully or partially absorbed by ionized absorbers, and the partial covering fraction is significantly variable. Variations of the partial covering fraction and the power-law normalization mostly explain the soft X-ray variation below 10 keV and the hard X-ray variations above 10 keV, respectively. The variable partial absorbers are composed of two layers with different ionization states/column densities. The observed X-ray spectral variations, energy-dependent light curves and RMS spectra are explained only by the two variable parameters.

E1.6-0030-18 THE RELATIVISTIC ACCRETION DISK AND THE ULTRA-FAST OUTFLOW IN IRAS 13224-3809

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Narrow-Line Seyfert 1 galaxies (NLS1) are a rare subclass of active galaxies that are usually characterized with a small central black hole mass accreting at rates close to the Eddington limit. We present a detailed time-resolved and flux-resolved spectral analysis of the recent 1.5 Ms XMM-Newton observing campaign on the NLS1 IRAS 13224-3809, taken simultaneously with 500 ks of NuSTAR data. The X-ray lightcurve shows three flux peaks, registering at about 100 times the minimum flux seen during the campaign, and rapid variability with a time scale of kiloseconds. This source is known to exhibit a complex combination of relativistic reflection from the accretion disk and absorption from a mildly relativistic outflow in addition to the primary powerlaw continuum. We will show that the spectral variability is dominated by the powerlaw continuum from the coronal region within a few gravitational radii from the BH and how the relativistic disk and the relativistic outflow components change with the flux level.

E1.6-0031-18 EVOLUTION OF THE ASYMMETRIC MULTI-PHASE DISC ATMOSPHERE IN THE X-RAY BINARY MXB1659-298, DURING ITS 2015-2016 OUTBURST

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Equatorial winds and disc atmospheres are fundamental components of accretion onto compact objects and they are typically traced through ionised absorption lines. I will report the analysis of the Chandra HETG, XMM and NuSTAR monitoring campaign of the last outburst of the high-inclination (eclipsing) transient neutron star Low Mass X-ray Binary MXB1659-298. We detected more than 60 absorption lines during the soft state HETG+NuSTAR observation, while only stringent upper limits are observed during the hard state. I will discuss the importance of thermal instabilities for this effect. We also observed, for the first time, a modulation of the intensity of the ionised absorption lines with orbital phase. I will finally discuss how these results shed new light onto our picture of the accretion phenomenon.

E1.6-0032-18 RAPID MID-INFRARED VARIABILITY IN AN X-RAY BINARY

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We present optical to mid-infrared (mid-IR) spectral–timing observations of the new, bright, black hole candidate transient X-ray binary, MAXI J1535–571. Mid-IR (5–12 micron) observations were acquired with VISIR on the VLT, and optical–near-IR monitoring was taken with the Faulkes, Las Cumbres Observatory (LCO) and Rapid Eye Mount (REM) telescopes. We detect bright (up to 100 mJy), highly variable mid-IR emission in September 2017 as the source made a transition from the hard state towards the soft state. We use X-ray data to track how the optical–IR changes as the source evolves in the hardness–intensity diagram.

The mid-IR 9–12 micron flux density faded dramatically by more than an order of magnitude over one week in September 2017. This is contemporaneous with a near-IR and optical fade of a factor of 10 and 2, respectively. Before the fade, the IR de-reddened spectrum can be described by an optically thin synchrotron power law, with a spectral break at the longer wavelengths to a flatter spectrum. This spectrum, and the wavelength dependence of the fade can be explained by a synchrotron jet which is quenching over the state transition, and a less variable disc component in the optical.

We also present the first (to our knowledge) mid-IR variability study of an X-ray binary on short (minute) timescales. On some dates the mid-IR flux of MAXI J1535–571 varied by a factor of two in less than 15 minutes, and on one date there is a sudden decrease of the flux to undetectable levels. The near-IR flux is also variable on short timescales. The mid-IR fractional rms variability on minute timescales is 15%, which is comparable to the optical fractional rms of GX 339–4 at similar time resolution. We compare these results to the expected fractional rms from the jet internal shock model of Malzac et al., and find that the variability amplitude is consistent with this model.

We also combine our optical–IR spectral energy distributions with radio, mm and X-ray data to build a coherent picture of the evolution of the broadband spectrum. We find that contrary to other sources, the jet does not simply fade over the transition, with the jet spectral break shifting to lower frequencies, but instead there are jet flares and rapid evolution of the jet spectrum that correlate with X-ray hardness deviations. These results represent an excellent case of multiwavelength jet spectral-timing and demonstrate how rich, multiwavelength timeresolved data of X-ray binaries over state transitions can help refine models of the disc-jet connection and jet launching in these systems.

E1.6-0033-18 STUDY OF TIMING EVOLUTION FROM NON-VARIABLE TO STRUCTERED LARGE-AMPLITUDE VARIABILITY TRANSITION IN GRS 1915+105 USING ASTROSAT/LAXPC

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In this work we present a sim 90 ks continuous monitoring of the Galactic micro-quasar GRS 1915+105 with AstroSat when the source undergoes a major transition from a non-variable state (similar to chi class) to a structured, large amplitude, periodic flaring state (similar to rho class). We show that such transition takes place via an intermediate state when the large-amplitude, irregular variability of the order of thousands of seconds in the soft X-ray band turned into a 100-150 sec regular, structured, nearly periodic flares, very similar to rho class/heartbeat oscillations. Intererstingly, the properties of a strong low-frequency quasi-periodic oscillation (LF QPO) in the frequency range 3-5 Hz remain stable during all three states. We also study time-lag and rms spectra at the QPO, harmonic and broad noise components and dynamic power spectra. We note few important differences between the flaring state and the rho class and conclude that the flaring state is a precursor of the rho class. Stability of the LF QPO during variability transition implies the disk-corona coupled radiation system which determines the LF QPO properties, mostly uninturrepted by the launch of long, large-amplitude flares, probably from the outer disk. However, the increase in the QPO frequency with the softening of the source is consistent with the significant decrease in the inner accretion disk radius.

E1.6-0034-18 ACCRETION STATES, BLACK HOLE SPIN, AND THE 2017 OUTBURST OF MAXI J1535-571

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After two decades of monitoring stellar mass black holes in outburst, there are still lingering questions about the geometry of the accretion disk and its evolution across state transitions. Does the disk extend all the way to the ISCO, or is it truncated at some distance from the black hole? How does this depend on accretion rate, luminosity, and X-ray spectral shape, and how is it connected to timing properties? The recent outburst of MAXI J1535-571, monitored extensively with NuSTAR and NICER, provides a prime opportunity to address these questions. I will present detailed analysis of the spectral evolution of the source over roughly three months, from its rising hard states through its >5 Crab peak, all the way to its soft, disk-dominated state. Applying relativistic reflection models and holding its spin constant across the outburst, I track the evolution of the inner radius of the disk from state to state. With hundreds of millions of counts in dozens of observations, these data offer an incredibly detailed view of the spectral geometry of MAXI J1535-571 for comparison to precision timing results.

E1.6-0035-18 STATE TRANSITIONS IN DWARF NOVAE AND COMPARISONS WITH THE BROADBAND NOISE CHARACTERISTICS

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Broadband noise in accreting systems have been a diagnostic tool in understanding the structure of accretion disks and state transitions. In this talk I will present broadband noise variations of dwarf novae (DN) in comparison with their energy spectrum changes using the X-ray wavelengths. DN demonstrate band limited noise in the UV and X-ray energy bands, which can be adequately explained in the framework of the model of propagating fluctuations (Balman & Revnivtsev 2012, Balman 2014, 2015). The detected frequency breaks are in the range (1-6) mHz and indicates an optically thick disk truncation in the inner disk of dwarf novae systems indicating existence of hot flows in the inner regions. Analysis of other available data reveal that during the outburst the inner disk radius moves towards the white dwarf and receeds as the outburst declines while changes in the X-ray energy spectrum is also observed. Cross-correlations between the simultaneous Optical, UV and X-ray light curves show time lags consistent with truncated optically thick disk and inner disk hot flows. I will also discuss the hysteresis in these systems and my recent calculation showing a correlation between the break frequency and the temperature of the hot inner thermal flow in the X-ray emitting region.

E1.6-0036-18 DETECTION OF TYPE-1 BURSTS FROM THE GALACTIC CENTER USING ASTROSAT-LAXPC

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We report the detection of two Type-1 X-ray bursts within a span of a few hours from a crowded region near the Galactic Center (GC) using Astrosat-LAXPC. The detected bursts exhibit a characteristic FRED profile, suggestive of a thermonuclear flash process observed in neutron stars. This region near the GC hosts several potential sources in the LAXPC field of view. The object closest to the LAXPC pointing, 1E 1743.1-2843, is a persistent LMXB, for which, the nature of the compact object is unknown so far. Two other potential candidates, GRS 1741.9- 2853 and SAX J1747.0-2853, are known to be transient low luminosity bursters. Three sources, KS J1741-293, 2E 1742.9-2929 and IGR J17473-272 lie close to the edge of the LAXPC field of view of this observation and for the bursts to be from one of these sources, have to be extremely luminous. We inspect all these sources as possible candidates using pointing information of all three LAXPCs, their relative efficiencies and the observed burst fluences. We also check the pre and post burst luminosity states of these objects. The LMXB object 1E 1743.1-2843 is a strong candidate for being the source of the two bursts. This would establish the presence of a neutron star primary for this binary,resolving the ambiguity associated with the nature of this system. We also examine the energy resolved burst characteristics and burst recurrence times. Results from search for high frequency QPOs will also be presented along with preliminary results obtained from burst spectroscopy.

E1.6-0037-18 PROBING THE NATURE OF THE ACCRETION FLOW IN LOW MASS X-RAY BINARIES USING THE SPECTRAL-TIMING PROPERTIES OF THE KILOHERTZ QUASI-PERIODIC OSCILLATIONS

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Over the last two decades several efforts have been made to try and explain the energydependent variability observed in low mass X-ray binary (LMXB) systems. The kilohertz quasi-periodic oscillations (kHz QPOs) represent the fastest variability so far observed from neutron-star (NS) LMXBs. We present a model that reproduces the fractional rms amplitude and time lags of the kHz QPOs as a function of photon energy and QPO frequency. Our model builds upon a previously explored idea, namely that the variability is driven by a coupled oscillation of the temperature of the accretion disc and the heating rate (and hence the electron temperature) of the corona. New here is that we explore the effect of the (expected) coupled oscillation of the electron number density (optical depth and physical size) of the corona and a range of physically motivated feed-back mechanisms between the disc and the corona. We further examined the impact of the seed photon spectra, a corona with a non-uniform optical depth and electron temperature, and the physical size of the corona on the QPO properties. We compared the predictions of our model to simultaneous XMM-Newton and the Rossi X-ray Timing Explorer (RXTE) energy spectra, and RXTE power-density and time-lag spectra of the NS LMXB 4U 1636-53. The ultimate goal is to unravel the underlying mechanisms that drive the variability of these sources.

E1.6-0038-18 TIMING AND SPECTRAL STUDIES OF SXP 15.3 NEAR ITS EDDINGTON LUMINOSITY

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SXP 15.3 (RX J0052.1-7319) is a Be X-ray binary pulsar located in the Small Magellanic Cloud. The source was classified as a transient X-ray binary candidate based on ROSAT observations in the 1990's, and pulsations at 15.3 s were subsequently discovered from an outburst in 1996 from the ROSAT data. The source has never been studied in an outburst or a bright state ever since. Following reports of an outburst in November 2017, we triggered a Target of Opportunity observation of SXP 15.3 with AstroSat. We report here the first broadband spectral and timing studies of the source, when the source was accreting near the Eddington limit of 1038erg/s. We discuss the energy dependence of the pulse profiles and the broadband spectrum in context of accr

E1.6-0039-18 THE REFLECTION SPECTRUM OF THE LOW-MASS X-RAY BINARY 4U 1636–53

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We present 3–79 keV NuSTAR observations of the neutron star low-mass X-ray binary 4U 1636– 53 in the soft, transitional and hard state. The spectra display a broad emission line at 5–10 keV. We applied several models to fit this line: A gaussian line, a relativistically broadened emission line model, kyrline, and two models including relativistically smeared and ionized reflection off the accretion disc with different coronal heights, relxill and relxilllp. All models fit the spectra well, however, the kyrline and relxill models yield an inclination of the accretion disc of 88o with respect to the line of sight, which is at odds with the fact that this source shows no dips or eclipses. The relxilllp model, on the other hand, gives a reasonable inclination of 56o. We discuss our results for these models in this source and the possible primary source of the hard X-rays.

E1.6-0041-18 X-RAY OBSERVATIONS OF TWO VERY FAINT X-RAY TRANSIENTS (VFXTS) DURING THEIR OUTBURSTS

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We will present results obtained from a detailed study of two VFXTs, namely; MAXI J1957+032 (J1957) and Swift J1357.2-0933 (J1357). J1957 showed four short outbursts since its discovery in 2015. The nature of the compact object is not clear. We found that the identification depends on the distance to J1957. If the source is <2 kpc, then J1957 might be a black hole system, for distances between 4-8 kpc our results suggest that the source harbors neutron star and if the distances are larger than 8 kpc it is difficult to infer strong constraint on the nature of the accretor. J1357 is the only confirmed black hole VFXT. A toroidal structure in the inner region of the disk has been postulated similar to the obscuring tori seen around AGN. On April 20, 2017, it went into outburst for the second time. Spectral fitting performed using data of Swift-XRT and NuSTAR showed no signatures of cut-off, or any reflection from the disc or the putative torus.

E1.6-0042-18 TIME DEPENDANT SPECTRAL PROPERTIES OF TWO COMPONENT ADVECTIVE FLOW

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We study time-dependent spectral properties and effects of Compton cooling using a timedependent viscous hydrodynamic flow coupled with radiative transfer processes. We consider a two-component accretion flow without any reflection symmetry at the equatorial plane in which Keplerian disc is simulated using αviscosity as prescribed in Giri, Chakrabarti 2013. Black body photons originating from Keplerian disc get inverse-Comptonized by hotter electrons present in halo and in the CENBOL region. We run many cases changing the halo accretion rate, critical optical depth (τ) and angular momentum (Λ) and investigate the properties of the spectrum. We also calculate disc accretion rate for different flow parameters and it can be observed that as disc rate increases cooling will also increase thus producing softer spectra.

E1.6-0043-18 BROADBAND RADIO PROPERTIES OF GALACTIC MICRO-QUASARS DURING HARD AND SOFT STATES

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Micro-quasars are known to show variability of different time-scales in all observable wavelengths. We will report how the broad-band radio properties of micro-quasars change during different spectral states of various micro-quasars. We have used Giant Meterwave Radio Telescope (GMRT) and Jansky Very Large Array (JVLA) and other available radio telescopes for our study. We will study disk-jet behavior of these micro-quasars and will comment on correlation and anti-correlation properties and time lag between X-ray and radio emissions.

E1.6-0044-18 LIMITS ON VISCOSITY PARAMETER IN ACCRETION FLOWS AROUND BLACK HOLES.

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We study accretion flows around black holes using two component accretion flow paradigm. An accretion flow around black holes have a Keplerian component (with super-critical viscosity parameter) enveloped by sub-Keplerian component (with sub-critical viscosity parameter). We study these component formations theoretically first. We study the flow parameter space which allows us to put a strict uppper limit on viscosity parameter values on the sub-Keplerian component. We use results obtained from observational analysis by other authors to calculate the value of viscosity parameter in Keplerian component and guess the values of critical value of viscosity parameter. We carry out this study for five different outbursting LMXRBs and find that all sub-Keplerian values of viscosity parameter were sub-critical and all Keplerian viscosity parameters were super-critical.

E1.6-0046-18 A CURIOUS CASE OF HMXB 4U 1700-37

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Raman Research Institute, Bangalore, India 4U 1700-37 is an eclipsing High Mass X-ray binary in a short orbital period of 3.412 days. In the absence of detectable pulsations, the orbital evolution is determined from the eclipse timing measurements, both from archival measurements as well as new measurements from long-term light curves obtained with the all sky monitors RXTE-ASM, Swift-BAT and MAXI-GSC. The orbital period decay rate of the system is estimated to be 10−7/yr, smaller compared to its previous estimates. The mid-eclipse times and the eclipse duration measurements obtained from 10 years long X-ray light curve with Swift-BAT are used to separately put constraints on the eccentricity of the binary system and measure any apsidal motion. We carry out a deepest search for pulsations and Cyclotron Resonance Scattering Feature (CRSF) using a 40 kilosec ASTROSAT LAXPC observation. These results will provide some newer insights into the nature of the compact object, which is either a very high mass neutron star or a very low mass black hole.

E1.6-0048-18 NEW FINDINGS IN THE GALACTIC WIND-FED X-RAY BINARY CYGNUS X-3 WITH TWO YEARS OF BROADBAND MONITORING USING ASTROSAT

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Possibly harboring a black hole at its center, the puzzling wind-fed Galactic X-ray binary Cygnus X-3 shows most powerful radio jets (sim20 Jy) among all Galactic sources. Using long-term monitoring program (sim2 years) with AstroSat, we explore the broadband X-ray spectroscopic evolution, its connection with the radio emission and timing properties of Cygnus X-3 at regular intervals and investigate the origin of spectra/timing correlated behavior and major radio jets in this source. We observe all spectral states previously reported but and found a new intermediate state where a flat hard X-ray spectrum is caused by the synchrotron radiation from the radio jet base. Using all available AstroSat observations, we also attempt to compute the hardness-intensity diagram ('q' diagram) of the source and compare with earlier results.

Using 0.3-80.0 keV broadband spectral modeling, we are able to constrain the nature of absorption and its variation at different parts of the binary orbital phase. We also notice that the size and the temperature of a large scattering medium around the accretion disk changes in different spectral states and we find evidence that such phenomena are closely connected with the radio jet intensity. Owing to the broadband spectroscopic capabilities and high efficiency at hard X-rays, we successfully carry out the most extensive investigation of the complex accretion geometry around Cygnus X-3 so far and present the results here.

E1.6-0049-18 THE LONG-TERM X-RAY VARIABILITY OF THE BLACK HOLE BINARY GRS 1915+105

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Since the discovering in 1992 August by GRANAT/WATCH, the violent X-ray activity in GRS 1915+105, one of the brightest objects in the X-ray sky even now, have been observed seamlessly over 25 years by multiple X-ray observation instruments.

Thanks to its brightness and various observations with the high timing resolution, it has been revealed that the celestial object exhibits 12 characteristic X-ray fluctuations in the time-scale of sub-second to an hour (Belloni et al. 2000), but few studies about the transition/relationship between the 12 states, or in the other words, the X-ray behavior in much longer time-scale (a month to years), are performed so far.

To reveal the comprehensive and global picture of the system, especially the accretion physics under the nearor super-Eddington accretion rate, we performed spectral and timing analysis for the X-ray light curve covering over 20 years obtained by RXTE/ASM and MAXI/GSC. Although the variation in the timescale of sub-second to an hour cannot be fully captured by the all-sky X-ray monitoring instruments, we found that the long-term X-ray variation is possible to be classified to three states based on the hardness-intensity relation, the shape of the spectrum, and the variance in flux, similar to the result shown in Belloni et al. 2000.

In this presentation, we show the newly discovered property in the long-term X-ray variation including the classification and then discuss the global dynamics of GRS 1915+105 based on the results.

E1.6-0050-18 RADIO VLBI AND X-RAY SPECTROSCOPY OF THE SS 433 JETS

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In the binary system SS 433, oppositely directed, precessing jets emit line emission from highly ionized plasma moving at 0.26c from the compact object. In a 2005 Chandra High Energy Transmission Grating Spectrometer (HETGS) observations of SS 433, we found a large Doppler shift change on a time scale of 20 ks, a time much shorter than the known dynamical times. The rapid change could be related to the formation and ejection of a jet knot, as observed in VLBI observations, perhaps as a leptonic jet impinges on a disk wind and shock heats it. More recent data were obtained to test this model in a long continuous HETGS observation. The VLBA and Chandra HETGS data were obtained but while no radio ejections were observed during the Chandra observation, there were interesting aspects to the observations. First, although the jet emission lines were expected to vary with the usual precession period (162 days) or with the period of the nodding motion (6.6 days), we did not detect the expected Doppler shifts in over 120 ks of exposure. Furthermore, there is new evidence for jet curvature that has not been previously reported. We will show how XARM can provide new constraints on the physical parameters at the jet origin.

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E1.6-0051-18 SPECTRAL-TIMING OF AQUILA X-1

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In this contribution we report on the spectral-timing analysis of Aquila X-1 observations taken with the Neutron Star Interior Composition Explorer (NICER). Leveraging NICER's excellent spectral and timing capabilities we extend, for the first time, the spectral-timing analysis of the accreting neutron star hard state to soft photon energies. We find that the slow X-ray variability shows a dramatic increase in amplitude towards its lowest photon energies. We discuss the implications of our results on the structure of the accretion flow around neutron stars, and highlight the similarities and differences with respect to hard state black hole systems.

E1.6-0053-18 SPECTRAL SIGNATURE OF TRANSITION BETWEEN BURST-ON AND BURSTOFF STATES OF VARIABLE SOURCES

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The class variable source GRS 1915+105 is different from the transient sources in the sense that it exhibits peculiar time variabilities in the range of a few seconds to days. Depending on cts/s in different energy bands and the color-color diagram, the variability was first grouped into seventeen classes. The variability arises because of the Comptonization of outflow and its subsequent fall-back, increasing the local disk accretion. Systematic evolution of this feature would be transparent if the evolution of accretion rates are studied. Chakrabarti et al. (2002) determined the inner disk temperature and spectral slope on soft and hard state and three intermediate states of GRS 1915+105 using diskbb+power-law model, and found that the slope gradually gets steeper as one moves from hard to soft state. We do the spectral fitting using TCAF+Cutoff power-law model, and the variation of the accretion rates agree with the previous findings. The burst-off states of the intermediate phase could be fitted with same TCAF normalization for the hard states, and in the burst on state, there is significant change in the disk rate. That gives a legitimate picture of the transition between hard to soft state vis-a-vis the accretion rate.

E1.6-0054-18 NEW GALACTIC BLACK HOLE CANDIDATE MAXI J1535-571: ANALYSIS WITH THE TCAF MODEL

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Recently discovered X-ray transient Galactic black hole candidate MAXI J1535-571 has been studied during its very first outburst after discovery using archival data of Swift XRT BAT instruments. Maximum X-ray flux in 0.3-10 keV band is observed to rise by a factor of 25 times as in the quiescent state, which was 4 Crab. Using the combined Swift XRT BAT observations, accretion flow properties during the 2017 outburst are studied from spectral fits with the Two-Component Advective Flow (TCAF) model fits file in XSPEC. We observed significant double Iron emission lines at around 6.5 keV in the spectra. Sharp type-C QPOs are also detected both in the raising as well as declining phases of the outburst. The monotonic evolution of the frequency of the dominating QPOs are studied with the propagating oscillatory shock (POS) model, to have estimation of the instantaneous locations, strength, velocity etc. of the propagating shock wave. The POS model fitted shock parameters are found to be consistent with the TCAF model fitted spectral (shock) parameters. We also estimate mass of the black hole to be 10 solar masses from our TCAF model fitted spectral analysis.

E1.6-0057-18 COMPLEX UV/OPTICAL EMISSION VARIABILITY IN 1H 0419-577

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We present a detailed study on the UV/optical variability and its connection to the X-ray emission using six XMM-Newton observations of a Seyfert 1 galaxy 1H 0419 - 577. All six observations consist of simultaneous coverage in the X-ray as well as in the UV/optical bands. The variable emission observed in all the bands appears correlated to each other. The UV/optical variations seem to follow the variations of X-ray band on time-scale of about three months, though, the estimation of such lag is not possible due to sparse data. The model-independent way using and indices also support the X-ray reprocessing when we compared with Grupe et al. 2010. Time-scale of variations is comparable to the size of broad line region. The broadband X-ray to UV/optical spectral modeling supports the X-ray reprocessing scenario due to the observed excess in the UV/optical bands over the best-fit model of X-ray plus disk model. Moreover, the spectral modeling in the X-ray band also favors the changes in the geometry of corona. Furthermore, optical emission seems delayed to the UV emission before the peak and in declining part, the optical emission appears more variable compared to the UV emission. Such variations also support the changes in the geometry of disk/corona.

E1.6-0058-18 CORRELATING TIME SERIES WITH SPECTRAL RESULTS OF RXTE DATA: OBSERVATIONAL EVIDENCES FOR FOUR DIFFERENT ACCRETION CLASSES

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We analyze RXTE/PCA data of black hole and neutron star sources. By analyzing independently the underlying time series (which helps in understanding their nonlinear variabilities) and spectral states, we try to correlate them. Depending on the variation in temporal classes, compact sources exhibit different nonlinear features. Sometimes they show low correlation/fractal dimension, but in other classes or intervals of time they exhibit stochastic nature. This is expected as the accretion flow is a nonlinear system involving magnetohydrodynamics. However, the more conventional way of addressing a compact source is the analysis of its spectral state. What is the connection of nonlinearity to the underlying spectral properties of the flow when the nonlinear properties are related to the associated transport mechanisms describing the geometry of the flow? The talk aims at addressing this question. Based on the connection between observed spectral and nonlinear (time series) properties of two X-ray binaries: GRS 1915+105 and Sco X-1, we attempt to diagnose the underlying accretion modes of the sources in terms of known accretion classes, namely, Keplerian disk, slim disk, advection dominated accretion flow (ADAF) and general advective accretion flow (GAAF). We explore the possible transition of the sources from one accretion mode to others with time. We further confirm that the accretion rate must play an important role in transition between these modes.

E1.6-0059-18 PROBING SUPERORBITAL VARIATIONS IN SMC X-1 WITH SUZAKU THROUGH SIMULTANEOUS TIMING AND SPECTRAL ANALYSIS

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SMC X-1 was observed with Suzaku ten times during different intensity states of the superorbital variation in 2011. We present a broadband (0.3-70 keV)spectral analysis and a detailed joint comparison of the spectra in these intensity states for the first time and interpret the results to map accretion geometry/mechanisms. The spectrum in all the states can be described by an absorbed powerlaw with a smoothened high energy cutoff. Additional black-body component and Fe K emission line is detected, apart from few other low energy emission lines. The spectral shape is also dependent on flux with the hard X-ray spectrum steepening with increasing flux. Through spectral analysis, we probe the nature of the absorber in the precessing warp of SMC X-1 that cause the superorbital modulation. We have carried out orbital corrections for Doppler shift in the HXD lightcurves and report detection of pulsations in hard X-rays in all but one observation. Detection of the X-ray pulses in the low state help us limit the contribution of the scattering/reprocessed component of the X-ray emission in the low state.

E1.6-0060-18 CLUMPY X-RAY OBSCURATION AND ECLIPSES: A NEW MODEL FOR AGN

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Most active galactic nuclei are seen through thick circum-nuclear gas and dust. Also, these column densities vary on time scales of days to years, indicating that the obscurer is made from clumps. We present the first clumpy obscurer model that reproduces eclipse events and column density distributions, and is also compliant with the CLUMPY optical/infrared model. We developed a new, open-source Monte Carlo code, XARS, to X-ray illuminate arbitrary geometries and present high S/N X-ray spectra for XSPEC. Preliminary fits show good agreement with NuSTAR spectral observations of some nearby Compton-thick AGN. However, an additional, Compton-thick inner wall is necessary. Physical interpretations of this new component, and its infrared counterpart, will be discussed.

E1.6-0061-18 INVESTIGATING STATE TRANSITION LUMINOSITIES OF BH X-RAY BINARIES IN THE OUTBURST DECAY

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We have performed a comprehensive spectral and timing analyses of black hole (BH) X-ray transients during outburst decay in order to obtain the distribution of state transition luminosities. Using the archival data of the Rossi X-ray Timing Explorer (RXTE), we have calculated the state transition luminosities for 12 BH sources in 19 different outbursts and for disk and power-law luminosities separately. Our results show a tight clustering in bolometric power-law luminosity around 1.85 ± 0.43 % Eddington (EDD) during transition to the hard state as well as disk black body luminosity around 4.92 ± 2.19 % EDD during a transition to hard-intermediate state. We also report a third clustering during index transition for power-law with a value and error of 2.85 ± 0.81 % EDD. We discuss the reasons for clustering and possible explanations for sources that show a transition luminosity below or above the general trend.

E1.6-0062-18 SPECTRAL VARIATIONS IN HERCULES X-1 AND RELATION TO STRUCTURE OF THE ACCRETION FLOW

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Spectra from Hercules X-1 (Her X-1) were extracted from Rossi X-ray Timing Explorer (RXTE) PCA observations taken over the lifetime of RXTE. This is the most extensive database of spectra for Her X-1, and the properties of this data set are described in Leahy and Igna (2011, ApJ, 736, 74). More recently this dataset was used to measure the X-ray corona in the binary system (Leahy, 2015, ApJ, 800, 32) and to detect atmospheric reflection of HZ Her in the low and short high states (Abdallah and Leahy, 2015, MNRAS, 453, 4222). The current work considers X-ray spectral variations in Her X-1. The variations are demonstrated to be consistent with the predicted changes in the reflected component from the inner disk edge in the model of Leahy (2002, MNRAS, 334, 847).

E1.6-0063-18 ACCRETION FLOW PROPERTIES OF MAXI J1543-564 DURING ITS INITIAL PHASE OF THE 2011 OUTBURST

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We study the initial phase of the 2011 outburst of the Galactic transient black hole candidate (BHC) MAXI J1543-564 using archival data of RXTE/PCA instruments. 2.5-25 keV PCA data are used to infer the spectral and temporal properties of this transient source during its very first outburst after discovery. We use additive table model fits file of the Two Component Advective Flow (TCAF) solution to study the accretion dynamics of the source during the initial phase of the outburst. Observed low frequency quasi-periodic oscillations (QPOs) showed monotonically increasing trend in frequency. We find that this evolution of the QPO frequencies fits well with the propagating oscillatory shock (POS) model to find instantaneous shock parameters. We see that POS model fitted extracted shock parameters, such as shock location, compression ratio, etc. roughly match with those from TCAF model. We estimate most accurately mass of the black hole from spectral fits with the TCAF solution and from QPO evolution fitted with the POS model.

Chakrabarti, S.K., Titarchuk, L.G., 1995, ApJ, 455, 623

Debnath, D., Chakrabarti, S.K., Mondal, S., 2014, MNRAS, 440, L121 Chatterjee, D., Debnath, D., Chakrabarti, S.K., et al. 2016, ApJ, 827, 88

E1.6-0064-18 ACCRETION - EJECTION MECHANISM OF SWIFT J1753.5-0127 WITH THE TCAF SOLUTION

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Galactic black hole Swift J1753.5-0127 was discovered 2005 June 30 by Swift/BAT. We studied 3-25 keV RXTE/PCA data for our spectral and timing analysis. The spectral analysis has been done with two components advective flow (TCAF) model fits file in XSPEC to extract physical accretion flow parameters such as, mass of the black hole, two types of accretion rates, and shock parameters, etc. From the nature of the evolution of spectral fitted parameters, we classified entire 2005 outburst of the source into two types of harder spectral states: hard (HS) and hard-intermediate (HIMS). According to TCAF solution unlike other models, TCAF model normalization must be constant for any particular source, since it is function of intrinsic source parameters: mass, distance and inclination angle. But during 2005 outburst of Swift J1753.5-0127, TCAF model normalization constant for all observations. Higher values of TCAF normalizations are required to fit 5 observed data in HIMS, which may be due to the jet activity, since jet also contributes in the X-rays. After introduction of a new method, we estimated jet contributions in X-rays. The jet is found to contribute maximum upto 32%. The correlation between radio and jet X-ray fluxes are studied to have knowledge of the jet properties. A weaker correlation between radio and jet X-ray fluxes during HIMS, indicates nature of jet may not be fully compact, but partially blobby, while during HS, it is fully compact. We have also estimated mass of the black hole $\sim 5.3 \pm 0.6$ M0.

Chakrabarti, S.K., Titarchuk, L.G., 1995, ApJ, 455, 623

Debnath, D., Chakrabarti, S.K., Mondal, S., 2014, MNRAS, 440, L121 Debnath, D., Jana, A., Chakrabarti, S.K., et al., 2017, ApJ, 850, 92

Jana, A., Chakrabarti, S. K., Debnath, D., 2017, ApJ, 850, 91

E1.6-0065-18 CAN NEUTRON STAR SPECTRUM ALSO BE EXPLAINED BY THE TCAF PARADIGM?

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Two-component advective flow (TCAF) solution provides a thorough understanding of spectral properties in terms of flow parameters for black hole candidates (BHCs), but a similar study about its suitability is yet to be done for neutron stars. From purely theoretical point of view, an accretion onto a neutron star is dissimilar only when the flow reaches very close to the compact objects. For a black hole, matter is advected in and for a neutron star flow has to stop at the surface and the energy must be released at the very spot. The shock at the surface of neutron star thus produces the normal boundary layer (NBOL) emitting a blackbody radiation. It is, therefore, no wonder that up to a great extent, the spectral properties of matter accreting on a neutron star, in the soft/hard X-ray band, are similar to those of stellar mass black holes. We propose that the TCAF solution should be applicable here if the NBOL component is added. We study spectral properties of TCAF around a neutron star. We compute the effects of thermal Comptonization of soft photons emitted from a Keplerian disc and the NBOL by the post-shock region of a sub-Keplerian flow, formed due to strong centrifugal barrier around the star. The shock location Xs is the inner edge of the Keplerian disc. We compute a series of realistic spectra assuming a set of temperature of the post-shock region TCE, the temperature of NBOL TNS and the shock location Xs. We find that the resultant spectrum becomes harder when the halo accretion rate ($\dot{m}$ h) and angle of observation is increased. The spectrum is controlled strongly by TNS due to its proximity to the Comptonizing cloud since photons emitted from the NBOL cool down the post-shock region very effectively. Finally, we compare our results with a few observed cases. We found that when the absorption of photons below 10 keV due to interstellar media is included, the spectra become realistic. Many of the weakly-magnetic accreting neutron stars, viz., Sco X-1, 4U 1705-44, 4U 1728-34, 4U 1820-30, GX 3+1, GX 340+0, 4U 1700-37,

have been observed and are being observed by numerous X-ray missions. These objects differ from each other in terms of the mass of the companion (LMXB/HMXB), the class they belong in (Z/atoll) and the frequency of their spectral activity (persistent/transient) and thus, can serve as a broad pool for the verification of our theoretical model. We plan on analyzing the spectral data from different satellites, especially in the hard X-rays beyond 50 keV, of such sources with our solution.

E1.6-0066-18 DOES THE GEOMETRY OF KEPERIAN DISK VARY DURING THE OUTBURSTS OF A TRANSIENT LMXB?

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The central object in a low-mass X-ray binary (LMXB) accretes matter from its companion star mainly via Roche lobe overflow; the Keplerian disk, having high angular momentum and high viscosity becomes instrumental in overall accretion. In the same transient LMXB, the accumulation radius, from where matter rushes towards the black hole due to thermal-viscous instability, may be different in different outbursts. Using RXTE/ASM long-term data and employing a simple timing analysis, we examine more than a dozen outbursts in transient LMXBs, exhibiting either multiple outbursts (GX 339-4 and H 1743-322) or sporadic outbursts (e.g. 4U 1543-47, etc.). It is found that the Keplerian disk indeed varies in its size from an outburst to another; this, in turn, dictates the brightness of outbursts. Both canonical and anomalous/failed outbursts can be distinguished from our results. Outbursts, in general, are shown to fall into two types, based on four features observed by us.

E1.6-0067-18 EVIDENCE OF TWO COMPONENTS IN ACCRETION FLOW FROM TIME LAG PROPERTIES: LONG-TERM RXTE/ASM DATA ANALYSIS OF SEVERAL COMPACT OBJECTS

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Long-term RXTE/ASM X-ray data of several Galactic black holes (persistent, class-variable, and transient) are analyzed. The results of this analysis show the existence of two components in accretion flow in both low-mass and high-mass X-ray binaries (LMXBs HMXBs). Large disks with long viscous timescales in the accreting matter with high angular momentum are prevalent in LMXBs due to processes like Roche lobe overflow, while small disks with little viscous delays are observed in HMXBs primarily because of wind accretion. Because of two viscous time scales in the two components, there would be significant lag between the timesof-arrival of these two components. A large Keplerian disk in LMXB should cause a larger time lag as compared to that in HMXB. To detect such a lag using the ASM data having limited energy resolution, we introduce an index (Θ), which is a proxy of the usual (i) hardness ratio (HR), (ii) photon index, (iii) spectral index (α), and (iv) Comptonization efficiency (CE) defined to be the ratio of the number of hard photons to the number of soft photons injected into the Compton cloud at each instant of time. Temporal variation of Θ also reveals spectral state transitions. Classic method of cross-correlation between the two photon fluxes may not necessarily reveal the aforesaid lag. But when Θ, being susceptible to changes in the hard flux, is considered as a reference, a significant time lag is observed between the two fluxes in LMXBs. However, this lag is negligible in HMXBs. We therefore establish that there are indeed two components in the accretion onto a black hole.

E1.6-0068-18 LONG TERM X-RAY/RADIO MONITORING OF GALACTIC MICRO-QUASAR CYGNUS X-1

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The Galactic micro-quasar Cygnus X-1 is known to show variability of different time-scale. We are reporting long-term monitoring of the source, covering more than twenty years of time-span, using The Rossi X-ray Timing Explorer (RXTE) and Jansky Very Large Array (JVLA). We will discuss jet-disk relation of the system and will comment on possible correlation/anti-correlation between X-ray and radio emission.

E1.6-0069-18 EVOLUTION OF ACCRETION DISC GEOMETRY IN GRS 1915+105 DURING CHI STATE

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The evolution of the low frequency quasi-periodic oscillations (LFQPOs) and associated time lag in out-bursting black hole sources as function of time can be explained by variation of the Compton cloud size. We attempted a similar study of a persistently variable source, GRS 1915+105 during its two different χ state. We study the evolution of LFQPOs, time lag and Comptonizing efficiency (CE) with propagatory oscillating shock (POS) solution. We find a systematic drifting of Comptonizing region with a constant velocity for the both χ state observations. These propagation is similar to what we observe in XTE J1550-564 during 1998 outburst. The time lag varies in a similar way as the size of the Compton cloud. Most interestingly, in both the cases, the lag switches sign (hard lag to the soft lag) at a QPO frequency of 2.3 - 2.5 Hz irrespective of the energy of photons. We also find, at very low frequencies > 1 Hz, the Comptonizing efficiency (CE) increases with frequency and at higher frequency the tend is opposite and the time lag is always positive at all energies when CE is larger than 0.85% for both the sources. We explain the accretion dynamics with possible accretion geometry.

E1.6-0070-18 DO JETS INDUCE SOFT LAGS OF GALACTIC BLACK HOLE CANDIDATES AND AGNS?

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Time and phase lags of Galactic black hole candidates and AGNs are becoming more and more important in the last few years. Many of the intriguing features of time lag properties are discovered in recent years. However, a true nature of lag variation remains complicated mostly because of the nonlinear physical mechanisms that are originating the lag of the photons which are coming from the accretion disks. The hard lag contribution is found to be originated from the inverse Comptonization and disk reflection mechanism. But, the exact reason for soft lags are yet to be unveiled. We draw correlations between the radio intensities of outbursting cases where soft lags are found. Finally, we correspond this result with the measured linear polarization variation in radio band of such candidates in precise time domain of hard to soft lag inversion.

E1.6-0071-18 MULTI-FREQUENCY OBSERVATION OF HIGH MASS X-RAY BINARY CYGNUS X-3 DURING FLARES

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We studied the multi-frequency properties of the Galactic high mass X-ray binary Cygnus X-3 during various flaring activities using The Rossi X-ray Timing Explorer (RXTE), the Giant Metrewave Radio Telescope (GMRT), Jansky Very Large Array (JVLA) etc. The flare of 2006 May-June was one of the largest flare in the history of the source which is thoroughly discussed. We also observed few large flares of this source between 2007 and 2009. We commented on correlation and lag between X-ray and radio emissions during flares. We construct the radio spectrum of the source in the rising and fading phase of flares using GMRT, JVLA and published results using RATAN. We clearly see that the turn-over frequency is shifting towards lower frequencies as the flares evolve gradually. The two point spectral index between 614 MHz and 235 MHz varies from positive (optically thick) and negative (optically thin) values which is consistent with the synchrotron self absorption model. We calculated some physical parameters of the source such as the size of emitting region using the synchrotron self absorption model. The size of the emitting region expands with the flare. We estimate the velocity of the expansion of the blob in the non-relativistic range from the expansion of the size of emitting region.

E1.6-0072-18 HIGHER ORDER STABILITY ANALYSIS FOR ASTROPHYSICAL ACCRETION PROCESSES

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We have done nth order perturbation analysis of the Navier-Stokes equation. Green's function is used to solve the n-th order velocity perturbation equation for accretion disc to deduct a stability criteria. Considering a thin disc, Shaker-Sunyeeb turbulent viscosity prescription is used for viscous terms. A local velocity stability criterion is proposed for a thin disc using Lynden and Bell's coordinate transformation method. Also, we used global boundary condition for accretion disc for finding boundary instabilities.

E1.6-0073-18 ROLE OF VISCOSITY AND COOLING ON THE ORIGIN OF SPECTRAL AND TIMING PROPERTIES: OBSERVATIONAL EVIDENCES

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Low angular momentum (sub-Keplerian) and low viscosity flow produce a standing shock (boundary of the Compton cloud) during the outburst of a transient black hole candidate. As the day progresses, cooling increases and the average shock location moves closer to the black hole to satisfy the Rankine-Hugoniot condition during the rising phase. Because of resonance between cooling time scale and infall time scale, the shock oscillates, producing low frequency Quasi Periodic Oscillations (QPOs) of monotonically increasing frequency. Exactly opposite situation prevails during the declining phase. The geometry of the Compton cloud also dictates the spectral states. Thus the QPOs, the spectral states, and the formation of the shock itself are linked to viscosity of the sub-Keplerian flow. We analyze a few transient sources and calculate their Keplerian (αK) and sub-Keplerian (αSK) component viscosity parameters during the rising and the declining phases of the outburst. We see that the viscosity parameter changes monotonically in a similar way for all the outbursting candidates during its evolution. We estimate the range of viscosity parameter which is required to trigger different spectral states. This is important, since some sources do not reach the soft or even the soft intermediate states. We shed light on this very important correlation. From our study, we infer that the typical range of αSK parameter of the sub-Keplerian flow is within 0.1 for the transient sources. Most importantly our calculated αK of these sources is well above αSK, which makes the analysis more consistent.

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E1.6-0074-18 VARIABILITY PROPERTIES OF TWO SEYFERT 1 ACTIVE GALACTIC NUCLEI MRK 493 AND ZW 229.015

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From the simultaneous X-ray and UV observations of the narrow-line Seyfert 1 AGNs Mrk 493 and Zw 229.015, we study their variability properties in appreciable depth. The UV/X-ray data of Mrk 493 show remarkable correlation between the variability in both bands. Crosscorrlation analysis reveal that variations in the UV emissionn lead the X-ray emission and the measured time lag is consistent with the Comptonizastion scenario where disc UV seed photons are Compton-upscattered in the corona into the observed X-rays. Although the longterm Swift UV/X-ray emission of Zw 229.015 does not show a clear lead/lag, the source appear to be brighter in the UV when softer in X-rays. Both sources additionally show soft X-ray excess in their energy spectra which are well fitted by both the thermal comptonization and reflection models. Moreso, our spectro-temporal analyses supports the existence of a compact corona with radius r~ 20Rg in AGNs

E1.6-0075-18 A COMPARISON STUDY OF LFQPOS IN NEUTRON-STAR AND BLACKHOLE LOW-MASS X-RAY BINARIES

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We studied comparatively the properties of low-frequency quasi-periodic oscillations in a sample of fourteen black-hole and four neutron-star low mass X-ray binaries observed by the Rossi X-ray Timing Explorer satellite. We examined the similarities between these two classes of systems in terms of the FWHM - frequency correlation of QPO fundamentals and harmonics. We find that the fundamentals and the harmonics of black holes are consistent with a frequency modulation, while the harmonics of neutron star systems suggests amplitude modulation. We also studied all the sources from our sample in the aperiodic variability amplitude - frequency diagrams. We find that systems with lower source luminosity are likely to have a higher total variability amplitude.

RESEARCH IN ASTROPHYSICS FROM SPACE (E)

NOVE ERUPTIONS, CATACLYMMIC VARIABLES AND RELATED SYSTEMS: OBSERVATIONAL VS. THEORETICAL CHALLENGES IN THE 2020 ERA (E1.7)

E1.7-0001-18 THE DISK-WIND-JET CONNECTION IN ACCRETING WHITE DWARFS AND RELATED OBJECTS

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I will review our current understanding of disk winds and radio jets in accreting white dwarfs. I will focus particularly on the phenomenology of these outflows compared to those observed in neutron star and black hole X-ray binaries. However, I will also discuss the physical mechanisms that may drive these different forms of mass loss. Finally, I will explore the impact of such outflows on the underlying accreting system itself, on our observations of it, and on its environment.

E1.7-0002-18 THE DISK INSTABILITY MODEL FOR CATACLYSMIC VARIABLES AND XRAY BINARIES

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The outbursts of dwarf novae cataclysmic variables (CVs) and low-mass X-ray binaries (XRBs) are thought to be due to a thermal-viscous instability of the accretion disk. The instability arises when hydrogen ionisation causes drastic changes in the opacity and thermodynamical properties of the disk. A fundamental prediction of this model is that, for a given masstransfer rate, systems are stable or unstable according to the size of the disk, mostly set by the orbital period. I will review how this compares with the observational data, focusing on our recent analysis of a large sample of CVs. I will conclude on the prospects for theoretical and observational progress in understanding the outbursts of CVs and XRBs through the disk instability model.

E1.7-0003-18 TURBULENT TRANSPORT OF ANGULAR MOMENTUM IN MAGNETIZED DISKS OF DWARF NOVAE

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The eruptive cycles of dwarf novae (DNe) are thought to be due to a thermal-viscous instability in the accretion disk surrounding the white dwarf. This model has long been known to imply enhanced angular momentum transport in the accretion disk during outburst. This is measured by the stress to pressure ratio α, with α 0.1 required in outburst compared to α 0.01 in quiescence. Such an enhancement in α has been observed in simulations of turbulent transport driven by the magneto-rotational instability (MRI) when convection is present, without requiring a net magnetic flux (Hirose et al. 2014). We will compare these results to our simulations of vertically stratified, radiative, shearing boxes with the thermodynamics and opacities appropriate to dwarf novae (Scepi et al. 2018). We will discuss the impact of Ohmic dissipation on transport in the quiescent state of DNe, which is poorly ionized and likely to be MRI-stable. Finally, we will present our recent work on the impact of a large scale magnetic field on the enhancement of α and the resistive quenching of the MRI. Ultimately, these results will help us build a disk instability model (DIM) taking into account the effects of magnetic fields.

E1.7-0004-18 SUPERHUMPS LINKED TO X-RAY EMISSION. THE SUPEROUTBURSTS OF WZ SGE-TYPE STARS.

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Only a handful of WZ Sge-type dwarf novae have been observed in X-rays, and until recently GW Lib was the only binary of this type with complete coverage of an X-ray light curve throughout a superoutburst. Here, we present extensive Swift X-ray observations of two other such systems to understand the extent to which the unexpected properties of GW Lib are common to the WZ Sge class. We analysed more than 4 years of Swift X-ray observations of the 2013 superoutburst, subsequent decline and quiescence of SSS J122221.7-311525, and Swift X-ray observations of the 2015 superoutburst of ASASSN-15po. We analysed the X-ray light curves and compared them with the behaviour of superhumps which were detected in the optical light curves. The results were compared with the properties of GW Lib. We found that in contrast to most of ordinary dwarf novae, SSS J122221.7-311525 and other WZ Sge-type stars showed an increase of their X-ray luminosity during an outburst and a very extended postoutburst decline lasting at least several hundred days. We have showed for the first time that the X-ray flux from SSS J122221.7-311525, GW Lib, ASASSN-15po, and possibly other WZ Sge-type systems is linked to their simultaneous superhump behaviour, thus linking the inner disc properties to those of the outer (possible whole) disc. This result suggests that models for accretion discs in high mass ratio accreting binaries are currently incomplete. The very long decline to X-ray quiescence is also in strong contrast to the expectation of low viscosity in the disc after outburst. We propose that the disc precession is a cause of an enhanced viscosity and an increased temperature of the inner disc, stimulating thus a matter drift through the disc during the decline stage of superoutbursts.

E1.7-0005-18 INSIGHTS FROM MULTI-WAVELENGTH OBSERVATIONS DURING HIGH AND LOW ACCRETION STATES OF NON-MAGNETIC CVS

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Close binaries containing a white dwarf accreting from a disk that receives material from a late stellar companion show an interesting variety of behavior that depends on their accretion rate and the changes in this rate. The highest accretion rates are evident during the bright states of novalikes, as well as the superoutbursts of the shortest period dwarf novae, followed by normal outbursts and the standstills of Z Cam systems. While the normal outbursts and superoutbursts of dwarf novae can be understood from the standpoint of disk and tidal instabilities, the changes in rates in novalikes when they enter low brightness states and the cause of extremely high rates for the systems between 3-4 hrs (SW Sex) remain elusive. The differences found from X-ray, UV and optical observations between these high and low states will be summarized as well as the prospects for increased understanding from the anticipated long term extensive coverage that will be provided by LSST and its resulting followup.

E1.7-0006-18 ACCRETION-INDUCED VARIABILITY ACROSS ALL SCALES

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Accreting objects are intrinsically variable on a wide range of timescales and wavelengths. This variability is mostly attributed to the accretion disks themselves, which transport material inwards through complex viscous processes. I will give a brief review of aperiodic variability (flickering) in accreting compact objects, with special emphasis on observations of accreting white dwarfs over the last decade, and present new observational results linking accreting systems across a wide range of scales, masses, and magnetic field strengths.

E1.7-0007-18 GW LIBRAE: A UNIQUE LABORATORY FOR PULSATIONS IN AN ACCRETING WHITE DWARF

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Non-radial pulsations in accreting white dwarf offer insight into the excitation of pulsation modes in atmospheres with mixed compositions of hydrogen, helium, and metals, and the response of these modes to changes in the white dwarf temperature due to accretion outbursts.

The dwarf nova, GW Librae stands out by having a well-established observational record of three independent pulsation modes present in the optical and ultraviolet which disappeared when the white dwarf temperature rose dramatically following its 2007 superoutburst. Our analysis of Hubble Space Telescope (HST) ultraviolet spectroscopy taken in 2002, 2010, and 2011, showed that pulsations produce variations in the white dwarf effective temperature as predicted by theory. However, in our 2013 May HST/Cosmic Origin Spectrograph (COS) ultraviolet observations, GW Lib, besides showing variability at 275 s, which is close to the post-outburst pulsations detected with HST in 2010 and 2011, the white dwarf exhibited a large-amplitude variability on an 4.4 h time-scale (Toloza et al. 2016, MNRAS, 459, 3929T). This long-term variability is intermittent and had been detected previously in the optical. The first observations of this phenomenon in the ultraviolet allowed us to demonstrated that it is caused by an increase of the temperature of a region covering up to 30 percent of the visible white dwarf surface. However our study could not unambiguously identify the nature that causes this variability. Two viable hypotheses are a short-lived accretion episode or non-radial pulsations on a rapidly rotating star.

To further investigate the complex behaviour of the white dwarf in GW Lib, we organised in 2017 an intensive simultaneous multi-wavelength campaign using Kepler/K2, HST /COS, and Swift. K2 observed GW Lib during Campaign 15 in short-cadence mode (60sec) for 80 consecutive days, and the data is soon to be released. The K2 observations were complemented on August and September 2017 with multiple Swift X-ray and with HST /COS. Our

preliminary analysis of the COS ultraviolet light curve shows again the presence of the long period modulation, superimposed by the short period pulsations.

Here, in addition to the published work, we will present the analysis of this new multiwavelength data set, which will provide the most detailed insight into the pulsations of the accreting white dwarf in GW Lib ever obtained.

E1.7-0008-18 V341 ARA – THE NOVA-LIKE VARIABLE THAT HAS IT ALL

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Non-magnetic nova-likes are cataclysmic variables with mass-transfer rates high enough to keep the accretion disk in a permanent high state. These systems are therefore great test beds for our understanding of steady-state accretion disks.

V341 Arae is an 11th magnitude blue object embedded in a large (8′ x 10′) emission line nebula. [O III] images suggest a parabolic bow-shock shape for the nebula, with V341 near the apex. The ionized mass of the nebula is very low compared to the canonical PN, though is inline with the spected form an old nova shell. The source was long misclassified as a Cepheid variable and first revealed as a nova-like CV by Samus, Pastukhova Durlevich (2007) and Frew (2008) independently. Even since then, it has remained surprisingly unnoticed by the CV community. The binary nature of the source is suggested by several strands of evidence: its blue optical colours, its X-ray luminosity and hardness, the presence of short time-scale flickering, and its optical spectrum (which contains broad absorption lines with emission cores). Remarkably, even though V341 Ara is one of the brightest novalikes known, even its orbital period has not yet been determined.

Here, we present results from a spectroscopic campaign we have been carrying out with the SAAO 1.9m telescope, in order to constrain the orbital period of the system. This is supplemented by archival data obtained with the CTIO 1.5m and new observations gather with SALT. We also present the results from long-term photometric light curves obtained by the ASAS-SN and KELT surveys, which reveal long-term (10 day) super-orbital (quasi-) periodicities.

E1.7-0009-18 ACCRETION IN MAGNETIC CVS FROM AN OBSERVATIONAL PERSPECTIVE

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The census of XMM-Newton observations of polars will be presented. The spectral evolution through high and low states, the physical structure of the accretion region, and the spectral energy distribution of the accretion process will be discussed based on the large body of archival data and detailed multi-wavelength campaigns of key objects. Gaia parallaxes will be used to derive luminosities, the first time for a large subset of MCVs and update the X-ray luminosity function.

An outlook is given on the expected results from eROSITA all-sky surveys beginning 2019 and detailed X-ray spectroscopic observations with ATHENA.

E1.7-0010-18 HIGH TIME RESOLUTION VARIABILITY, OPTICAL PHOTOMETRY AND POLARIMETRY STUDIES OF MAGNETIC CVS

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Magnetic cataclysmic variables (mCVs) present a host of opportunities for time-resolved studies of accretion dominated by magnetic fields. Since their initial discovery by virtue of X-ray emission, they have been subject to multi-wavelength studies which have continued to reveal new insights. Here we review the role of high time resolution optical observations of mCVs and discuss how these have impacted on our understanding of the accretion processes at work. Recent work by us has included the search for observations of QPOs, which would appear to be rarer than initially thought. Polarimetry has always been a crucial tool to unlock the nature of the accreting magnetic white dwarfs in these systems and recent results in this area will also be presented.

E1.7-0011-18 MEASURING THE MASSES OF INTERMEDIATE POLARS WITH NUSTAR

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The X-ray spectra of intermediate polars can be modelled to give a direct measurement of white dwarf mass. However, as the characteristic temperature of the standing shock located above the surface of the white dwarf is typically > 10 keV, we require telescopes capable of detecting hard X-rays. I will first discuss the fitting of accretion models to NuSTAR spectra of three intermediate polars; V709 Cas, NY Lup and V1223 Sgr in order to determine their masses. From fits to their 3–78 keV spectra, we find masses of 0.88+0.05, 1.16+0.04 and 0.75 ± 0.02 M0 for V709

Cas, NY Lup and V1223 Sgr, respectively. Our measurements are generally in agreement with those determined by previous surveys of intermediate polars, but with typically a factor 2 smaller uncertainties. This work has paved the way for an approved NuSTAR Legacy Survey of white dwarf masses in magnetic CVs, utilizing 1Ms of time to observe 25 magnetic CVs. The survey aims to constrain the mass distribution of magnetic white dwarfs in our Galaxy, which has important implications for binary evolution models and the production of type Ia supernovae. Finally, I will present the first results from the survey, which began observations in November 2017.

E1.7-0012-18 WHITE DWARF MASSES IN INTERMEDIATE POLARS

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We present results of white dwarf (WD) mass measurements in a sample of intermediate polars (IPs) observed by Suzaku and NuSTAR. A novel two-parameter grid of accretion-column spectra accounting for the finite magnetosphere size was used for this aim. The grid parameters are the WD mass, ranging between 0.3 - 1.4 solar masses, and the normalized magnetospheric radius Rrmm/RrmW D ranging between 1.5 - 1000. The fit to the hard X-ray spectrum of some IPs gives a strip on the WD mass - Rrmm plane, and a lower limit of the WD mass could be found assuming that the magnetospheric radius equals the radius of corotation. Assuming additionally that the break frequency in the power spectra of IPs corresponds to the Keplerian frequency at the magnetosphere allows then to estimate the WD mass and the magnetospheric radius simultaneously. This new method was tested using EX Hya, and allowed to obtain the WD mass in GK Per. We also showed that the magnetospheric radius in that IP increased from 2.8pm0.2 to sim4.3 RrmW D when its luminosity decreased from the maximum to quiescence during the outburst. This method was used for all available IPs observed by Suzaku and NuSTAR. Obtained WD masses are compared with masses published by other authors including those obtained with optical methods.

E1.7-0013-18 PROPERTIES OF HARD X-RAY BRIGHT POLARS

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Polars are a subclass of magnetic cataclysmic variables (CVs) in which a strongly magnetic white dwarf accretes matter from a late-type, Roche-lobe filling mass donor. They are usually soft X-ray bright and hard X-ray dim, due to either buried shocks or strong cyclotron cooling, depending on system parameters. Indeed, the majority of the 100 currently-known polars were detected in the ROSAT all-sky survey. However, a small subset of polars have been detected as bright hard X-ray sources in INTEGRAL and Swift BAT surveys, and they make up a small, but increasingly non-negligible, fraction of INTEGRAL and BAT-detected CVs. I will present the current sample of polars detected in the BAT 105-month survey, as well as results of pointed X-ray observations of a subset of them. I will then summarize the current status towards understanding why a subset of polars are hard X-ray bright.

E1.7-0014-18 X-RAY PROPERTIES OF MAGNETIC CATACLYSMIC VARIABLES

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Among hard X-ray galactic sources detected by the SWIFT and INTEGRAL surveys, those discovered as accreting white dwarf binaries have surprisingly boosted in number, representing 20% of the galactic sample. The majority are identified as magnetic Cataclysmic Variables (mCVs) of the Intermediate Polar type suggesting this subclass as an important costituent of galactic population of X-ray sources. We will discuss the X-ray emission properties as observed with our-ongoing XMM-Newton programme of newly discovered sources that enlarged sample almost by a factor of two, identifying commonalities and outliers.

E1.7-0015-18 RADIO OBSERVATIONS OF MAGNETIC CATACLYSMIC VARIABLES

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The Jansky Very Large Array was used to observe 121 magnetic cataclysmic variables (MCVs). We report radio detections of 18 stars. Thirteen are new radio sources, increasing the number of MCVs that are radio sources by more than twofold, from 8 to 21. Most detections are at 8.7 GHz (X-band) with a lesser number at 5.4 and 21.1 GHz (Cand K-bands). With the exception of AE Aqr whose flux density is typically > 5 mJy, the flux densities are in the range of 24-780 uJy. Thirteen of the detections show highly circularly polarized emission, which is characteristic of electron-cyclotron maser emission. The maser emission most likely occurs as a result of magnetic reconnection events near the surface of the red dwarf. Kbanddetections of such emission imply localized surfacemagnetic fields of >4 kG. The data suggest that MCVscould possibly be divided intotwo classes of radio emitters: those dominated by weakly polarizedgyrosynchrotron emission and those byhighly polarizedelectron-cyclotron maser emission.

E1.7-0016-18 MHD SIMULATION OF ACCRETION CURTAINS IN MAGNETIC CVS

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A three-dimensional numerical model for accretion in the magnetosphere of a white dwarf in a magnetic cataclysmic variable is developed. The model is based on the equations of modified MHD, where a strong external magnetic field acts as an efficient fluid with which the plasma interacts. The suitability of the model is confirmed by modeling the accretion in a typical intermediate polar EX Hya. Results of simulations show that the accretion in EX Hya proceeds via accretion columns, which are not closed and have curtain-like shapes. These columns are very thin and the hot spots cover a small fraction of the accretor surface. The numerical results are confirmed by comparison with available EX Hya system observations.

E1.7-0017-18 GROND OBSERVATIONS OF MAGNETIC CVS

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We present the first results from a large project to obtain simultaneous optical and IR data of magnetic cataclysmic variables (mCVs) in preparation of observations that will be obtained with current and future X-ray observatories. The main goal is to characterize the IR light curves of a large sample of magnetic CVs homogeneously to determine system parameters as well as improve the ephemerides for these objects. With these measurements we would like to improve our knowledge of the space density of magnetic cataclysmic variables (mCVs). Until now it has been difficult bring the results from theoretical predictions and measurements together due selection effects (the main difficulty being flux limitation). To extend our sample to include fainter mCVs we are currently obtaining g'r'i'z'JHK measurements using the GROND 7 channel imaging instrument mounted on the 2.2m telescope at La Silla, Chile. From the light curves obtained with GROND we can determine the distance to objects by using the relationship between the distance and K-band surface brightness of the secondary star.

E1.7-0018-18 NEW RADIAL VELOCITY OBSERVATIONS OF V630 CAS: A 2.5 DAY ORBITAL PERIOD CATACLYSMIC VARIABLE

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We present new radial velocity observations of this difficult-to-observe object due to its long period and to its alias-day synchronization. New semi amplitude of both components are derived as well as an an estimation of the mass ratio and the most probable inclination angle. Since the secondary is highly visible, we discuss its evolutionary state.

E1.7-0019-18 A WHITE DWARF DISPLAYING MAGNETICALLY GATED ACCRETION BURSTS

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The accreting white dwarf MV Lyrae spends most of its time in an optically bright luminosity state but occasionally drops by more than a factor of 250 for short durations (weeks to months), sometimes fading to V 18. Here we present Kepler observations of MV Lyrae during a lowstate, displaying quasi-regular bursts of about 30minutes duration roughly every 2hours. The timescale and amplitude of these bursts indicate the presence of an unstable, magnetically regulated accretion mode, which in turn implies the existence of magnetically gated accretion. We are able to infer both the white dwarf magnetic field strength as well as the inner disk truncation radius throughout the magnetically accretion bursts. Additionally, to confirming a new accretion mode for white dwarfs, our results extend the connections between accretion onto white dwarfs, young stellar objects and neutron stars, for which similar magnetically gated accretion cycles have been identified.

E1.7-0020-18 PHASE-RESOLVED SPECTROSCOPY AND PHOTOMETRY OF THE ECLIPSING POLAR, UZ FORNACIS

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We present phase-resolved spectroscopy and high-speed photometry of the eclipsing polar, UZ Fornacis. The blue continuum of UZ For is dominated by singleand/or double-peaked emission from the HeII, HeI and the Balmer lines. The red spectrum shows weak emission and absorption from NaI doublet at 8183 Å and 8194 Å and strong emission from CaII lines at 8498 Å and 8542 Å. Doppler tomography, using the inside-out technique based on the fast maximum entropy, of the strongest features reveal the presence of emission from the threading region, the ballistic and magnetic confined accretion stream as well as the irradiated face of the secondary star. We have obtained 31 new mid-eclipse times of UZ For to test the two-planet model proposed to explain the variations in its eclipse times. The new data agree with the predicted model but requires the outer planet to be highly eccentric. The orbital periods for the inner and outer planets are 5.17(2) and 14.76(3) years, respectively.

E1.7-0021-18 DISCUSSION I: CV OUTFLOWS, ACCRETION PHYSICS, DISK STRUCTURE, AND OBSERVATIONAL TOOLS

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Chair: K. Mukai, Co-Chairs: D. De Martino, D. Bisikalo

E1.7-0022-18 CV OUTFLOWS, ACCRETION PHYSICS, DISK STRUCTURE, AND OBSERVATIONAL TOOLS–CONTINUED

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This is the continuation of the discussion section, Discussion I

E1.7-0023-18 HYDRODYNAMIC SIMULATIONS OF CLASSICAL NOVAE OUTBURSTS AND THEIR EVOLUTION TO SUPERNOVA IA EXPLOSIONS

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We have continued our studies of accretion onto white dwarfs by following the evolution of thermonuclear runaways on Carbon Oxygen (CO) white dwarfs. We have varied the mass of the white dwarf and the composition of the accreted material but chosen to keep the mass accretion rate at 2 10–10M0 yr–1 to obtain the largest amount of accreted material possible with rates near to those observed. We assume either 25% core material or 50% core material has been mixed into the accreting material prior to the explosion. We use our 1D, Lagrangian, hydrodynamic code: NOVA. We will report on the results of these simulations and compare the ejecta abundances to those measured in pre-solar grains that are thought to arise from classical nova explosions. We find that in all cases and for all white dwarf masses that less mass is ejected than accreted and, therefore, the white dwarf is growing in mass as a result of the accretion and resulting explosion. We also find that these simulations are producing a significant amount of 7Li and, in addition, the best agreement with both nova explosions and pre-solar grains are with those simulations that assume 25% core material is mixed into the accreting material. This work was supported in part by NASA under the Astrophysics Theory Program grant 14- ATP14-0007 and the U.S. DOE under Contract No. DE-FG02- 97ER41041. SS acknowledges partial support from NASA, NSF, and HST grants to ASU. WRH is supported by the U.S. Department of Energy, Office of Nuclear Physics. Our results benefitted from collaborations and/or information exchange within NASA's Nexus for Exoplanet System Science (NExSS) research coordination network sponsored by NASA's Science Mission Directorate.

E1.7-0024-18 AT THE FOREFRONT OF MULTI-OUTBURST MODELING OF NOVA EXPLOSIONS

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Most nova evolution simulations consider several consecutive outbursts for a white dwarf (WD) of given mass and temperature and for a constant accretion rate. The results show that the nova characteristics depend strongly both on the WD mass and on the accretion rate. Although these calculations have been successful in reproducing the wide ranges of observed nova properties, there remain open questions that can only be answered by long term multi-cycle calculations that account for the evolution of the WD as well as the evolution of the binary system, which determines the rate of mass transfer.

We have followed the evolution of WDs of various initial masses through long series (thousands to tens of thousands) of nova cycles and we will show the gradual changes in mass and in internal structure that occur, as well as the resulting changes in the nature of nova outbursts. We consider both hydrogen and helium accretion and address the consequences of helium flashes. We show the circumstances under which WDs can grow up to the Chandrasekhar mass, to become progenitors of type Ia Supernovae (SN). We also consider the evolution of the companion and the change in separation of the binary system, which leads to a variable mass transfer rate. We account for the various mechanisms that affect the binary separation, including the illumination of the companion by eruptions (in parametrized form). These results may serve to characterize observed nova systems, predict future eruptions and detect potential progenitors of type Ia SN.

E1.7-0025-18 NOVA OUTBURSTS AND THE MESA MODELS

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For over 45 years, 1D stellar models have been used to simulate classical nova outbursts. These models continue to be useful, but the tools to model them have evolved and multiplied. This has given rise to a rich variety of predictions full of emergent consensus and intriguing discrepancies. A newcomer to the field is the open source Modules for Experiments in Stellar Astrophysics, or MESA. The star module in MESA is a general purpose stellar evolution code for evolving spherically-symmetric objects from planets to core collapse supernovae to accreting neutron stars. In this talk I present MESA models of accreting white dwarfs from accumulation through the thermonuclear runaway, outburst, and the post-outburst supersoft phase. I'll call special attention to points of uncertainty arising from different physical assumptions and areas of deficiency in the models' abilities to reproduce observations. I'll conclude with a broad outline of what is needed to enhance 1D models to extend their utility into the 2020 era where highquality multi-wavelength data will become the norm for nova observations.

E1.7-0026-18 MULTI-WAVELENGTH STUDIES OF NOVAE: THERMAL EMISSION

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The rapid response capabilities of the Swift satellite, together with the daily planning of its observing schedule, make it an ideal mission for following novae in the X-ray and UV bands, particularly during their early phases of rapid evolution and throughout the super-soft source interval. A number of both classical and recurrent novae have been extensively monitored by Swift throughout their super-soft phase and later decline. We report results from these observations, including the high-amplitude flux variation often see at the start of the super-soft emission, the differing relationships between the X-ray and UV variability, and the spectral evolution seen in the X-ray band.

E1.7-0027-18 SWIFT-XRT OBSERVATIONS OF SHORT PERIOD OSCILLATIONS SEEN IN THE SUPER SOFT SOURCE EMISSION FROM CLASSICAL AND RECURRENT NOVAE

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We report short timescale, soft X-ray flux modulations seen by the Neil Gehrels Swift Observatory X-ray Telescope (XRT) during the super soft source (SSS) emission phase from novae. A periodogram analysis revealed oscillations were visible in the 0.3 10.0 keV XRT light curves obtained from RS Oph (period, P=35.0 s), KT Eri (P=34.9 s), V339 Del (P=54.0 s), and V5668 Sgr (P=69.7 s), with fractional rms variabilities ranging from 1 – 8 per cent.

During day 32 59 of the RS Oph outburst, the oscillation central frequency appeared quite variable, ranging from 26.2 31.1 mHz, caused by a lower coherence at this time. However, after day 50 the oscillation became more coherent, with a frequency that slowly increased from 28.3 28.9 mHz over 9 days, before the trend reversed. The oscillation frequency was less variable in KT Eri and V339 Del. No other correlations, such as between the oscillation frequency or amplitude with source intensity, were apparent.

A wavelet analysis of the variability seen in RS Oph, KT Eri and V339 Del revealed the oscillations were sometimes visible for entire XRT snapshots lasting 1.0 1.5 ks, yet on other occasions, they were detected for only 120 s (i.e. 2 4 cycles). The modulation fractional amplitude was variable, occasionally reaching values of 15 20 per cent for a few cycles. During times when the coherence was low, the oscillation phase was seen to jump by 0.4 0.6 cycles in RS Oph, then remain stable for 10 cycles. KT Eri showed smaller phase jumps of 0.2 cycles.

We detect a significant spectral variation through the 35 s oscillation seen in RS Oph, with the spectrum becoming harder at the time of the modulation maximum. Fits to the oscillation maximum and minima spectra suggest the increased flux between 0.6 0.75 keV in the former is caused by a 25 per cent reduction in the oxygen column density at this phase.

We discuss the possible origins behind the oscillations.

E1.7-0028-18 THE COMPLICATIONS OF LEARNING FROM SUPER SOFT SOURCE XRAY SPECTRA

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Super-Soft-Sources (SSS) are emitted by hot white dwarfs hosting nuclear burning on their surface. Observations of SSS promise to reveal information about the central nuclear burning engine that keeps the whole system alive. Important parameters are the effective temperature, chemical composition of material before it is ejected, and mass of the underlying white dwarf. CCD spectra of SSS can in many cases already be reproduced by a blackbody model yielding an effective temperature and radius. However, without physically realistic assumptions the values are not reliable. Atmosphere models can also reproduce CCD spectra (no wonder with more parameters), but their parameters cannot be constrained from observations and are thus not more reliable than blackbody parameters. High-resolution X-ray grating spectra do allow atmosphere models to give us more information, because they resolve absorption lines and their profiles. However, we have not found any atmosphere model yet that reproduces the observed spectra well enough to provide parameters that can be trusted. I will present examples of SSS spectra, illustrating the complexity of them discussing the challenges we are facing during interpretation.

E1.7-0029-18 MODELLING OF COMPLEX ABSORPTION ON HIGH-RESOLUTION X-RAY SPECTRA OF NOVAE: THE CASE OF V4743 SGR

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Nova V4743 Sgr was discovered in outburst on September 2002 and was observed by XMMNewton RGS (Reflection Grating Spectrometer) on April 2003. The RGS spectra of V4743 Sgr show complex absorption features and the previous studies indicate a blueshift in the spectra, hence we considered there exist a collisionally ionised hot absorber and/or a photoionized warm absorber component originating from wind and/or ejecta. We utilise SRON software SPEX

3.03.00 for our analysis and use its absorption models. The light curve showed oscillations in the count rate during the observation. The spectral analysis of the entire spectrum indicates that the models are inadequate. Taken into account the oscillations in the spectrum we considered to work on several resolved spectra on QPO time-scale. One of the best fit for a chosen RGS spectrum yields a blackbody for the continuum with temperature range 41-45 eV. We assumed two warm and one hot absorption components yielding blue shifts 1200-3500 km/s, along with an interstellar absorption and a dust absorption components. The resulting two warm absorption models have NH1 3.5-4 1021 cm−2 and NH2 9-7.5 1020 cm−2 with ionization parameter Log(ξ1) 3.7 erg cm s−1 and Log(ξ2) 1.3 erg cm s−1. The hot component has

NH 0.4-0.7 1024 cm−2 and temperature deviating between 1.5-3.2 keV. The best fits for the other spectra can also be obtained with the same composite model. The χ2 values differs from region to region and ranges between 2.3-7.2.

E1.7-0030-18 TRANSIENT SUPERSOFT X-RAY BINARIES IN THE MAGELLANIC CLOUDS OBSERVED WITH SALT AND ASTROSAT

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We have exploited the ToO capability of SALT, and its blue-sensitive spectrograph RSS, together with ASTROSAT to observe X-ray binary transients in the Magellanic Clouds, including new and known supersoft systems (SSS). These are generally accepted to be examples of steady thermonuclear burning on the surfaces of white dwarfs accreting at or above the Eddington rate. To achieve such rates requires an inverted mass ratio (i.e. the donor is heavier than the white dwarf), but this paradigm has never been confirmed as no accurate mass measurements have ever been possible, due to the extreme brightness of the continuously hot accretion disc. Through the SALT Transients Large Program we have studied highly variable SSS with the aim of searching for evidence of the nature of the donor stars in SSS, and to study their behaviour as a function of X-ray flux level.

E1.7-0031-18 WHAT WE HAVE LEARNED FROM THE BRIGHTEST NOVAE IN THE XRAY BAND IN THE MAGELLANIC CLOUDS

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Classical and recurrent novae in the Magellanic Clouds offer the advantage of following nova eruptions at known distance. In the soft X-rays, the lack of conspicuous interstellar absorption towards the Clouds compensates for their distance, on average 10 times larger than known Galactic novae, so high resolution X-ray spectra of good quality can be obtained. In this talk I will review the results of two works done with two different teams of coauthors, on Nova LMC 2009a and on Nova SMC 2016a, respectively. N LMC 2009a was a luminous recurrent nova and had a relatively slow X-ray development, with spectra in which the absorption features are less deep than in most novae. The second nova, N SMC 2016a, was unusually luminous at all wavelengths, and may be the prototype of a rare class of "hyperluminous" novae. Its spectra shows very deep, blue-shifted absorption features, which evolved quite rapidly. The peak effective temperatures we derived for the white dwarfs of both novae imply massive objects, most likely exceeding 1.2 solar masses. I will show what we learned about the chemistry and physics of these novae that exploded in lower metallicity environment than the Galactic ones. I will also discuss what we expect to be able to learn with Athena.

E1.7-0032-18 MULTIWAVELENGTH OBSERVATIONS OF THE TWO REMARKABLE NOVAE SMCN 2016-10A AND V407 LUP

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In this presentation I will elaborate on multiwavelength observations of the very fast and extremely bright nova SMCN 2016-10a. This observational set is one of the most comprehensive for any nova in the Small Magellanic Cloud. The progenitor system contains a bright disk and a main sequence or a sub-giant secondary. The nova is very fast with t2 4.0 1.0 d in the V - band. If the nova is in the SMC, at a distance of 61 10 kpc, we derive MV,max 10.5 0.5, making it the brightest nova ever discovered in the SMC and one of the brightest on record. In the talk, I will also highlight very interesting results on the remarkable nova V407 Lup, which is an intermediate-polar candidate.

E1.7-0033-18 ALMA OBSERVATIONS OF THE SHELL AROUND NOVA V5668 SGR

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Nova Sgr 2015b is a peculiar dust forming nova (Banerjee et al. 2015) that has been extensively observed in multiple wavelengths from radio (Linford et al. 2015) to gamma-rays (Cheung et al. 2015). A broad ionization range (Kuin et al. 2015) indicates a clumpy ejecta early after outburst. The formation of the unstable 7Be isotope has been confirmed in this nova (Tajitsu et al. 2016) as well as a slowly anisotropic expanding shell. We present ALMA long baseline (C40-9) observations of this recent shell with 0.029" resolution, both in the continuum at 230 GHz and in the H30α NLTE boosted recombination line. We have detected a 0.45" shell from the 2015 outburst. The presence of a highly structured ejecta 2.5 years after outburst is discussed in comparison with older resolved shells.

E1.7-0034-18 THE OUTBURST OF THE SLOW CLASSICAL NOVA V612 SCT 2017.

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We present the results of multicolor photometry and optical spectroscopy of the slow classical nova V612 Sct. Our UBVRI CCD photometry was obtained with 0.18 and 0.6m telescopes and optical echelle spectra (spectral resolution 12000 and 24000) with 0.6 and 1.3m telescopes of the Astronomical Institute of the Slovak Academy of Sciences at the Stará Lesná and Skalnaté Pleso observatories. Our data were completed by the AAVSO International Database and the Astronomical Ring for Access to Spectroscopy (ARAS) data. The nova V612 Sct underwent its outburst in June 2017 and reached the brightness maximum on July 30, 2017. We used the maximum magnitude - rate of decline relations to find the absolute magnitude of the nova at maximum. We estimated the value of colour excess and calculated the distance to the nova. The Hα and Hβ line profiles allowed us to study the structure of the nova V612 Sct expanding envelope. We identified principal and diffuse enhanced P-Cygni absorptions, which originate in two separate expanding shells. We investigated the evolution of radial velocities of both shells and expansion velocities found from the Hα and Hβ emission lines.

E1.7-0035-18 POPULATIONS AND PROPERTIES OF CLASSICAL AND RECURRENT NOVAE IN M31

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The first nova in the Andromeda galaxy (M31) was discovered over a century ago and today we know of more than one thousand such objects. This unparalleled sample permits study of the physical properties and distributions of various sub-classes of novae, such as spectral classes, donor stars, or stellar environments, together with their rates. In this talk we present recent results from multi-wavelength observations of M31 novae and discuss their relevance and connection to new theoretical nova models. Particular focus will be given to recurrent novae, their population properties, rates, and importance for the single-degenerate channel of type-Ia supernova progenitors.

This talk will be given in tandem with Dr. Matt Darnley (LJMU).

E1.7-0036-18 POPULATIONS AND PROPERTIES OF CLASSICAL AND RECURRENT NOVAE IN M31

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The first nova in the Andromeda galaxy (M31) was discovered over a century ago and today we know of more than one thousand such objects. This unparalleled sample permits study of the physical properties and distributions of various sub-classes of novae, such as spectral classes, donor stars, or stellar environments, together with their rates. In this talk we present recent results from multi-wavelength observations of M31 novae and discuss their relevance and connection to new theoretical nova models. Particular focus will be given to recurrent novae, their population properties, rates, and importance for the single-degenerate channel of type-Ia supernova progenitors.

This talk will be given in tandem with D Martin Henze (SDSU).

E1.7-0037-18 NOVAE AS GAMMA-RAY SOURCES FROM RADIOACTIVITIES AND PARTICLE ACCELERATION

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Nova explosions synthesise radioactive nuclei, which are emitters of γ-rays in the MeV range. Lines at 478 and 1275 keV correspond to 7Be and 22Na decays. In addition, positron-electron annihilation also produces γ-ray emission, with the 511 keV line and a continuum below it. γ-ray spectra and light curves are unique tools to trace the corresponding isotopes and to give insights on the properties of the expanding envelope. Photons in the MeV energy range from nova explosions have not been detected yet, because past and current instruments (e.g., CGRO/Comptel and INTEGRAL/SPI) are not sensitive enough, and only novae closer than about 1 kpc are expected to be detected; there have not been candidates so far. More optimistic perspectives will be offered by the ESA (M5) proposed mission e-ASTROGAM.

Another type of γ-ray emission from novae originates in particle acceleration in strong shocks related to mass ejection. Shocks can be either external - between the nova ejecta and the dense wind of the red giant companion in symbiotic recurrent novae - or internal - within the nova ejecta of classical novae. Collisions between accelerated protons produce neutral pions which decay emitting photons with energies larger than 100 MeV (hadronic process); relativistic electrons are responsible for Inverse Compton emission, also at high energies (leptonic process). Fermi/LAT has detected high-energy γ-rays in several novae, of both types, since its launch in 2008.

A review and update of both topics will be presented, together with the implications for the understanding of nova nucleosynthesis (MeV γ-rays) and shocks during mass ejection (GeV γ-rays).

E1.7-0038-18 GAMMA-RAY NOVAE: FERMI-LAT OBSERVATIONS AND THEORETICAL PROSPECTS

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Fermi-LAT collaboration Fermi-LAT collaboration

Novae are now firmly established as a high-energy (>0.1 GeV) gamma-ray source class by the Fermi Large Area Telescope (LAT). In symbiotic-like binary systems such as V407 Cyg 2010, there is a clear theoretical framework for the production of accelerated particles in the nova ejecta from passage of the shock through the dense wind of the red giant companion as was previously proposed for RS Oph 2006. The high-energy gamma-ray emission detected in classical novae, sited in compact binary systems with less evolved stellar companions, cannot be explained in the same way. It could, instead, be produced by internal shocks within the ejecta. We summarize the Fermi-LAT gamma-ray observations of novae, highlighting the main properties that will guide further studies particularly in the MeV energy range.

E1.7-0039-18 HIGH ENERGY EMISSION FROM THE RECURRENT NOVAE RS OPH & V745 SCO

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In recent years, eleven nova explosions have been detected by the Fermi /LAT satellite, ten classical novae and two symbiotic recurrent novae. The very high-energy γ-ray emission in novae is produced by π0 decay and/or Inverse Compton, which is a consequence of particle, p and e−, acceleration. The strong shock between matter ejected by the white dwarf and the circumstellar medium is responsible for this process. RS Ophiuchi was the first nova for which particle acceleration was predicted, during its 2006 outburst. Our aim is to understand the acceleration process through the analysis of contemporaneous X-ray emission.

We present the shock wave evolution of the recurrent novae V745 Sco and RS Oph based on the analysis of early X-ray observations. We analyse X-ray observations of V745 Sco by Swift /XRT simultaneous to particle acceleration and thus Fermi /LAT detection. Then, we study the XMM-Newton's observations of RS Oph early after its 2006 outburst both with RGS spectrograph and EPIC-MOS camera. Finally, we compare the observations of these two novae with other X-ray satellite data and with the IR and radio emission contemporaneous of early hard X-ray emission. This study allows us to globally describe the evolution of the nova remnant the first days after nova outburst and its relationship with particle acceleration.

E1.7-0040-18 NOVA OUTFLOWS, MODELLING TNRS AND THE OUTBURST VERSUS MULTI-WAVELENGTH OBSERVATIONS AND LINKS TO SN TYPE IA-CONTINUED

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This is the continuation of the Discussion II

E1.7-0041-18 DISCUSSION II: NOVA OUTFLOWS, MODELLING TNRS AND THE OUTBURST VERSUS MULTI-WAVELENGTH OBSERVATIONS AND LINKS TO SN TYPE IA

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European Space Astronomy Centre, Villanueva De La Canada, Spain Solen Balman, solen.balman@gmail.com

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We will make summary of the presented results from the meeting with a focus on discussion of multiwavelength observations of Novae in outburst including spectral evolution and variability of the outburst, ejecta interactions, morphology and particulary the puzzling Gamma-ray emission. We will elaborate on multidimensional modeling of the standard nova theory with the TNR, ejection mechanisms, outflow complexity and morphology, nova abundances and its implications. Finally, speculate on the future of nova studies; the directions that need to be taken and discuss the future missions which will help to improve the problems that we tackle.

Chair: M. Orio; Co-Chairs: J. Osborne, J-U Ness

E1.7-0042-18 MODELLING OF THE MAGNETIC FIELD DISTRIBUTION IN THE MAGNETIC CATACLYSMIC VARIABLES

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We have proposed that high field magnetic white dwarfs are the result of close binary interaction and merging during common envelope evolution. We now synthesise a population of binary systems to investigate the hypothesis that the magnetic fields in the accreting magnetic white dwarf in cataclysmic variables also originate during stellar interaction in the common envelope phase. We have found that those systems that emerge from common envelope more tightly bound form the cataclysmic variables with the strongest magnetic fields. We vary the common envelope efficiency parameter alpha and compare the results of our population syntheses with observations of magnetic cataclysmic variables. We find that common envelope interaction can indeed well explain the observed characteristics of these binaries at low values of alpha.

E1.7-0043-18 THE SYMBIOTIC BINARY POPULATION CHARACTERISTICS, MODELS AND EVOLUTION

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Symbiotic stars are long-period strongly interacting binaries in which the first-formed white dwarf accretes material from a red giant companion. Their study is essential to understand the evolution and interaction of detached and semi-detached binaries involving RGB and AGB stars. I will discuss progress in deriving physical properties of these binaries as well as challenges they continually pose to the binary evolution theory. Among these are the issues regarding stability of mass transfer and synchronization in systems with tidally distorted giants, distribution of the orbital parameters of S-type systems, and their chemical peculiarities.

E1.7-0044-18 AM CVN STARS: THEIR POPULATION CHARACTERISTICS AND EVOLUTION

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First recognised 51 years ago, AM CVn stars are compact close binaries in which white dwarfs accrete from hydrogen-deficient companion stars. We know of about 50 AM CVn stars, half of them discovered within the past 8 years. Their orbital periods range from 5 to 65 minutes, which makes them strong emitters of gravitational radiation at frequencies accessible to space-based detection. Gravitational radiation is the determining factor in the evolution of AM CVn stars, and leads to a very strong stratification of their properties with orbital period. I will review the properties of the known population of AM CVn stars and discuss their evolution. I will show that we currently face a conundrum in understanding the origin of these stars because all identified pathways to their formation face problems when confronted with observations. Understanding this is key for a quantitative prediction of their significance as supernova hosts and for the Galactic spectrum of gravitational waves below periods of 15 minutes.

E1.7-0045-18 SECULAR EVOLUTION OF CVS AND ASSOCIATED SPACE DENSITIES

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The standard model of evolution of cataclysmic variables has been around for over 3 decades. Within this time, both theoretical and observational progress has deliver a robust description of the overall population properties of CVs. However, several discrepancies between predictions and properties of the observed CV population remain. In the last few years, efforts have concentrated in forming an observational picture from the youngest systems (post-common envelope systems) to the oldest (period bouncers). This has allowed to probe the evolution of CVs in a wider time-scale and directly test our assumptions implemented in the theory. In parallel, the advent of new stellar evolution codes and binary population synthesis codes have allowed to trace the different outcomes and shortcomings of the standard model, such as common envelope physics and influence of nova eruptions, and its impact in the present-day CV population. In this review talk, I will provide the current state of our knowledge of CV evolution and present the recent theoretical and observational breakthroughs of the past years. In particular, I will focus on the impact of these results on the space densities of the present CV population. The next decade will deliver a deeper and rich multi-wavelength all-sky dataset which will enable us to probe both ends of the evolution (as well as everything in between) and will provide firmer limits to the true space density of the CV population.

E1.7-0046-18 A SYSTEMATIC STUDY OF THE SPECTRAL ENERGY DISTRIBUTION OF WZ SGE-STARS REVEALS NEW SOLID CANDIDATES FOR PERIOD-BOUNCERS.

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According to standard evolutionary theory, cataclysmic variables (CV) evolve from longer to shorter orbital periods until a minimum period P min is reached. The period bouncers are such CVs that have passed beyond P min and are evolving back toward longer periods, with the donor star now extremely dim. This has long been predicted to be the "graveyard" and current state of 70% of all CVs, though only about a dozen of more or less robust candidates for such period bouncer systems have been identified until now, out of a thousand of known CVs. CVs of the WZ Sge-type have been long considered as potential period-bouncer candidates. However, only very few of recently discovered WZ Sge-type stars were observed spectroscopically in quiescence due to their faintness (19-22 mag). Thus, the lack of information on many WZ Sge-type stars does not allow us to put restrictions on their system parameters and to confirm or deny their period bounce nature. The determination of system parameters requires many hours of observations with very large telescopes. This explains why direct (spectral) evidence for brown-dwarf donors exists only for a couple of CVs. We recently took a novel, simpler yet equally valuable approach based on multicolour broadband photometry, without the recourse to spectroscopy, to reveal the best candidates for the period bouncers. By adopting such an approach, we have already studied 30 WZ Sge-type stars (the observations are still in progress) and have found solid evidence for very low-mass donor stars of very low luminosity in several of them. In this presentation, we will discuss the various methods by which post period-minimum CVs can be recognized, and will highlight recent progress in this field.

E1.7-0047-18 CV EVOLUTION AND THE WHITE DWARF MASS PROBLEM

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Although the theory of CV evolution is able to explain several observational aspects, strong discrepancies have existed for decades between observations and theoretical predictions of the orbital period distribution, the location of the minimum period, and the space density of CVs. Moreover, in 2011 we showed that the average white dwarf (WD) mass observed in CVs is significantly higher than the average mass in single WDs or in detached close WD+MS binaries that are going to become CVs (Zorotovic, Schreiber & Gaensicke 2011). We also confirmed the absence of helium-core WDs (with masses below 0.5 Msun) in CVs, which is not observed in their immediate detached progenitors. These results are in strong disagreement with theoretical models, because nova eruptions are supposed to prevent the WD to increase in mass during the CV phase. This highly motivated us to revise the theory of CV formation and evolution. We developed a new empirical model for angular momentum loss in CVs that allows us to explain the high average WD mass observed in CVs and the absence of CVs with helium-core WDs (Schreiber, Zorotovic & Wijnen 2016). This model seems to solve not only the WD mass problem but also several other previously mentioned disagreements between theory and observations. Moreover, it also provides us with a very likely explanation for the existence of low-mass WDs without a companion (Zorotovic & Schreiber 2017).

E1.7-0048-18 TESTING THE PRESENT MODELS OF CV EVOLUTION

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Cataclysmic Variables (CVs) are one of the best classes to test our understanding of the evolution of compact, interacting binaries: they are numerous, relatively bright, and both stellar components are structurally simple. Nonetheless, our recent results from a large HST program (Pala et al. 2017) have highlighted a number of discrepancies between current population models and observations. Only once these discrepancies are resolved we can trust the theoretical models to be sensibly applied to more complex systems, such as black hole binaries, X-ray transients or SN Ia progenitors.

In particular, one of the most striking disagreements is the lack of period bouncers, i.e. old CVs in which the companions have been eroded down to brown dwarf masses. These systems are predicted to make up for 70% of the observed CV population, yet very few have been identified so far, suggesting that the physical mechanisms driving CV evolution (such as the mechanisms of angular momentum loss, the common envelope phase and/or the response of the companions to the mass loss) are still not completely understood. For this reason we have started a high cadence photometric survey using JAST/T80Cam aimed to find these elusive systems and we present here the preliminary results from this observing program.

E1.7-0049-18 THE HIBERNATION THEORY OF CVS REVISITED: CLUES FROM NEW MODELS AND THE M87 HST SURVEY

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Is the mass transfer rate Mdot from red dwarfs to white dwarfs a constant during the millenia between nova eruptions? The original hibernation scenario of cataclysmic binary evolution (Shara et al 1986) posited that Mdot varies by orders of magnitude, driving old novae to eventually look like dwarf novae, and perhaps detached systems. I will review observational and theoretical evidence for and against hibernation that has accumulated over the past 30 years. I will also present the results of the longest-ever HST survey of M87, seeking the stillelusive Rapidly recurring Novae which are the best canddate CV SNIa progenitors.

E1.7-0050-18 THE ORIGIN OF MAGNETIC WHITE DWARFS AND MAGNETIC CATACLYSMIC VARIABLES

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The first detection of a magnetic field in a star other than our own Sun, 78 Vir, was obtained in 1947 and the first magnetic white dwarf, Grw+70o8247, was discovery in 1970. However, the origin of magnetic field in stars, from pre-main sequence to the compact star stage, is still one of the main unanswered questions in astrophysics. It is also quite curious that there is not a single magnetic white dwarf paired with a non-degenerate companion star in a non-interacting binary. In order to explain this peculiar finding, we cannot employ a process that impedes the formation of a strong magnetic field in a proto-white dwarf when it has a companion, because such a process would also prevent the formation of magnetic cataclysmic variables (MCVs) which are binary systems consisting of a magnetic white dwarf accreting mass from a red dwarf companion. This curious puzzle points to the absurd conclusion that MCVs have no progenitors! This is the reason why it has been proposed that fields in certain classes of magnetic stars are generated through an $\alpha\,\Omega$ dynamo within the common envelope of a binary system where a weak seed poloidal field is twisted up by differential rotation to create a strong toroidal field. However toroidal and poloidal fields are unstable on their own, so once the toroidal field reaches its maximum strength and differential rotation subsides, the decay of toroidal field leads to the generation of a poloidal field with the two components stabilising each other and limiting field growth until they reach a final stable configuration. According to this scenario, the closer the cores of the two stars are drawn before the envelope is ejected, the stronger the final field of the star emerging from common envelope will be. The strongest fields occur when the two stars merge and form an isolated magnetic white dwarf. If the two stars do not merge but come out of common envelope just before mass transfer starts, they become the progenitors of the MCVs. The most strongly magnetic binaries would appear as pre-polars where the magnetic white dwarf accretes matter from the wind emanated from its companion.

In this solicited talk I will present very recent results on the generation of fields in isolated and binary magnetic white dwarfs showing that binary interaction and stellar merging can indeed explain the strong fields observed in these exotic objects.

E1.7-0051-18 POSSIBLE EVOLUTION OF MAGNETIZED WHITE DWARFS BY ACCRETION LEADING TO HIGHLY MAGNETIZED SUPER-CHANDRASEKHAR WHITE DWARFS

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We sketch a possible evolutionary scenario by which a highly magnetized super-Chandrasekhar white dwarf could be formed by accretion on to a commonly observed magnetized white dwarf. This is an exploratory study, when the physics/astrophysics in CVs is very rich and complex. Our current exploration is however simplistic and based on the phenomenon of flux freezing. Nevertheless, our proposal and initial choice of evolution has observational support, like, the recent discovery of a large number of magnetized white dwarfs by SDSS. Based on this, we also explore the possibility that the white dwarf pulsar AR Sco acquired its high spin and magnetic field due to repeated episodes of accretion and spin-down. An accreting white dwarf can lead to a larger mass and consequently a smaller radius thus causing an enhanced rotation period and magnetic field. This spinning magnetic white dwarf temporarily can inhibit accretion, spin down, and, eventually, the accretion can start again due to the shrinking of the binary period by gravitational radiation. The repetition of this cycle can eventually lead to a highly magnetized white dwarf (B-WD), recently postulated to be the reason for over-luminous type Ia supernovae. This evolution leading to a spinning B-WD could also be an ideal source for soft gamma-ray repeaters (SGRs) and anomalous X-ray pulsars (AXPs). SGRs/AXPs are generally believed to be highly magnetized, but observationally not confirmed yet, neutron stars. Invoking B-WDs to explain them does not require the magnetic field to be as high as for neutron star based model, however reproducing other observed properties intact.

E1.7-0052-18 EVOLUTION OF MAGNETIC CVS BETWEEN POLARS AND INTERMEDIATE POLARS

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From the X-ray, UV, and optical (photometric/spectroscopic / polarimetric) observations, the temporal and spectral features have been investigated for few magnetic CVs. Various attempts were made with these observed features which allow to probe the exact geometry, structure and the properties of magnetic CVs which further helps us to classified these systems either as polars or an intermediate polars. The selected MCVs also serve as an important tool to improve our understanding regarding the various classes of magnetic CVs from intermediate polars to polars. The observed spectra of most of the magnetic CVs probed through the various theoretical models to explain well about these systems. Shock parameters like shock temperature and shock height have also estimated using the hard X-ray spectrum of the system which is further used to determined the mass of the white dwarf. The nature and origin of the strong fluorescent Fe Kα emission line at 6.4 keV in magnetic CVs is also investigated with their detailed study. The phase-resolved X-ray spectroscopy also have a great potential and provide us the dependence of spectral parameters on the binary and rotational phases.

E1.7-0053-18 POPULATION STUDIES OF SINGLE AND BINARY WHITE DWARFS

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The vast majority of stars will end their lives as white dwarfs, Earth-sized electron-degenerate stars. As part of close binaries, white dwarfs give rise to a wide range of spectacular phenomena, including accretion disc instabilities, explosive shell burning, and their total annihilation in Type Ia supernovae. Due to their small radii, white dwarfs are intrinsically faint objects, and until recently, much of our knowledge regarding these stellar remnants has been based on serendipitous discoveries.

I will review how large-area surveys providing colour information, time-domain photometry, and spectroscopy enable us to move from individual object studies to the analysis of large and homogeneous samples, and I will discuss the observational results in the context of population synthesis models. I will in particular focus on the impact that the Sloan Digital Sky Survey and the Catalina Real Time Transient Survey had, and highlight the enormous potential of the Gaia mission for the study of white dwarfs, both single and in binaries. Finally, I will conclude with an outlook on a number of forthcoming spectroscopic and photometric surveys, including WEAVE, DESI, SDSS-V, 4MOST, and LSST.

E1.7-0054-18 ULTRAVIOLET VARIABLE STARS IN THE SWIFT GALACTIC BULGE SURVEY

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X-ray transients with peak X-ray luminosities below 1E36 erg/s are called very faint X-ray transients (VFXTs). These systems seem to have little or no accretion, and occasionally they leave their quiescent state to enter in outburst. At large distances these systems are usually very difficult to detect by all-sky monitors given their faint luminosities. The Swift Galactic Bulge survey (SBS) is an imaging survey of 16 square degrees of the Galactic Bulge in X-rays and Ultraviolet using the detectors XRT and UVOT on board the Neil Gehrels Swift Observatory. The SBS has helped to detect a handful of new VFXTs, as well as several variable stars. I will present results of the analysis of the SBS UV images. I will mostly focus on the discussion of the UV behavior of several variable sources, which likely include cataclysmic variables. I will describe the spacial distribution and optical properties of these SBS UV variables. I will also mention results about the UV counterparts of the newly detected VFXTs.

E1.7-0055-18 AN X-RAY VIEW ON CATACLYSMIC VARIABLES IN SOLAR NEIGHBORHOOD AND IN THE GALAXY BULGE

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We have carried out a systematic investigation on the population of Cataclysmic Variables (CVs) in solar neighborhood and in the Galaxy bulge (GB). The Fe emission lines, the shock temperature and the white dwarf masses were compared and correlations were drawn for a sample of Suzaku observed local CVs. Based on the Fe line ratio, we conclude that the Galactic Bulge X-ray Emission (GBXE) is dominated by non-magnetic CVs, or dwarf novae (DNe). From the Fe line ratio - WD mass - shock temperature correlation, the mean WD mass of CVs in the GBXE was determined to be 0.8 solar mass, which is consistent with the value of WDs in local CVs.

E1.7-0056-18 THE WHITE DWARF BINARY PATHWAY PROJECT

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Type Ia Supernovae (SN Ia) represent a very, perhaps even the most, important step on the extra-galactic distance ladder, and they have led to ground-breaking discoveries such as dark energy. Despite their outstanding importance, we still struggle to understand the details of the evolutionary pathways that produce SN Ia. The two main progenitor channels that have been proposed are the single degenerate channel in which the white dwarf accretes from a nondegenerate companion and the double degenerate channel which explains SN Ia explosions as the merger of two white dwarfs. However, whether nature has a strong preference for one of these channels, or whether a combination of several evolutionary channels contributes to the observed SN Ia rate remains an open question. This is partly because the direct progenitor systems for both channels are difficult to characterise observationally and partly because binary population models are uncertain and contain several unconstrained parameters. We run a large program on detached white dwarf + AFGK main sequence star binaries because this evolutionary stage is part of both main pathways towards SN Ia. By characterizing a large sample of these binaries we aim at providing the much needed observational constraints for calibrating binary population models which will significantly contribute towards solving the SN Ia progenitor puzzle.

E1.7-0057-18 EVOLUTIONARY LINKS BETWEEN POST-ABG/POST-RGB BINARIES AND ACCRETING WHITE DWARFS

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For lowto intermediate-mass stars, their AGB phase of evolution is terminated either by a powerful dust-driven wind or via a binary interaction. It is well established that binary interactions can alter the intrinsic properties of stars (such as: pulsation, mass-loss, photospheric chemistry, dust-formation, circumstellar envelope morphology etc.) and plays a dominant role in determining its ultimate fate. While past studies have shown that binarity can end the life of a star on the AGB, our recent studies have revealed that, in specific cases, binarity can also pre-maturely terminate the RGB evolution of a stars's life. A characteristic feature of these evolved binaries is the presence of a Keplerian circumbinary disk of gas and dust. These discs are an integral component of many post-AGB/ post-RGB binaries, driving the loss of angular momentum and playing a lead role in the evolution of these systems. Additionally, some of these systems also show a high-velocity outflow, originating from the circum-companion disc. In this talk I will review our advances in the research landscape of post-AGB and post-RGB binary stars, focussing on their observational properties, spectral energy distribution, photospheric chemistry, the characterisation and evolution of their stable circumbinary discs, and the evolutionary connection between the enigmatic post-AGB and post-RGB binaries, and other systems whose primary component is a White Dwarf.

E1.7-0058-18 BOTTLE ACCRETION IN A DETACHED MAGNETIC BINARY: A DETAILED PICTURE.

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In close detached post-common-envelope binaries, both components may have sufficient magnetic fields to become coupled and synchronized, thereby channelling the entire stellar wind from the late pre-main sequence star to the white dwarf. In binaries with K and earlier types, the accretion rate can be significant. We studied one such system, V1082 Sgr by means of fast, continuous long-term photometry using the K2 satellite and high-resolution spectroscopy. The data allowed us to reconstruct a detailed picture of the binary system and obtain several precise parameters.

E1.7-0059-18 DISCUSSION III: ACCRETING WD BINARIES, THEIR EVOLUTION AND LINKS TO XRBS AND AGB BINARIES

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We will make summary of the presented results from the meeting with a focus on the population studies and evolutionary connections of CVs and related systems (other AWB and XRBs) that will include post-common envelope WD binaries, the identification of correct angular momentum braking law(s) and angular momentum loss mechanisms, accretion and the progenitors of CVs. We will discuss evolution of AWBs towards Nova eruptions and SN Ia explosions.

Chair: E. Sion (may also be L. Schmidtobreick); Co-Chair: G. Tovmassian, V. Suleimanov, (may be included S. Balman)

E1.7-0060-18 ACCRETING WD BINARIES, THEIR EVOLUTION AND LINKS TO XRBS AND AGB BINARIES–CONTINUED

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This is the continuation of the Discussion III

E1.7-0061-18 WIDE-FIELD ULTRAVIOLET IMAGER FOR ASTRONOMICAL TRANSIENT STUDIES

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Ultraviolet (UV) domain plays a vital role in the studies of astronomical transient events but the UV time domain sky is largely unexplored. We have designed and build a wide-field UV imager for UV transient studies which can be flown on a range of available platforms, including highaltitude balloons, CubeSats, and other small satellite space missions. The major scientific goals are to study the variability of astronomical sources, detection of transients such as supernovae, novae, tidal disruption events and AGN variability. The instrument has a 70 mm aperture with a circular field of view of 10.8 degrees and the observation window is 280 - 390 nm. The detector for the instrument is a Micro Channel Plate (MCP) based detector with photon counting capability. A FPGA based detector readout mechanism and real-time data processing have been implemented. The imager is designed in such a way that its lightweight and compact nature is well fitted for a CubeSat dimension. Here we present the scientific potential of the proposed wide-field UV transient imager and the instrumentation (optomechanical design and interface, detector readout, electronics module etc.) involved. Our sophisticated design provides a low-cost implementation of the proposed payload. The transient survey with the proposed imager will have an overlap in time with other ongoing and planned astronomical facilities for transient studies, such as LIGO, SKA, LSST etc.

E1.7-0062-18 EVIDENCE FOR SPIRAL SHOCKS IN THE ACCRETION DISC OF SDSS1238

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Spiral shocks and magnetorotational instability (MRI) are thought to drive angular momentum transport in the accretion discs of cataclysmic variables (CVs). It has been suggested that spiral shocks dominate during quiescence, when the gas in the disc is mostly neutral and the efficiency of MRI results greatly reduced. In contrast, during outbursts the disc material is almost fully ionised, and angular momentum transport should be driven by both MRI and spiral shocks. Although spiral shocks have been observed in the accretion discs of novalike CVs and dwarf novae during outbursts, at present, there are only few clues (derived from the analysis of Doppler maps) on their presence in the accretion discs of quiescent CVs.

We present here high-time-resolution photometry and phase-resolved spectroscopy of the shortperiod (80.52 min) CV SDSS J123813.73−033933.0 (SDSS1238), observed with HST, the Kepler/K2 mission and the VLT. The light curve of SDSS1238 shows a double hump quasisinusoidal photometric modulation at half the orbital period. This phenomenon has been observed to be stable on time scales of years and the HST data unambiguously demonstrate that it arises from two heated regions on the white dwarf that become alternatingly visible to the observer every half orbital period. We suggest that the double-hump modulation is related to spiral shocks in the accretion disc resulting in an enhanced accretion rate heating two localised regions on the white dwarf, with the structure of the shocks fixed in the binary frame explaining the period of the double humps. This represents the first direct evidence that strong spiral shocks can steadily develop in the quiescent accretion disc of CVs and that, by reaching the inner part of the disc, they can drive accretion onto the white dwarf.

E1.7-0063-18 MULTICOLOR MONITORING OF WZ SGE - TYPE STAR TCP J18154219 + 3515598 IN VARIOUS STAGES OF OUTBURST ACTIVITY.

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We present U BV RI monitoring of the new dwarf nova object during its main outburst in June 2017, a post-super-outburst phase, series of rebrightenings and a quiescence stage. We found the period of superhumps (Psh) close to 0.063 days. The period variations are analyzed by the (O-C) method during different stages of outburst activity.

We constructed and interpreted the multicolor and color indices light curves as well as the tracks of the object in various two-color diagrams. We estimated changes of the color temperature during the outburst and brightness decline, the luminosity, the value of dP/dT, the superhumps excess (Psh/Porb − 1), the mass ratio, the distance to the system and other physical parameters.

The time intervals between rebrightenings of our object are compared with other similar objects. After the series of rebrightenings our object returned to a quiescence stage, when only irregular brightness fluctuations were observed.

E1.7-0064-18 TV COL: A CASE STUDY OF REFLECTION AND COMPLEX ABSORPTION OF X-RAYS IN INTERMEDIATE POLAR SYSTEMS

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Once produced by accretion onto a white-dwarf, X-ray photons of intermediate polar systems interact with a rich medium surrounding the degenerated star. It comprises (i) the stellar surface itself, (ii) the accretion disk that arises when material from the low-mass companion star overflow the Roche lobe and orbit the white dwarf, and (iii) the accretion column over the star from material of the inner part of the accretion disk which is swept and tapered by magnetic lines of the compact object. While a fraction of the X-rays suffers from photoelectric absorption inducing a deficit in the observed flux, more pronounced in soft X-rays, another part is reflected and results in a surplus of hard X-rays around 10-50 keV. Thus, the investigation of both “deficit” and “surplus” allows constraining the geometry of the system. Here we present a case study of reflection and complex absorption in intermediate polar systems by exploring the case of TV Col. It is among the hard X-ray brightest IPs and therefore suitable for a detailed study. First, we discuss quantitatively the need to have a broad spectral coverage in X-rays to carry out that study in intermediate polar systems, dissociating the contribution of absorption and reflection. Second, we describe the spectral properties of TV Col and how it constrains the white dwarf mass.

E1.7-0065-18 AN ENGINE OF GAS-DYNAMICAL ORIGIN OF FLARES ACTIVITY IN BINARY STAR SYSTEMS WITH WHITE DWARFS

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In the population of binary stars, stellar flares appeared as periodic or non-periodic variations in the luminosity, which manifest in their light curves. They are characterized by small magnitude and rather long timescales. The transition from a quiescent to an active state requires an engine, by which to increase the accretion rate in a level high enough that outflow development is able to be produced. It has been recently studied the relation between the flow structure transformation and the brightness variability in some binary stars, appeared in an events like bursts, flickerings or flares. We suggest that the vortices and vortical-like wave structures, which are formed in the accretion flow, could be a productive source and an efficient engine for flares activity. The investigations in this paper are made for SS Cyg, V592 Cas and MV Lyr.

E1.7-0067-18 A STUDY ON THE INTRINSIC ABSORPTION MODEL AND THE WHITE DWARF MASSES OF INTERMEDIATE POLARS

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X-ray spectroscopy can be used to constrain shock temperatures and white dwarf (WD) masses in magnetic cataclysmic variables (mCVs), especially intermediate polars (IPs). However, the previously inferred WD masses based on Suzaku observations are not fully consistent with the optical measured values, which could be due to the flaws when describing the intrinsic absorption of IPs. In this work, we introduce a new log-normal distributed absorption model to characterize the intrinsic absorption of IPs, and perform X-ray spectroscopy on archival Suzaku observations of IPs. Our results show satisfying chi2 values. More importantly, our inferred WD masses agree well with the optically determined values. We futher show the different treatment of intrinsic absorption could greatly affect the inferred WD masses in IPs.

E1.7-0068-18 EXPLORING ON-BOARD X-RAY TRANSIENT DETECTION WITH ATHENA - WIDE FIELD IMAGER

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X-ray transients, like novae, GRBs, compact objects, for example, are among the most enigmatic objects in the cosmic sky. The unpredictability of their transient behaviour has been a study of much interest in the recent years. While significant progress has been made in this direction, a more complete understanding of such events is often hampered by the delay in the rapid follow-up of any transient event. An efficient way to mitigate this constraint would be to devise a way for on-board detection of such transient phenomenon so that multi-wavelength follow-up observations can be carried out near simultaneously. The Wide Field Imager (WFI), which is a part of the upcoming X-ray mission Athena, with its 40′ X 40′ field of view can add some valuable contribution to this. In this work, we discuss an algorithm for the on-board detection of such X-ray transients with WFI. We will also present a few test cases for the feasibility test of that algorithm on Swift-XRT data. Finally, we discuss the type of X-ray transients best suited for on-board detection from WFI, their probability of detections and the useful science that can follow.

E1.7-0069-18 MAGNETARS AS HIGHLY MAGNETIZED LOWLY LUMINOUS WHITE DWARFS

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Soft gamma-ray repeaters (SGRs) and anomalous X-ray pulsars (AXPs) are generally believed to be the sources of highly magnetized neutron stars, namely magnetar model. However, such a high field invoked in this model, of the order of Peta Gauss, has not been observationally confirmed yet. In this talk, we plan to reopen the possibility of explaining magnetars by magnetized white dwarfs, originally proposed by Paczynski and Usov independently in 90s. However, we now explore them based on our recently proposed highly magnetized white dwarfs (B-WDs), which are also lowly luminous, hence do not suffer from any UV constraint. Interesting, invoking B-WDs to explain SGRs/AXPs does not require the magnetic field to be as high as that required for neutron star based model, however reproducing other observed properties intact. The plan is to show how different mass-radius relation for spinning B-WDs (different compared to neutron stars and white dwarfs following Chandrasekhar's theory) is adequate to explain several properties of SGRs/AXPs.

E1.7-0070-18 STRONGLY MAGNETIZED WHITE DWARFS AND THEIR STABILITY

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The mass of a non-magnetic, non-rotating white dwarf is bounded by a maximum value, known as Chandrasekhar mass-limit (1.4 M0). The characteristic light curve of type-Ia supernovae is attributed to the direct consequence of crossing this maximum mass-limit in an accreting binary system. We study the strongly magnetized white dwarf configurations in a self-consistent manner as a progenitor of the over-luminous type-Ia supernovae. We compute static axisymmetric equilibria of white dwarf stars containing a strong magnetic field and present the modification of white dwarf mass-radius relation caused by the magnetic field. From a static equilibrium study, we find that a maximum white dwarf mass of about 1.9 M0 may be supported if the interior poloidal field is as strong as approximately 1010 T. On the other hand, if the field is purely toroidal the maximum mass can be more than 5 M0. From the perturbation study we find that these strongly magnetised axisymmetric configurations are sensitive to magnetic instabilities where the perturbations grow at the corresponding Alfvén time scales. Hence, we conclude that the presence of long-lived magnetically supported massive magnetic white dwarfs is unlikely.

E1.7-0071-18 THE X-RAY PROPERTIES OF INTERMEDIATE POLAR XY ARI

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XY Ari is one of the few known eclipsing intermediate Polar. We present results of total spectrum and spin phase-resolved X-ray spectroscopy of XY Ari. We utilize archival data of XMM-Newton EPIC-pn and MOS in a quiescent state of the source. The X-ray orbital modulation and spin pulse variations are investigated in 0.2-10 keV energy band and also in different energy bands. Our results confirmed the broad orbital modulation observed with various observations at hard X-ray (>1.6 keV). The pulse profile showed a double peak profile as expected from two pole accretion and it is found to be energy dependent. The adopted model is composed of CEVMKL and a Gaussian line at 6.43 eV to account for the continuum which is partially absorbed. The maximum plasma temperature is found 28 keV with an iron abundance 0.37. We find two intrinsic partial covering absorption columns of 6.2 x1022 cm−2

and 105.3 x1022 cm−2 with covering fraction of 0.53, 0.41 respectively. The X-ray luminosity of the source is 4.2 x1032 erg s−1 in the 0.2-10 keV energy band assuming a 270 pc distance.

The spin-phase resolved spectral analysis of XY Ari confirm the variation of the absorption column parameters. The energy dependent nature of the X-ray spin pulse and the presence of absorption in its spectrum are seen generally in IPs indicating an accretion column absorbing structure.

E1.7-0072-18 A NEW CATALOGUE OF GALACTIC NOVAE

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We compiled a new Galactic novae catalogue by collecting important parameters of these sources such as their light curve parameters, classifications, FWHM of Hα, distances and interstellar reddening estimates. The catalogue is also published on a website with a search option via a SQL query and an online tool to re-calculate the distance/reddening of a nova from the reddening-distance relations derived using the same methodology in Ozdonmez et al. (2016). In this poster, I will present the catalogue itself and the website of the catalogue covering results obtained from the compilation of this catalogue such as spatial distribution, Galactic model parameters.

E1.7-0073-18 INCLINATION DEPENDENT VARIABILITY PROPERTIES OF COMPACT BINARY SOURCES

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In X-ray binaries, fast variability in X-ray emission on time-scales of milli-seconds to seconds is a common and very complex phenomenon. Studies of energy dependent temporal properties in different variability time scales can thus diagnose dynamics of accretion geometry. We study the energy dependent temporal properties in different variability time scale for the edge on (high inclination) and face on (low inclination) compact binary sources. We find different variability signatures for the high and low inclination objects. We discussed all possible mechanisms, specifically reflection and focusing effect due the gravitational bending of photons, which could be controlling the property of the variability. We explain the variability properties within the framework of a single two component advective flow model.

E1.7-0074-18 THE XMM-NEWTON OBSERVATION OF THE DWARF NOVA EY CYG AND THE SECONDARY STAR

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We present the X-ray spectral and temporal analysis of dwarf nova EY Cyg (45 ksec) using the XMMNewton Observatory archival data obtained in quiescence. We find orbital modulations in the X-rays. We simultaneously fitted EPIC pn, MOS1 and MOS2 data using a model for interstellar absorption (tbabs) and a multi-temperature plasma emission model (CEVMKL) which yields a maximum temperature kTmax of 15.0 keV with an unabsorbed X-ray flux and luminosity in the 0.1 to 50.0 keV energy band of 2.0x10−12ergcm−2s−1 and 2x1031ergs−1,

respectively. The fit shows an excess in the soft energies which can onlt be modeled using a MEKAL model at 3sigma significance with a temperature of 0.1 keV with an unabsorbed X-ray luminosity of 1.5x1030ergs−1. This confirms that the secondary is a K-type star as was suggested.

E1.8-0001-18 INTRODUCTION AND OVERVIEW OF THE SPACE VLBI MISSION RADIOASTRON

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The RadioAstron Space VLBI mission utilizes the 10-m radio telescope on board the dedicated Spektr-R spacecraft to observe cosmic radio sources with an unprecedented angular resolution at 92, 18, 6 and 1.3 cm in total and polarized light. The longest baseline of the space-ground interferometer is about 350 000 km. It successfully operates since 2011 together with up to 40 largest ground radio telescopes. Proposals for its observations are invited annually with deadlines at the end of January. Formal resolution as high as 8 and 11 microarcsec has been achieved for mega-masers and quasars observed at 22 GHz, respectively. Successful results have been obtained in all areas of its science program including active galactic nuclei, pulsars and scattering, galactic and extragalactic masers, gravitational redshift measurements.

E1.8-0002-18 THE TANAMI PROGRAM FOR VLBI MONITORING OF SOUTHERN AGN

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the TANAMI team the TANAMI team

VLBI monitoring observations are the backbone of the TANAMI multi-wavelength program monitoring gamma-ray detected AGN. TANAMI is the only source of parsec scale information on extragalactic jets in the southern third of the sky, encompassing many sources of interest. The detection of extraterrestrial neutrinos by IceCube makes a comprehensive astronomical multi-wavelength program to observe AGN jets indispensable for astroparticle physics.

With new high-energy neutrino events and gamma-ray sources to be discovered as well as substantially improved data on current sources, long term VLBI monitoring remains a crucial part of the study of AGN, as it is the only method for measuring parsec scale jet kinematics and structural changes. This is essential information for both the RadioAstron AGN Survey and for studying the broad-band spectral energy distribution in order to understand AGN high-energy emission mechanisms.

The TANAMI project and recent results will be described in this talk.

E1.8-0003-18 RADIOASTRON POLARIZATION KSP: PROBING THE INNERMOST REGIONS OF BLAZAR JETS AT TENS OF MICROARCSECONDS RESOLUTION

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RadioAstron provides the first true full-polarization capabilities for space VLBI observations on baselines longer than the Earth diameter. We present the results of our “Polarization” Key Science Program aimed to study the innermost regions of AGN jets and their magnetic fields at the highest angular resolutions achieved to date. Among our earlier results, we have successfully imaged the jet in BL Lac at an angular resolution of 21 microarcseconds, revealing a large scale helical magnetic field in the vicinity of the central black hole. Our quasi-simultaneous RadioAstron, Event Horizon Telescope (EHT), and GMVA observations of OJ287 reveal a highly twisted jet at an unprecedented angular resolution of 10 microarcseconds (26 Schwarzschild radii); these are analyzed in combination with our multiwavelength monitoring to test jet formation models and the supermassive binary black hole scenario proposed for this source.

E1.8-0004-18 RADIOASTRON IMAGING OF NEARBY RADIO GALAXIES

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RadioAstron Nearby AGN Key Science Program uses ultra high angular resolution radio observations provided by the space-VLBI mission RadioAstron to study the structure of the radio jets in nearby active galactic nuclei close to their launching site. Our space-VLBI images of radio galaxies 3C84 and M87 well resolve both jets in transverse direction, revealing structures that are not seen in the ground-based VLBI data. In 3C84, we are able to reliably resolve the limb-brightened jet just 30 microarcseconds from the core in our 22GHz image, which allows us to measure the jet collimation profile from 102 to 104 gravitational radii from the black hole. We find a very broad, almost cylindrical structure extending all the way to the core. The bright outer layer has a transverse radius of 250 gravitational radii at only 350 gravitational radii (deprojected) from the core, which raises the possibility that the jet sheath originates in the accretion-disk. Our 5GHz RadioAstron image of 3C84 discovers a previously unseen lowintensity emission from a cocoon-like structure around the recently restarted, one parsec long, jet. The cocoon pressure provides a natural explanation for the cylindrical jet profile seen in the 22GHz image. In the case of M87, we have obtained a high dynamic range 1.6GHz image with space baselines up to 5 Earth diameters. The image shows a striking internal structure in the M87 jet starting from the core and extending up to 450 mas. The image reveals a structure of helical filaments inside the jet. This is the first time such a pattern is clearly seen in the acceleration and collimation zone. The implications of this will be discussed.

E1.8-0005-18 INNERMOST REGION OF THE BLAZAR S5 0716+714 FROM RADIOASTRON POLARIMETRIC OBSERVATIONS AT 22 GHZ

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We present results of μas radio polarimetric imaging of one of the most studied BL Lac object S5 0716+714, observed with the RadioAstron space-VLBI mission. The source is well known because of its extreme and rapid variability through the whole electromagnetic spectrum. S5 0716+714 gamma-ray activity is strongly related to the inner jet morphology, which together with the short-scale variations at radio and optical bands makes the blazar the best candidate for an intrinsic origin of its intra-day variability (IDV).

Our observations of the source was made with the 10-m space radio antenna and eleven ground stations on 2015 January 3-4 at 22 GHz. The projected baselines reached 4-6 Earth's diameters in length, resulted in angular resolution of 24 μas, the highest for the studied source to-date. The S5 0716+714 image revealed elongation of the apparent base of jet within innermost 0.2 mas in direction, almost perpendicular to the larger-scale flow. This is consistent with the temporal variations of the inner jet direction with the amplitude of about 60 degrees, resulted from our analysis of multi-epoch observations of the blazar within the VLBA-BU-BLAZAR monitoring program at 43 GHz. We suggest, that this fine-scale region of the S5 0716+714 jet may be responsible for the IDV and flaring activity of the source.

The source exhibits large-scale magnetic field, perpendicular to the jet flow, which is consistent with its helical geometry. We detect compact linearly polarized component in the innermost 0.2 mas of the jet, which coincides well with the position of a stationary feature, seen in other studies, and points on possible association with the recollimation shock.

E1.8-0006-18 RESULTS FROM THE RADIOASTRON AGN POLARIZATION KSP: OBSERVATIONS OF 3C273 AT MINIMUM ACTIVITY

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The RadioAstron active galactic nuclei (AGN) polarization Key Science Project (KSP) aims at exploiting the unprecedented angular resolution provided by RadioAstron to study jet launching/collimation and magnetic-field configuration in AGN jets. The targets of our KSP are some of the most powerful blazars in the sky. We present observations at 22 GHz of 3C273, performed in 2014, designed to reach a maximum baseline of approximately nine Earth diameters. Reaching an angular resolution of 0.3 mas, we study a particularly low-activity state of the source, and estimate the nuclear region brightness temperature, comparing with the extreme one detected one year before during the RadioAstron early science period. We also make use of the VLBA-BU-BLAZAR survey data, at 43 GHz, to study the kinematics of the jet in a

~1.5-yr time window.

We find that the nuclear brightness temperature is two orders of magnitude lower than the exceptionally high value detected in 2013 with RadioAstron at the same frequency (1.4 1013 K, source-frame), and even one order of magnitude lower than the equipartition value. The kinematics analysis at 43 GHz shows that a new component was ejected 2 months after the 2013 epoch, visible also in our 22 GHz map presented here. Consequently this was located upstream of the core during the brightness temperature peak. Fermi-LAT observations for the period 2010-2014 do not show any γ-ray flare in conjunction with the passage of the new component by the core at 43 GHz. Conclusions. These observations confirm that the previously detected extreme brightness temperature in 3C 273, exceeding the inverse Compton limit, is a short-lived phenomenon caused by a temporary departure from equipartition. Thus, the availability of interferometric baselines capable of providing μas angular resolution does not systematically imply measured brightness temperatures over the known physical limits for astrophysical sources.

E1.8-0007-18 CORES OF ACTIVE GALACTIC NUCLEI STUDIED AT UNPRECEDENTED RESOLUTION

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RadioAstron AGN survey team

The Space Very Long Baseline Interferometer RadioAstron has performed a survey of 248 radio-loud AGNs at 18, 6, and 1.3 cm at projected spacings up to 350,000 km. Significant detections at space-ground baselines were found for 164 AGNs. Formal resolution as high as 11 microarcsec has been achieved. Apparent brightness temperature up to about or higher than 1014 K was found in cores of observed AGNs. These measurements challenge our understanding of the non-thermal continuum emission in the vicinity of supermassive black holes. Physical implications of these findings will be discussed. While the survey was dedicated to total intensity measurements, we have also discovered that fractional linearly polarized correlated flux density increases with long SVLBI projected spacings. This suggests the presence of ultra-compact regions with ordered magnetic field, most probably within the core of those quasars.

E1.8-0008-18 INTER-STELLAR SCINTILLATION, ISS, AND INTRINSIC VARIABILITY OF RADIO AGN

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A comparison of the ISS observations from our VLA 5 GHz MASIV survey and the published OVRO 15 GHz intrinsic variability observations reveals a significant relationship between these two parameters. This relationship can be attributed to the mutual dependence of intrinsic variability and ISS on radio core compactness at 50 - 100 micro-arcsecond scales. For the full MASIV sample we find that the Fermi-detected gamma-ray loud sources exhibit significantly higher 5 GHz ISS than the gamma-ray quiet sources.

E1.8-0009-18 IMPLICATIONS OF REFRACTIVE SCINTILLATION FOR OBSERVATIONS OF ACTIVE GALACTIC NUCLEI WITH RADIOASTRON

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Interstellar scattering imposes a fundamental limitation on the angular resolution of radio observations. With the combination of extremely high brightness temperatures in active galactic nuclei (AGN) and the unprecedented resolution afforded by Earth-space baselines with RadioAstron, we are now confronting this limit directly. In particular, the scattering introduces refractive substructure, which produces interferometric signatures that can mimic those of ultra-compact intrinsic structure. Nevertheless, the scattering also enables new measurements of intrinsic structure, including precise estimates of brightness temperature and core shift with sparse data. We will discuss the effects of refractive interstellar scintillation on microarcsecond imaging of AGN with RadioAstron, new techniques to mitigate the scintillation, and new measurements enabled by the scintillation.

E1.8-0010-18 IMAGING STRONG BLAZARS WITH SPACE VLBI

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Imaging observations performed with RadioAstron as part of a key science program on studies of powerful extragalactic jets have provided a series of detailed multi-frequency images of a number of the strongest blazars of the radio sky. The observations were made at the wavelentghs of 18, 6, and 1.3 cm, targeting prominent radio sources such as 0836+710, 3C 345, 3C 273, and 1642+690, with ground-space baselines reaching up to about 10 Earth diameters. The resulting improved angular resolution enables resolving the internal structure of the outflows and detecting regions with extremely high brightness temperatures exceeding 1013K. These images have enabled multifaceted studies of physical conditions in the relativistic jets to be perf o resolution mm V LBI imaging at 3.5 mm with the Global Millimeter V LBI Array, and in some cases, even with the Even Horizon Telescope at Λ 1.3 mm. We present here some highlights of the RadioAstron observations of prominent radio sources and discuss ample potentials for their synergy with mm-VLBI observations. This synergy should address some of the still unanswered questions on the physical nature of relativistic jets and nuclear regions in active galaxies.

E1.8-0011-18 PULSARS OBSERVED WITH RADIOASTRON

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Pulsars are pointlike at the highest attainable angular resolution, and present excellent targets for studies of the effects of interstellar scattering at meter to decimeter wavelengths. Studies of the scattering of pulsars enable understanding of the interstellar medium, and provide essential insights into observations of compact radio sources at the highest attainable angular resolutions. Conversely, scattering acts as an enormous optical system that provides insight into the electrodynamics of pulsars.

Using the uniquely long interferometer baselines offered by the Radioastron mission, we have detected and characterized “cosmic prisms,” large-scale plasma gradients that deflect source images and geometrically disperse pulses from pulsars. We have detected at least two varieties of substructure within the scattered images of pulsars, and extended their study to active galactic nuclei. We have observed the spatial decorrelation of giant pulses from the Crab pulsar on Earth-space baselines. We have detected and

analyzed the orderly "scintillation arcs" that mark the scattering of nearby strong pulsars. We discuss these results, and their interpretation.

E1.8-0012-18 REVEALING COMPACT STRUCTURES OF INTERSTELLAR PLASMA IN THE GALAXY WITH RADIOASTRON.

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One of the scientific research fields of RadioAstron project is probing the interstellar plasma by radio pulsars. Pulsars are point radio sources and not resolved even by space-ground interferometer. Nevertheless, RadioAstron interferometer provides great advantages in the study of scattering effects since it makes it possible to measure directly the angular size of the scattering disks that are usually enclosed in the interval from 0.01 to 0.001 arcseconds at decimeter wavelengths. For ground interferometers such scattering disks are usually unresolved. During the execution of RadioAstron pulsar scientific program a number of major results were obtained:

As a result of the analysis of observations of several pulsars, conducted with RadioAstron, scattered screens were localized in the direction toward these pulsars. We emphasize that the uniform model of scattering plasma distribution on the line of sight does not fit any pulsar.

Non-isotropic structures of inhomogeneities in the interstellar plasma were revealed. Such structures may be connected with the influence of the magnetic field.

Detection of the "cosmic prism" at distances as small as a few parsecs. Such effective scattering layers of plasma in the local interstellar medium were postulated before to explain the rapid variability of compact extragalactic sources.

Substructure in pulsar scattering disks was discovered. The presence of such structure requires the update of radio waves scattering physics.

Studying giant pulses from the Crab pulsar revealed the decisive role of the plasma located in the vicinity of the nebula itself on the observed scattering effects.

In this report we present above mentioned results in some details

E1.8-0013-18 STUDIES OF MASERS IN STAR FORMING REGIONS OF OUR GALAXY AND MEGAMASERS IN EXTERNAL GALAXIES

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Observations of the masers in the RadioAstron (RA) mission yielded detections of fringes for a number of sources in both H2O and OH maser transitions. Several sources display numerous ultra-compact details. This proves that implementation of the space VLBI technique for maser studies is possible technically and is not always prevented by the interstellar scattering, maser beaming and other effects related to formation, transfer and detection of the cosmic maser emission. RA observations provided absolute record of the angular resolution in astronomy. Fringes from the NGC 4258 megamaser were detected on baseline 26.7 Earth Diameters (340,000 km). This corresponds to the angular resolution 8 as sufficient to measure parallax of the maser source in the nearby galaxy LMC. The sharpest "direct" linear resolution <4.e11 cm was achieved in observations of the maser in Orion. RA also detected the smallest structures ever observed in a Galactic maser. Analysis of the data on Cep A water maser indicates that the source contains features with the sizes about the diameter of the Sun. The space-Earth cross power spectrum shows two unresolved components smaller than 15 as (1.6e11 cm) separated by 160±35 as which differ in velocity by 0.5 km/s. The brightness temperatures are >2.e14 K, and the line widths are 0.5 km/s. Most of the flux density (90 per cent) is contained in a halo of diameter 1 mas. We discuss possible interpretations for the compact structure.

E1.8-0014-18 RADIOASTRON REVEALS SUPER-COMPACT STRUCTURES IN THE FLARING WATER MASER SOURCE G25.65+1.05

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G25-maser

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In recent years the water maser source in the massive star-forming region G25.65+1.05 (IRAS 18316-0602, Mol 62, RAFGL 7009S) has undergone several powerful flares. During regular monitoring of the source with the 22-m radio telescope in Pushchino (Moscow Region) a strong burst was detected with the peak flux density of the strongest maser line increasing from 70 Jy (on 16.06.2016) to 50,000 Jy (on 12.12.2016), i.e., a more than 500-fold increase. A second super-burst was observed with the RT-22 in Simeiz (Crimea), detecting a flux density of 20,500 Jy. The maximum flux density of 65 kJy was detected on 16.09.2017. The maser source was observed several times with the space-ground interferometer RadioAstron (RA) and also with the VLBA and the EVN ground-based interferometers. Strong fringes were obtained during the 29.09.2017 session on the space-ground baselines RA-Torun and RA-HartRAO, with baseline lengths from 8.6 to 9.3 Earth Diameters. The angular resolution of 24 μas corresponds to a linear size for the emitting region of about 0.05 AU (assuming a source distance of 2.08 kpc). This is the first time that such compact structures have been detected in water masers. The extraordinarily high intensity of the observed flare provides a large dynamic range for the analysis of the compact components found in this source. The differing responses on the space-ground and ground-ground baselines indicates that a range of size scales are present. Using the precise spatial distribution of individual maser components, it is possible to identify hierarchical structures within the masers. These observations serve to clarify the nature of the masing source, which in turn offers additional insights into the high mass star formation process.

E1.8-0015-18 TOWARD A SENSITIVE TEST OF THE EINSTEIN EQUIVALENCE PRINCIPLE BY MEASURING THE GRAVITATIONAL REDSHIFT WITH RADIOASTRON

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The incompatibility of general relativity and quantum theory is a fundamental problem in our understanding of the physical world. The Einstein equivalence principle (EEP) is a cornerstone of general relativity, and the gravitational redshift is a consequence of the local position invariance aspect of it. An accurate measurement of the gravitational redshift and a comparison with prediction is therefore of prime importance. Here we report on such a measurement. The Spektr-R spacecraft of the RadioAstron mission was launched in 2011 into a highly elliptical orbit around Earth. Since early on the spacecraft has been used for astrophysical observations of compact radio sources with the technique of space VLBI (very long baseline interferometry). The spacecraft has a hydrogen maser frequency standard on board that operated till 2017. For several years the downlink signals at 8.4 and 15 GHz, locked to the frequency of the hydrogen maser, were recorded at ground stations, which are also equipped with hydrogen masers. About 2900 sessions each with 100,000 frequency recordings at each of the two frequencies were obtained. During the 9-day elliptical orbits the spacecraft traveled through the varying gravitational potential of Earth, which according to the EEP should cause an oscillating gravi tational redshift of the downlink signals. The predicted relative frequency shift varied between

6.8 10−10 and 4 10−10. The data from the RadioAstron mission are being largely independently analyzed by more than one group to provide for a better reliability of our anticipated final results. We report on our analysis of data recorded at the ground stations in

Pushchino, Russia, and Green Bank, USA, and discuss the possibility of testing the EEP with a higher sensitivity than that obtained from the Gravity Probe A mission.

E1.8-0016-18 ON THE PROSPECTS OF IMAGING THE EVENT HORIZON OF SAGITTARIUS A* FROM SPACE

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Very Long Baseline Interferometry (VLBI) at sub-millimeter waves has the potential to image the shadow of the black hole in the Galactic Center, Sagittarius A* (Sgr A*), and thereby test basic predictions of the theory of general relativity. In our work, the imaging prospects of a new Space VLBI mission concept have been investigated. An initial design study of the concept has been performed for the purpose of the Event Horizon Imager (EHI) experiment. The concept may be suitable for imaging Sgr A* at frequencies up to 690 GHz, which has significant advantages over performing Earth-based VLBI at 230 GHz. The investigated setup consists of two satellites in polar or equatorial circular Medium-Earth Orbits with slightly different radii. This setup will result in a dense spiral-shaped uv-coverage with long baselines, allowing for extremely high-resolution and high-fidelity imaging of radio sources. We simulate observations of a general relativistic magnetohydrodynamics (GRMHD) model of the accretion flow around Sgr A* for the proposed configuration and noise calculated from model system parameters. After gridding the uv-plane and averaging visibilities accumulated over multiple months of integration, images of Sgr A* with a resolution of up to 4 uas (about 8% of the shadow diameter) could be reconstructed. The black hole shadow could be measured much more precisely than with ground-based VLBI, allowing for stronger tests of General Relativity and accretion models.

E1.8-0017-18 SYSTEM DESIGN PROGRESS IN THE EVENT HORIZON IMAGING USING THE CONCEPT OF SPACE-TO-SPACE VLBI FROM MEDIUM EARTH ORBITS

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Earth-based aperture synthesis is limited in resolution by the Earth diameter and suffers from a sparse spatial frequency sampling. Its observing frequency is restricted by the atmospheric propagation effects. This work considers a space-borne interferometer concept, which is free of the above-mentioned constraints. The concept assumes two identical satellites in polar or equatorial orbit of Medium Earth Orbit altitude that is suitable to image the shadow of the event horizon of the Sagittarius A* (Sgr A*) with the angular resolution of circa 5 micro arc-seconds at the frequency above 600 GHz. This work provides the requirements to (i) the knowledge of positions of phase centers of space-borne antennas, (ii) the accuracies of the altitude and orbit control systems, and the visibility of navigation satellites, (iii) the frequency plan for the interferometer and its inter-satellite links. The work presents the current progress in the intersatellite links for velocity (and distance) measurements, and data exchange including but not limited to link budgets, critical components, and performance quality factors. Sensitivity details of the interferometer are presented. Two sub-mm-class radio astronomy antennas are installed on separate identical satellites. The selected orbits provide well-sampled spatial frequency coverage, and allow us to operate outside the radiation belts of the Earth magnetosphere and consider a centimeter-level on-the-fly accuracy of the relative orbit determination using the global navigation satellite system (GNSS). To compress the downlink signal bandwidth, the cross-correlation is done onboard each satellite within the delay window defined by the orbit determination accuracy. The sub-mm baseline localization is done using the GNSS navigation, the altitude and orbit control (AOCS) sensors, and inertial navigation sensors, the inter-satellite velocity and range observables altogether. The image reconstruction is completed on the ground using sets of discrete readings of the cross-correlation function. The work results have been obtained using simulations of the synthesized array and the characteristics of the GNSS, the available technologies for the AOCS, and limitations of the radio communication regulations. The presented performance calculations and the instrument block diagram are in line with the available technology for sub-mm-class space-borne antennas, quasi-optics, amplifiers, mixers, and digitizers. This interferometer concept has potential to permit imaging of the shadow of the Sgr A* with the resolution of a few micro arc-seconds which is significantly sharper than achievable from the Earth surface. The presentation provides the current progress on the orbit simulations and the whole system, and the input information for the development of the key systems of the mission.

E1.8-0018-18 THE CHINESE SPACE VLBI PROPOSALS AND THE EARTH-MOON VLBI EXPERIMENT

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The Chinese VLBI (VeryLong Baseline Interferometry) Network - CVN consists of five radio telescopes and one data processing center. The earth-based CVN will plan to extend to the space in the future and there are several proposals. The first one is the mm Space VLBI Array, which includes two earth satellites with 10m antennas and the highest band of 46GHz. The research purpose of the mm Space VLBI Array is Super Massive Black Hole, Disk Structure and dynamics, mass of SMBH and Jets in Active Galactic Nuclei (AGN). Another proposal is the Radio Observatory in Space for Exploring the universe (ROSE), which is proposed to image the fine structure of compact celestial objects such as black hole, pulsar and so on. The mission plans to launch a 30 meter-diameter radio telescope into a 2000km x 70000km elliptical orbit, and works together with the earth-based VLBI network, Square Kilometre Array (SKA) and Five-hundred-meter Aperture Spherical radio Telescope (FAST) to get very high resolution and very high sensitivity. ROSE is operated at decimeter and long centimeter. In the subsequent China's Lunar Exploration Project, there will be an Earth-moon VLBI experiment, using the antenna of the lunar orbit Tracking and Data Relay Satellite (TDRS) to construct the first Earth moon space VLBI experimental system. We hope using this earth-moon VLBI system to verify the key space VLBI technology. Because the Earth moon VLBI baseline is over 300km, the experiments of astrometry, astrophysics and the deep-space tracking will be carried. After this, a 10 m antenna is planned to be constructed on the moon surface in the future.

E1.8-0019-18 ROADMAP TOWARDS A SPACE-BASED RADIO TELESCOPE FOR LOW FREQUENCY RADIO ASTRONOMY

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Low-frequency radio astronomy to date has focused its operations mainly on the frequency regime above 30 MHz, for example through LOFAR, the Low Frequency Array, based in the Netherlands. Below 30 MHz, Earth-based observations are limited due to a combination of severe ionospheric distortions, full reflection of radio waves below 10-30 MHz, solar eruptions and the radio frequency interference (RFI) of man-made signals. There are, however, interesting scientific processes that naturally take place at these low frequencies. A spaceor Lunar-based low-frequency radio array would suffer significantly less from these limitations and hence would open up the last, virtually unexplored frequency domain in the electromagnetic spectrum. This is a region of the electromagnetic spectrum which is essentially unexplored by astronomy.

A roadmap has been initiated to explore the opportunity to build a swarm of satellites to observe the frequency band below 30 MHz, the Orbiting Low Frequency Antennas for Radio

Astronomy (OLFAR). OLFAR is a space-based low frequency radio telescope that will explore the universe's so-called dark ages, map

the interstellar medium, and discover planetary and solar bursts in other solar systems. The telescope, composed of a swarm of at least fifty distributed satellites working together as a single instrument, will be sent to a location far from Earth in order to avoid the high RFI found at frequencies below 30 MHz originating from Earth. The OLFAR telescope is a novel and complex system, requiring not-yet proven technologies and systems, therefore, a number of key technologies are still required to be developed and proven. Most of these can be tested on Earth, but several aspects require in-space verification.

The NCLE (Netherlands China Low Frequency Explorer) project will be the first milestone in this roadmap. In 2018, NCLE will be launched on the Chinese Chang'e 4 satellite. It will consist of a single antenna for the low frequency regime. The first data at low frequencies, far away from the RFI from Earth, will provide the first information of the possible science.

In this paper, the roadmap, science opportunities, and the technological and programmatic challenges will be presented.

E1.8-0020-18 THE SUN RADIO INTERFEROMETER SPACE EXPERIMENT (SUNRISE) MISSION CONCEPT: DEVELOPMENT STATUS

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We present an overview of the development status of the Sun Radio Interferometer Space Experiment (SunRISE) mission concept. SunRISE is space-based sparse array, composed of six 6U small spacecraft (SmallSats), designed to localize the radio emission associated with coronal mass ejections (CMEs) from the Sun. Radio emission from CMEs is a direct tracer of the particle acceleration in the inner heliosphere and potential magnetic connections from the lower solar corona to the larger heliosphere. Furthermore, CME radio emission is quite strong such that only a relatively small number of antennas is required, and a small mission would make a fundamental advancement. Indeed, the state-of-the-art for tracking CME radio emission is defined by single antennas (Wind/ WAVES, Stereo/SWAVES) in which the tracking is accomplished by assuming a frequency-to-density mapping.

This type of Heliophysics mission would be inherently cost prohibitive in a traditional spacecraft paradigm. However, the use of SmallSats, accompanied by the miniaturization of sub-system components, enables the development of this concept at lower cost than ever before.

This paper presents the most recent updates on this mission concept, with a focus on the implementation and how it meets the science objectives. The science payload is described, with an initial "benchtop" unit having been constructed to demonstrate its performance. It then describes the mission concept of operations, which consists of six 6U SmallSats placed in a "graveyard orbit," just above geosynchronous orbit (GEO) for six months. A key aspect of the mission concept is that the SmallSats are in a passive formation, requiring only knowledge of their positions and minimal control, in order to form an interferometer.

The information presented about SunRISE is pre-decisional and is provided for planning and discussion purposes only. Part of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

E1.8-0021-18 SPACE VLBI: FROM FIRST IDEAS TO THE OPERATIONAL MISSION

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This COSPAR session is dedicated to the results of the Russia-led international Space VLBI (SVLBI) mission RadioAstron. De facto, this mission concludes the first generation of SVLBI facilities, which commenced with the Japan-led international mission VSOP (VLBI Space Observatory Programme) launched in 1997 and preceded by the SVLBI demonstration experiment with the Tracking and Data Relay Satellite System (TDRSS) in 1986-1988. While the comprehensive lessons learned from the first demonstration and two dedicated SVLBI missions are still awaiting thorough attention, several preliminary conclusions can be made. This presentation addresses some key scientific and technological issues as they progressed over four decades from the original SVLBI concepts to the operational missions.

E1.8-0023-18 RADIOASTRON AND THE RISC; A SENSE OF PLACES

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Since it was formed in 1988, the RISC, the RadioAstron International Science Council, has played a leading role in co-ordinating the science and the international involvement in this Russian-led International VLBI mission. For the 30th Anniversary of the RISC's formation, I have assembled a number of multi-wavelength sketches and images drawn from the places where, and near where the RISC has met over the past decade and a half. These are presented here as RISC reminiscences and re-views.

E1.8-0024-18 USING HIGH-RESOLUTION VLBI TO PROBE GAMMA-RAY EMISSION IN 3C 84

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NASA Goddard Space Flight Center, Greenbelt, Maryland, United States 3C 84 is unique in that it is one of the few non-blazar AGN that is detected at ultra high energies (including MAGIC in addition to Fermi/LAT). The source itself has been increasing in flux density at both radio and Gamma-rays since approximately 2005 with VLBI observations showing that this rising emission is associated with a slowly moving component south of the jet-launching (C1) region, commonly known as "C3". Recent analysis of multi-wavelength Korean VLBI Network data has suggested multiple locations of Gamma-rays within 3C 84. In addition to the slowly rising trend in C3, smaller scale rapid variation of radio and Gamma-ray fluxes are associated with the C1 region, but that the correlations observed are due to random processes. We than applied wavelet analysis using the WISE package to the kinematics of 3C 84 using 43 GHz data from 2010 until now. We find that a large flare beginning in early 2015 and currently decaying is apparently due to the emission of a new component from the C3 region. Additionally, there appears to be evidence for helical trajectories with Gamma-ray flaring being possibly associated with when the helical path passes through our line-of-sight.

E1.8-0025-18 SHADOWS AROUND SUPERMASSIVE BLACK HOLES AS A TOOL TO TEST GR AND ALTERNATIVE THEORIES OF GRAVITY

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We obtained analytical expression for shadows around supermassive black holes for a wide class of spherically symmetric black hole solutions, such a Reissner - Nordstrom with a tidal charge, dyonic Reissner - Nordstrom – (anti) de-Sitter, black hole in Horndeski gravity. Therefore, observations of such shadows could be indicator of an alternative theory of gravity. We also found properties of shadows around Kerr black holes. which could be observed in the future with the Event Horizon Telescope and projected space-ground interferometer Millimetron.

RESEARCH IN ASTROPHYSICS FROM SPACE (E)

ULTRAVIOLET ASTRONOMY AND THE QUEST FOR THE ORIGIN OF LIFE (E1.9)

E1.9-0001-18 THE EVOLUTION AND DISPERSAL OF PLANET-FORMING DISKS

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Disks of gas and dust around Myr-old stars are the birth sites of planets. Hence, their evolution and dispersal directly impact what type of planetary systems can form. I will review empirical constraints on disk evolution and dispersal with emphasis on those that come from disks caught in the act of clearing out planet-forming material. I will also discuss theoretical models that offer a physical interpretation and summarize their successes and shortcomings. I will conclude by highlighting which investigations are most promising to further constrain our physical understanding of disk evolution and dispersal.

E1.9-0002-18 THE SURFACE UV ENVIRONMENT ON PLANETS ORBITING M-DWARFS: NEED FOR EXPERIMENTS & IMPLICATIONS FOR ORIGINS-OF-LIFE CHEMISTRY

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Rocky, temperate planets orbiting M-dwarf stars are of intense astrobiological interest because they are the only potentially habitable worlds accessible to biosignature search over the next 10+ years (e.g., Proxima Centauri b, LHS1140 b, TRAPPIST-1 system). Simultaneously, recent experimental and theoretical work suggests that ultraviolet (UV) light may have played a key role in the origin of life on Earth, and especially the origin of RNA. Characterizing the UV environment on M-dwarf planets is crucial to understanding whether life as we know it could emerge on such worlds.

In this work, we couple radiative transfer models to observed M-dwarf spectra to determine the surface UV environment on prebiotic Earth-analog planets orbiting M-dwarfs. We calculate dose rates to quantify the impact of different surface UV environments on prebiotically important photoprocesses. We consider factors that could influence the surface UV environment, including flares, atmospheric surface pressure, and varying UV output early in the star's life.

We find that M-dwarf planets have access to 1000 times less bioactive UV fluence than the young Earth. It is uncertain whether UV-dependent prebiotic chemistry, such as recently discovered pathways for the synthesis of ribonucleotides and sugars, could function on UVpoor M-dwarf planets. Laboratory studies are required to determine whether UV-dependent prebiotic chemistry can proceed on M-dwarf planets and, if not, whether elevated UV irradiation during stellar flares can substitute.

Our work suggests a potential advantage for active M-dwarfs relative to quiet M-dwarfs as habitable planet hosts. Further, if laboratory studies confirm that UV-dependent prebiotic chemistry cannot proceed on M-dwarf planets, then biosignature searches on such worlds will empirically test whether UV light is required for the emergence of life.

E1.9-0003-18 UV IRRADIATION AND DISK WINDS: THE IMPACT ON DISK EVOLUTION

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The evolution and dispersal of protoplanetary discs is a key issue for understanding the star and planet formation processes. Photoevaporation processes play an important role and have been thoroughly analyzed. However, the role of outflows is often neglected. In this contribution, the role of disk-winds in disk evolution is analyzed. Magnetized disk winds are kept by ambipolar diffusion heating at a temperature of roughly 10,000 K. As a result, disks are illuminated from above (below) by thin veils of plasma. In this contribution, numerical calculations of the impact of the outflow radiation on the evolution of accretion disks is presented.

E1.9-0004-18 EXOPLANETARY RESEARCH IN THE UV

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Observing exoplanets in the ultraviolet enables the exploration of the outskirts of planetary atmospheres. Initial Hubble Space Telescope (HST) observations have shown that strongly irradiated gas giants experience atmospheric thermal escape (or "evaporation"). The refurbishment of HST during its last servicing mission, with the repair of the Space Telescope Imaging Spectrograph and installation of the Cosmic Origins Spectrograph, allowed extending these early results to a whole new class of planets in different masses and irradiation regimes. The discovery of a huge hydrogen cloud escaping from a gently irradiated Neptune-mass planets triggered renewed interest in the ultraviolet observation of transits and a window into the evolution of low-mass planets. This is of critical interest with respect to the "evaporation valley(s)" in the exoplanet population unveiled by the Kepler space telescope. I will review recent results and interpretation, especially from on-going observational efforts, including large HST programmes relevant to comparative exoplanetolgy, star-planet interaction and the search for water on habitable-zone planets.

E1.9-0005-18 EXPLORING HABITABILITY UNDER AN ENVIRONMENT OF STRONG SUPERFLARES AT A TIME WHEN THE OZONE LAYER FIRST FORMED ON EARTH

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Kepler-96 is an active solar-type star harbouring a Super-Earth planet in close orbit. Its age of 2.3 Gyr is the same as the Sun when there was a considerable increase of oxygen in Earth's atmosphere due to micro-organisms living in the ocean. We present the analysis of superflares seen on the transit lightcurves of Kepler-96b. The model used here simulates the planetary transit in a flaring star. By fitting the observational data with this model, it is possible to infer the physical properties of the flares, such as their duration and the energy released. We found 3 flares within the energy range of superflares, where the biggest superflare observed was found to have an energy of 1.81 1035 ergs. The goal is to analyse the biological impact of these superflares on a hypothetical Earth in the habitable zone of Kepler-96 assuming this planet has protection via different scenarios: an Archean and Present-day atmospheres. Also, we compute the attenuation of the flare UV radiation through an Archean ocean. The conclusion is that considering the increase in the UV flux by the strongest superflare emission, E. Coli and D. Radiodurans could survive on the surface of the planet only if there was an ozone layer present on the planet atmosphere. However, they could escape from the hazardous UV effects at a depth of 28m and 12m below the ocean surface, respectively. For smaller superflares contribution, D. Radiodurans could survive in the surface even in an Archean atmosphere with no ozone.

E1.9-0006-18 THE CORE PROGRAM CALL OF THE WSO-UV MISSION

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The World Space Observatory – Ultraviolet (WSO-UV) mission will be the only 2-m class UV telescope with capabilities similar to those of the HST for the decade after finishing HST mission because of the fact that no large UV-observatories are planned to be launched by most of space agencies in the coming 10 - 15 years. The large UVOIR observatories of the future will appear not earlier than in 2030s. The WSO-UV has been described in detail in many publications. Here we would like to present updated characteristics of its instrumentation as well as the current state of the project. The special attention is paid to the Core Program of the WSO-UV and tools for Core Program Application. We plan to announce a Call for the WSO-UV Core Program at the end of 2018.

E1.9-0007-18 CHARACTERIZING THE IN-FLIGHT PERFORMANCE OF UVIT INSTRUMENT AND STAR FORMATION PROPERTIES OF A GALAXY

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Ultra Violet Imaging Telescope (UVIT) is one of the instruments on India's first multi-wavelength mission, AstroSat, which provides a unique opportunity to observe the UV sky simultaneously in three channels. We have performed an independent characterization of the FUV and NUV detectors of UVIT payload on-board and found that the performance is close to that expected from the ground-based calibration. We have reduced and analysed the data using JUDE software and found that the photometric sensitivity is same as GALEX in the NUV broadband filter and about 35% that of GALEX in the FUV broadband filter. The PSF of the instrument is of the order of 1.2 to 1.6 arcsecs. We derived the distortion correction but recommend that it be applied post processing as part of the astrometric solution. Since the higher angular resolution, higher sensitivity and multiple filters of UVIT are well suited for the study of the detailed features of galaxies, the study of ultraviolet properties of a galaxy using UVIT data is in progress. The details of these studies will be presented during the meeting.

E1.9-0008-18 ULTRAVIOLET CHEMISTRY IN WARM LITTLE PONDS ON ROCKY PLANETS AROUND COOL STARS

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It is likely that the building blocks of life were generated photochemically from hydrogen cyanide and an anion in liquid water. The generation of these building blocks depends on the ultraviolet spectrum of the host star. Comparing the rates of photochemical formation of simple sugars from hydrogen cyanide and an anion in liquid water ('light chemistry') versus the bimolecular formation of insert adducts in the absence of light ('dark chemistry'), alongside UV spectra of a variety of stars taken from the MUSCLES database, we can determine an 'abiogenesis zone' outside of which the building blocks of life cannot form via known photochemical pathways. The abiogenesis zone can be determined in terms of stellar effective temperature and the planet's semi-major axis. Our results indicate that rocky planets around quiet M dwarfs will not be able to generate the building blocks of life photochemically. I will finish with a brief discussion on the implications our results have for active M dwarfs.

E1.9-0009-18 THE GROWING CASE FOR LIFE AS A COSMIC PHENOMENON

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A series of astronomical observations obtained over the period 1986-2017 are in striking evidence with the theory that comets harbour a viable biological component that led to the beginnings of life on Earth. These include (1) near infrared spectra of the dust from comet Halley obtained in 1986, (2) near and mid-infrared spectra of comet Hale-Bopp in 1997, (3) near and mid-infrared spectra of comet Tempel I in 2005, (4) the discovery of an amino acid and degradation products attributable to biology in the material recovered from the Stardust Mission in 2009, (5) jets from comet Lovejoy showing both a sugar and Ethyl alcohol and finally a diverse set of data from the Rosetta mission. The conjunction of all the available data points unerringly to the operation of cometary biology and interstellar panspermia rather than the much weaker claim of comets being the source of the chemical building blocks of life.

We conclude with specific predictions on the properties expected of extra terrestrial life if it is discovered on Enceladus, Europa and beyond. A radically different biochemistry elsewhere could be considered as a falsification of the theory of interstellar panspermia.

E1.9-0010-18 STELLAR DRIVERS FOR ATMOSPHERIC CHEMISTRY AND EVOLUTION: UV EXOPLANET CHARACTERIZATION FROM HUBBLE TO LUVOIR

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High-energy stellar photons and particles regulate the atmospheric temperature structure and photochemistry on orbiting planets, influencing the long-term stability of planetary atmospheres and the production of potential "biomarker" gases. In the first part of the talk, I will describe results from an ongoing panchromatic survey (Chandra/XMM/Hubble/ground) of M and K dwarf exoplanet hosts, focusing on two main results: 1) the evolution of the high-energy spectral energy distribution as a star's habitable zone moves inward from 1 to 0.1 AU, including implications for the possible abiotic production of the suggested biomarkers O2 and O3, and 2) new estimates of the high-energy particle fluxes (from CMEs/SEPs) from these stars based on solar UV flare/particle flux measurements. I will conclude by discussing UV spectroscopic characterization of exoplanetary systems in the era beyond Hubble. Using the UV capability and high sensitivity of future large space observatories, e.g, the Large/Ultraviolet/Optical/InfraRed Surveyor (LUVOIR) LUMOS spectrograph, we will not only be able to carry out high-fidelity host star characterization of every potentially inhabited planetary system studied by LUVOIR, we will also open the door to statistical-scale studies of atmospheric escape physics for the first time.

E1.9-0011-18 INVESTIGATING DIFFUSE ASTROPHYSICAL OBJECTS USING A MINIATURIZED UV SPATIAL SPECTROMETER

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We describe a spectroscopic program to probe the physical properties of several important classes of astrophysical objects in our galaxy and beyond, that, by their nature, are faint, extended and diffuse. These classes include the astrospheres around dying stars, the interstellar medium of our Galaxy, supernova remnants, and the circumgalactic medium around nearby galaxies. Traditional slit spectrographs lack the sensitivityfor detecting the faint UV emission that can be used to characterize the diuse, hot gas in these objects. We utilize a novel spectroscopic instrument, called the Spatial Heterodyne Spectrometer (SHS), which provides significant gains in sensitivity over a slit-spectrograph, and makes it possible (in a relatively short time) to study important UV lines with high-spectral resolution, in order to probe the diuse gas in these objects.

E1.9-0012-18 DESIGN AND ANALYSIS OF MECHANICAL SYSTEMS ON BOARD A 6U CUBESAT BASED UV SPECTROGRAPH FOR TRANSIENT STUDIES

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CubeSat Based payloads for scientific missions gain considerably over dedicated large scale scientific missions in terms of cost, time and launch opportunities. We have designed a UV Spectrograph on borad a 6U CubeSat for a Lower Earth Orbit (LEO) mission, such a CubeSat provide a versatile platform to conduct a survey of FarUV (FUV) region. Survey of FUV region can provide insight into understanding of transient events such as Supernove, Novae and dynamics as well as evolution of 'hot gas' in our galaxy and interstellar medium etc. The instrument has a spectral coverage from 120 to 320 nm with a medium resolution of 5000. The detector is a GaN - Micro Channel Plate (MCP) based detector with photon counting capability. Mechanical structure and majority of sub-systems were made with Carbon fibre Reinforced Polymer (CFRP). CFRP was choosen due to its high tensile strength and low thermal expansion properties. In this work we present the aspects involving the design of mechanical structure and Finite Element based Stress, vibrational and thermal analysis of the various components of the payload and the entire assembly.

E1.9-0013-18 CUBESAT BASED UV SPECTROGRAPH (CUBS)

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CubeSats provide affordable launch opportunities and it is a cost-effective solution for space astronomy. CubeSats based payloads can make significant observations at the relatively underexplored regions of the UV spectrum. CubeSat Ultraviolet Bright Spectrograph (CUBS) is a near ultraviolet (200-300 nm) spectrograph designed to fit into a 2U CubeSat. The aggressive timeline drives the design to include only off-the-shelf items to minimize procurement delays and cost. The grating used is a ruled UV grating with 600 lines/mm with an efficiency of more than 65CUBS primary scientific objective is to look for M-Dwarf UV flares and this UV activity will have a strong impact on the habitability of any possible planet around the star. UV light may have played a key role in the origin of life on Earth and characterizing the UV environment on M-dwarf planets is important for understanding the potential habitability. Another interesting scientific objective is to look at the origin of the 2175 A° extinction bump. To detect the strength of extinction bump CUBS will acquire the spectrum of bright stars in the wavelength range 200-300 nm. CUBS will also acquire NUV spectrum of solar system objects which are not usually observed by other space telescopes because of brightness limitations, a CubeSat size spectrograph could look at solar system objects and even comets close to its perihelion. The main challenges in the design of the instrument were to use only off-the-shelf items and the size and weight constraints imposed by CubeSat standards. We will describe the scientific potential of CUBS and the various aspects of instrument design and development.

E1.9-0014-18 ROUND TABLE ON JOINT INITIATIVES ON CUBESAT SIZE PROJECTS

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Round Table on Joint Initiatives on CubeSat size projects

E1.9-0015-18 COMPUTATIONAL TEST ON BIOMARKERS DETECTABILITY IN EXOPLANETS ATMOSPHERES WITH WUVS

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Transmission spectroscopy of exoplanets in the UV is a promising tool for the characterisation of Earth-like atmospheres. In particular, large abundances of molecular oxygen and ozone can be used as spectroscopic biosignatures on Earth. We want to tackle the detectability of biomarker species with the World Space Observatory - Ultraviolet (WSO-UV) instrumentation through simulations of transiting exoplanets.

The WSO-UV is a space telescope to be launched in 2023, equipped with a high resolution spectrograph (WUVS - WSO UltraViolet Spectrograph) that provides high resolution spectroscopy (R 55,000) to observe point sources in far and near UV. The spectral ranges of each channel, VUVES (102-180 nm) and UVES (174-310 nm), are in good agreement with the O2 and O3 spectral bands in the Earth atmosphere.

The detectability of these species in an exoplanet atmosphere can be evaluated from an appropriate overall instrument model through simulations of the expected observations. The instrumental performance of the observatory can be evaluated in terms of noise source response, data quality, and number of counts detected for different types of observing configurations. We have developed a WSO Simulator tool that includes each of the channels of the observatory for the validation of the expected instrumental response. This tool includes new functionalities as a response to the community to the preparatory activities prior to the launch of the mission. The simulator also allows for testing the feasibility of the scientific programs and as a preparatory step for the scientific data processing.

The WSO Simulator was implemented as a further development of the PLATO Simulator, but it has been adapted to the instrument specific characteristics of WSO-UV. In this work we discuss the WUVS echelle spectrographs. The implementation details of the WSO Simulator and the model describing the host star, the exoplanet, and its atmosphere are also described here.

Taking a host star-exoplanet configuration similar to Sun-Earth and an Earth atmosphere model, we use the WSO Simulator to generate synthetic time series of the resulting observations. Further analysis on the outcome of these images is provided, including the detectability of the molecular oxygen and ozone.

E1.9-0016-18 THE ROLE OF THE VISCOSITY ON THE DISPERSAL OF IRRADIATED PROTOPLANETARY DISCS

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The study of planet formation processes and life emergence in the Universe relies on the study of the evolution of the Pre-Main Sequence Stars (PMS stars). The available observational data point to the ubiquitousness of protoplanetary discs on these stars. These discs are the natural scenario for planet formation processes, and understanding their evolution and the mechanisms and time-scales by which the disc is eventually dispersed is a key issue in planet formation theories. The disc evolution and dispersal influences planet formation. Changes in the accretion processes modify the disc's chemistry, the dust-to-gas ratio and can starve the gas reservoir available for planet formation. The gas giant and terrestrial planets begin to form in between the accretion and post-accretion phases of the disc. Therefore, it is very important to analyse the mechanisms driving the accretion rate shutdown.

A first approach to this problem focuses on modelling the transport of angular momentum in the disc as a viscous process. This model can be enhanced by adding the effect of UV and RX gas photoevaporation. These photoevaporation processes, coupled with the viscous evolution, produce a gap in the inner disc at the point when the photoevaporation rate and the accretion rate become comparable, making it a convenient way to shutdown the mass accretion. The observed pile-up of Jupiter-mass planets can be also explained by the interaction between migrating planets and the gap-opening due to this photoevaporation. Unfortunately, the viscosity mechanism driving the disc evolution is not fully understood. Traditionally, these uncertainties have been bypassed through the use of the α-parametrisation introduced by Shakura and Sunyaev. However, the most adequate value (if any) for α has not been settled yet. A common value is $\alpha = 0.01$, because it provides evolutionary time-scales in line with some known properties of discs. But, one can find a wider range of values in the literature, ranging from 0.1 to 0.001 and even lower.

Our work addresses the impact of these viscosity values on some diagnostic tools that are used when comparing observational and theoretical data. We have implemented a grid of disc models, with the disc mass, the star mass and the stellar radiation (EUV and RX) as parametric space. We have evolved every grid system under different viscosity values. Then, we have compared the results with observed systems. As the viscosity decreases, the models get closer to the observed values more easily than when the values are higher. We describe the changes in the slopes of the relationships between accretion rate against disc mass (and also against stellar mass), with and without the effect of photoevaporative winds. The slopes of these relationships change with the age of the system. But, because these time-scales depend on the disc and stellar mass, the slopes change with these parameters accordingly. Moreover, these changes are more or less noticeable as the viscosity changes.

Our results indicate that, as foreseen, matching viscous models with observed systems is not trivial, and the results strongly depend on α. However, the analysis of how the theoretical curves evolve along the grid of models allow to better select the viscosity values in every case. And the study of the gap opening and the accretion shutdown times-scales in the grid provides some constraints for planet formation processes. Finally, we note that the EUV luminosities of stars are very poorly known at typical star-forming region distances, and they are at best indirectly determined. Because our simulations indicate they play a key role in disc evolution, one may conclude that future UV missions are required for providing further data in this area.

E1.9-0017-18 COATINGS FOR IMPROVED FAR-UV ASTROPHYSICS OBSERVATIONS

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Knowledge of temperature, densities, and chemical abundances of hot plasmas that exist in stars including the Sun, in the interstellar and intergalactic medium, and in active galactic nuclei can be optimally determined through observations in key diagnostic spectral lines, many of which are in the far ultraviolet range (FUV, 100-200 nm), such as the Lyman series of atomic Hydrogen and Deuterium, and the Lyman bands of their molecules, along with lines of OI and OVI, CIV, etc. For habitable exoplanet search, the FUV spectrum of M stars is a useful diagnostic tool of biologically generated gases in planet atmospheres. Measuring the magnetic field in the different layers of the Sun's atmosphere can be optimally performed by means of polarimetry in the FUV and in the UV. The development of more efficient FUV coatings is key to advance in many fields of astrophysics and solar physics. With this goal, GOLD (Spanish acronym of Thin Film Optics Group) has been devoting a long effort to develop highperformance coatings to address specific targets. In this poster, GOLD's capacity to develop and measure FUV coatings will be summarized. A 75-cm diameter chamber in an ISO-6 clean room is used to prepare FUV coatings satisfying space requirements. The main deposition technique is evaporation and ion-beam-sputtering is also available. Coating performance is conveniently measured with an in-house reflectometer covering the 40-190 nm spectral range. The presentation will display the performance of FUV coatings that can be prepared at GOLD:

Transmittance filters peaked at Λ 120 nm with a strong peak-to-visible rejection

Broadband mirrors with enhanced FUV reflectance

Narrowband mirrors tuned at FUV wavelengths as short as H Lyman β (102.6 nm)

Polarizers at H Lyman α (121.6 nm) and other FUV and UV spectral lines

Research in Astrophysics from Space (E)

Structure, Evolution and Dynamics of Neutron Stars (E1.10)

E1.10-0001-18 MULTI-WAVELENGTH FACILITIES FOR NEUTRON STAR RESEARCH

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Neutron stars are, in general, emitters of electromagnetic radiation over a very broad range of wavelengths. These sources also exhibit rapid multi-wavelength flux variability. Simultaneous or near-simultaneous observations of this variable emission reveal in detail the physical processes at play in and around these objects. Timely access to observing facilities spanning many wavebands is crucially important for this line of research, but this remains a difficult logistic challenge. This talk will present an overview of the facilities available for multi-wavelength rapid variability studies, with focus on broadband, fast-timing platforms such as AstroSat and Insight-HXMT.

E1.10-0002-18 OBSERVATIONAL TESTS OF ACCRETION-DRIVEN SPIN-UP/DOWN PROCESS IN X-RAY BINARY PULSARS WITH 7-YEAR MAXI AND FERMI/GBM DATA

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The relation between the luminosity and the spin-period change in X-ray binary pulsars reflects the manner of mass accretion onto the magnetized neutron stars, and thus provides us information on the neutron-star physical parameters related to the mass M, radius R, and the surface magnetic field B. To observationally study the relation, we analyzed X-ray light curves obtained by the MAXI all-sky survey and pulse-period data taken by the Fermi Gamma-ray Burst Monitor pulsar project, both continuously cover 7 years since 2009 August.

In 4U 1626-67, a low-mass X-ray binary pulsar which repeated transitions between spin-up and spin-down phases every few ten years, the observed relation between the X-ray intensity and the pulse-period change has been successfully explained by the disk-magnetosphere interaction model proposed by Ghosh & Lamb (1979), including both the spin-up to the spin-down phases over the past 6 years. Assuming a distance of 10 kpc and using the surface magnetic field

B measured with the cyclotron resonance, the model indicates the mass M =1.8-1.9M0 and the radius R =11.4-11.5 km (Takagi et al. 2016). Thus, the method provides a new way of constraining the mass-radius relations.

For a more systematic study, we selected 12 Be binary pulsars which showed, in these 7 years, large outbursts with the peak luminosity exceeding 1037 erg s−1. In all the 12 objects, the luminosities and the spin-frequency derivatives, observed during the outbursts, were found to follow positive correlations that are close to the proportionality, as expected by most of the theoretical models. The coefficient of the proportionality agrees, within a factor of 3, with the prediction by the Ghosh & Lamb (1979) when assuming a typical mass and radius, and employing the surface magnetic field measured with the cyclotron resonance. The scatter of the observed coefficients around the model predictions is reasonably explained by uncertainties in the pulsed-emission anisotropy and the distance estimate (Sugizaki et al. 2017).

After calibrating the theoretical model, we also analyzed the data of X Persei, the Be binary pulsar with a low luminosity (S 2 1035 erg s−1), which once showed a transition from the spindown to spin-up in 2002 (Lutovinov et al. 2012). Although the Ghosh & Lamb (1979) model again successfully explained the observed relation between the luminosity and the spin-period change covering both the spin-up and spin-down phases, the data require a strong magnetic field

B 1013 G as well as a relatively high mass M 1.7M0. These results point to an intriguing possibility that X Persei is a magnetar-equivalent object in a binary, and such strong-field neutron stars possibly have somewhat higher mass than the ordinary ones with B ~ 1012 G.

E1.10-0003-18 EFFECTS OF THERMONUCLEAR X-RAY BURSTS ON NON-BURST EMISSIONS IN THE SOFT STATE OF 4U 1728-34 USING ASTROSAT/ LAXPC

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The continuum spectrum from Neutron Star thermonuclear bursts can be used to measure the neutron star radius, which is a crucial parameter in probing the nature of the degenerate core matter of neutron stars. During a thermonuclear burst, we see a significant enhancement of the neutron star's persistent emission, the cause for which is not conclusively known. In this work, we attempt to comprehend the reasons for the evolution of persistent emission, as seen during the thermonuclear bursts in the soft state of 4U 1728-34. For the first time, we employ the Large Area X-ray Proportional Counter (LAXPC) instrument aboard AstroSat for such a science goal. The large surface area of LAXPC combined with its fine timing resolution allows us to probe the evolution of persistent and burst spectra within the short timescales of different phases of the burst. Our analysis shows that, the burst emission is not reprocessed by the corona covering the neutron star. Rather, the burst emission increases the accretion rate perhaps due to Poynting-Robertson drag on the accretion disk, and the resulting enhanced disk emission gets Comptonized by corona covering the disk. This finding provides a way to distinguish between the burst and non-burst emissions, which is necessary to reduce the systematics associated with neutron star radius measurements.

E1.10-0004-18 NASA'S NEUTRON STAR INTERIOR COMPOSITION EXPLORER (NICER): MISSION OVERVIEW AND INITIAL RESULTS

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Keith C. Gendreau, Craig B. Markwardt, and members of the NICER Science Team's topical Working Groups

In operation since July 2017 as an external attached payload on the International Space Station, NICER is the first high-energy astrophysics mission devoted to the study of neutron stars in their many guises. Offering a unique timing-spectroscopy capability in the soft X-ray (0.2–12 keV) band, NICER has observed a wide variety of rotation-, accretion-, and magneticallypowered neutron stars with the key aims of constraining the dense-matter physics of their interiors, understanding the processes that drive dynamic internal and external phenomena, and probing thermal and nonthermal emission mechanisms. We provide an overview of the instrumentation and performance that enable NICER's science objectives, and highlight results from the mission's first year of operations.

E1.10-0005-18 NICER VIEW OF THERMONUCLEAR X-RAY BURSTS AND BURST OSCILLATIONS

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The Neutron Star Interior Composition Explorer (NICER) is NASA's new X-ray timing instrument onboard the ISS that was launched in June 2017. With a large effective area, low background, very precise absolute timing and great low energy response, NICER has been doing a fantastic job in observing many interesting phenomena related to neutron stars and black holes. One of the main objectives of the NICER mission is to study phenomena related to Type I X-ray bursts, which are thermonuclear flashes observed from the surfaces of accreting neutron stars in Low Mass X-ray Binaries, such as photospheric radius expansion and burst oscillations. NICER's large effective area and excellent low energy response enable new, detailed studies of these bursts in the soft X-ray band. In this talk I will present some of the early results from the first year of the NICER mission regarding Type I X-ray bursts and searches for burst oscillations.

E1.10-0006-18 CHARACTERIZING THE PROPERTIES OF NEUTRON STARS IN THE NUSTARNICER ERA

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Over the past several years we have been able to perform inner disk measurements with NuSTAR that are unbiased by pile-up effects. From these measurements we are able to infer different properties about the neutron star itself, such as magnetic field strengths, boundary layers, and constraints on the equation of state. Observations of a number of neutron stars over range of Eddington ratios has allowed us to probe the extent of the inner disk over a range of mass accretion rates. There does not appear to be a clear trend between mass accretion rate and the location of the inner disk radius, consistent with several previous studies that were complicated by pile-up effects. When comparing the magnetic field strengths from reflection modeling methods to those seen for accreting millisecond X-ray pulsars (AMXPs), we find the magnetic field strengths to be consistent over comparable Eddington ratios; demonstrating that Fe lines can be used to place limits to first order. With the addition of NICER, we gain access to lower energy features below 3 keV that are also free from pile-up effects. Utilizing the combined bandpass and sensitivity of both NuSTAR and NICER opens a new opportunity to capture multiple emission features arising from bright sources to map out different observables within the disk and disentangle truncation mechanisms in systems.

E1.10-0007-18 THE EQUATION OF STATE OF NEUTRON STARS

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The interiors of neutron stars present conditions of extremely high density at sub-Fermi temperatures, analogues of which are so far not reproducible in laboratory experiments. The exact nature of strong interaction at such close packing remains unknown, and this has led to a rich variety of predictions for the Equation of State (EoS) of neutron stars over many decades. Recent observations of pulsars, X-ray binaries and Gravitational Wave events hold much promise to narrow down the acceptable range of possible EoS. In this talk I will review the broad physics inputs in different families of Equations of State, and what remains viable in the light of existing observational constraints.

E1.10-0008-18 A 2.3 SOLAR-MASS NEUTRON STAR

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The macroscopic properties of neutron stars depend on how sub-atomic particles interact in their interiors. These interactions, encoded in the equation of state, are specially uncertain in the central regions, where densities exceed that of an atomic nucleus. The maximum mass of a neutron star can discriminate between proposed equations of state. New millisecond pulsars in compact binaries provide a good opportunity to search for the most massive neutron stars. We present observations and detailed modeling of an extremely irradiated companion to a millisecond pulsar, using the largest optical telescope on Earth. We develop and apply a new method to measure the velocity of both sides of the companion star, and find that the binary hosts one of the most massive neutron stars known to date, with a mass of 2.27+0.17−0.15 MSun. A 2.3 Solar-mass neutron star would rule out most currently proposed equations of state, casting doubt on the existence of exotic forms of matter in the core.

E1.10-0009-18 PARAMETRIC HOT EQUATION OF STATE FOR NEUTRON STARS

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Observations of neutron stars provide one of the best ways of probing the ultra-dense matter equation of state (EOS). While many theoretical models of the cold EOS have been formulated, only a small number of EOS that include thermal effects have been calculated. However, such hot EOS are a necessary component for simulating and understanding observations from neutron star mergers, short gamma-ray bursts, or the formation of proto-neutron stars. In this talk, I will present a new parametric hot EOS that we have developed. This parametrization of thermal effects can be added to any cold EOS, even with no detailed knowledge of the particle potentials or interactions. I will compare our parametric hot EOS to existing models in order to highlight the wide range of physics that our parametrization can span, using a small number of physically-motivated parameters.

E1.10-0010-18 EVOLUTION OF NEUTRON STARS IN PROGENITORS OF BINARY MERGER GW SOURCES

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Evolution of binaries leading to mergers that are observable gravitational wave sources will be reviewed with particular attention to the formatıon and evolutıon of neutron stars in such binaries.

E1.10-0011-18 THE RADIUS OF THE QUIESCENT NEUTRON STAR IN THE GLOBULAR CLUSTER M13

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X-ray spectra of quiescent low-mass X-ray binaries (qLMXBs) containing neutron stars can be fit with atmosphere models to constrain the mass and the radius. Mass-radius constraints can then be used to place limits on the equation of state of dense matter. However, derived radius constraints depend heavily on the distance to the neutron star, a quantity which is often difficult to constrain without parallax measurements. We therefore turn to qLMXBs in globular clusters, whose distances are known to within 5 10%. We perform fits to the X-ray spectrum of a quiescent neutron star in the globular cluster M13, utilizing data from ROSAT, Chandra and XMM-Newton, and constrain the mass-radius relation. Assuming an atmosphere composed of hydrogen and a 1.4M0 neutron star, we find the radius to be 12.2+1.5

km, a significant improvement in precision over previous measurements. I will discuss how the composition of the atmosphere affects the derived radius, finding that a helium atmosphere implies a significantly larger radius. I will also discuss the results in the context of the recent binary neutron star merger, GW170817, which provided limits on the tidal deformability of neutron stars, in turn implying limits on the neutron star radius that are in agreement with our measurements for M13.

E1.10-0012-18 TESTING NUCLEAR PHYSICS FROM SPACE WITH QUIESCENT LOW-MASS X-RAY BINARIES

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X-ray observations of quiescent low-mass X-ray binaries (qLMXBs) provide one of the methods to understand the internal structure of neutron stars and therefore place constraints on the nuclear physics of dense matter. The hot thermal emission from the surface of neutron stars in qLMXBs permits measurements of the neutron star radius. In the past few years, promising results were obtained from statistical analyses that combined the X-ray spectra of qLMXBs. These analyses have required simplistic or analytical parametrizations of the Equation of State of dense matter (the relation between pressure and density of matter). In this talk, I will summarize these previous results, and present new constraints obtained from the direct confrontation between a realistic parametrization of the equation of state and the astrophysical data from qLMXBs In an effort to be conservative with the observational constraints, I will also discuss the current limitations of the qLMXB method, and how they can be overcome with more observations of qLXMBs with current and future instrumentation.

E1.10-0013-18 FUNDAMENTAL PHYSICS WITH RADIO PULSARS

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In this talk, I will summarize some recent advances in the study of gravity, gravitational waves and nuclear physics that have emerged from the study of radio pulsars. These include extremely precise tests of general relativity from pulsar - neutron star binaries, constraints on the nature of gravitational radiation from timing of pulsar - white dwarf systems (binary and triple), and constraints on the strong nuclear force from mass measurements and limits on the moment of inertia of a few pulsars. I will offer some perspectives on future advancements on these topics, particularly in the context of upcoming work with ground-based gravitational wave detectors.

E1.10-0014-18 ENIGMATIC MODE-SWITCHING PULSARS POSE CHALLENGES TO PULSAR EMISSION THEORIES

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Simultaneous X-ray radio observations of three radio-mode switching pulsars revealed enigmatic results that pose challenging questions to pulsar emission theories. Synchronous X-ray and radio mode switching was discovered for the old and nearly aligned PSR B0943+10 (Hermsen et al. 2013). When this paragon of pulsar mode switching switches from a radio “bright” mode to a radio “quiet” mode, the X-ray flux in anti-correlation increases by a factor of 2.4 and the pulsed fraction changes in magnitude and as a function of energy (Mereghetti et al. 2016). But, in an X-ray radio campaign on the nearly orthogonal radio-mode switching PSR B1822-09 no evidence was found for mode switching in X-rays (Hermsen et al. 2017). Most surprisingly, for another nearly orthogonal pulsar, PSR 0823+26, we recently discovered correlated synchronous X-ray radio mode switching. The results might be broadly consistent with predictions of local phenomenon at the polar cap, but might also imply global magnetospheric rearrangements as proposed in radio studies of intermittent pulsars.

All three middle-aged/old pulsars exhibit thermal pulsed emission with very high pulsed fractions (up to about 80%) which cannot be modelled with isotropic thermal emission from hot spots on the magnetic poles. Magnetized partially ionized hydrogen atmosphere models can explain the observed general X-ray characteristics. However, we showed that the geometry (viewing angle and magnetic axis w.r.t. the rotation axis) derived from the X-ray data are not consistent with that derived from radio data. For an explanation, one might speculate that multi-pole fields near the star cause the radio and X-ray polar caps not to be in the same location.

Co-authors of the presentation are authors of Hermsen et al. (2018)

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E1.10-0015-18 THE POPULATION OF GALACTIC X-RAY BURSTERS AS SEEN BY INTEGRAL OVER 14 YEARS IN SPACE

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Type-I X-ray bursts are thermonuclear explosions on the surface of weakly magnetized accreting neutron stars (NS) in Low-Mass X-ray Binary (LMXB) systems where the mass donor is typically an evolved star. Observationally, X-ray bursts can show a large variety in profiles, but generally they exhibit a fast rise and a longer, usually power-law like, decay. Burst rise times vary from less than a second to 10 s, and decay times are in the range of seconds to minutes. Bursts radiate X-ray spectra with blackbody shapes, (kT 3 keV) that cool during the burst decay.

The Joint European Monitor for X-rays (JEM-X) onboard INTEGRAL is a coded-mask instrument operating in the 3-35 keV energy range, where the bulk of the X-ray burst energy is released. JEM-X provides a fully-coded field of view of 4.8 $\times$ 4.8 degrees, which allows concurrent monitoring of several X-ray bursters in one pointing.

In this talk I will provide an overview of the results of 14 years of INTEGRAL observations of the population of Galactic X-ray bursters.

E1.10-0016-18 TYPE-I X-RAY BURSTS: WHERE ARE WE (HEADED)?

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It is almost time for celebration. It is almost 50 years ago that the first thermonuclear shell flash from a neutron star was detected as a type-I X-ray burst. While it took years between the detection of the first and second event, X-ray bursts are now detected once or twice a day on average, from a population of roughly 100 neutron stars in the Galaxy. Much has been learned and the learning curve has not flattened yet about the unstable thermonuclear fusion of hydrogen, helium, carbon etc. in the upper 100 m of neutron stars. Concept X-ray observatories such as eXTP (China and Europe) and Strobe-X (USA) can revolutionize the field by enabling detailed studies of, among others, flame spreading over the neutron star surface and constraining the equation of state of neutron star matter. We review the state and future of this field of research.

E1.10-0017-18 THE DEPENDENCE OF THE RATE OF TYPE I BURSTS ON ACCRETION AND SPIN RATE

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The Type I Bursts are stupendous X-ray flashes from accreting neutron stars that are emitted when the accumulated matter undergoes a thermonuclear runaway which spreads over the whole surface of the star.

Nuclear burning and its dependence on the mass accretion rate are fundamental ingredients for describing the bursts complicated observational phenomenology. While theory predicts that the burst rate should constantly increase with increasing accretion rate until stabilization, many sources eventually experience decreasing burst rate versus increasing accretion rate.

I will show how, by considering different conditions across the stellar surface as a function of accretion rate and spin frequency, it is possible to resolve this apparent contradiction between theory and observations and I will discuss the implications of this scenario for our understanding of nuclear burning on neutron stars.

E1.10-0018-18 INSIGHT-HXMT AND SWIFT OBSERVATIONS OF RAPID BURSTER: TYPEI & TYPE-II X-RAY BURSTS BEHAVIOR

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Type II X-ray bursts remain largely a puzzle, only detected in two sources: Rapid Burster (MXB 1730-335,hereafter RB) and Burst Pulsar. We performed a visual inspection of all the HXMT and Swift/XRT light curves of RB. In total, from the RB, we identified 4 type I and 450 type II bursts by Swift/XRT, 321 type-II X-ray bursts by HXMT/LE. 1. Among them, 2 type-I X-ray bursts shows photospheric radius expansion (PRE), which is the only two PRE burst in this source since RB was discovered, and the second PRE burst is the first time reported. Here we report on the two PRE bursts, which allows us to constrain the mass and radius of the neutron star in RB. 2. All the type-II X-ray bursts spectra are combined, and the combined spectra are well fitted by absorbed two blackbody with BB temperatures of 0.3 and 1.7 keV,or absorbed nthcomp. The two BB, are thought to corresponding to the accretion disk and surface of neutron star, such explanations seem at odds with the observed phenomena that a type I burst taking place during a type II burst, because there is only one neutron star surface. We prefer the nthcomp model, i.e., the type-II bursts are only from the disk.

E1.10-0019-18 FORMATION AND STABILITY OF OSCILLATING SHOCKS IN INVISCID ADVECTIVE FLOWS AROUND NEUTRON STARS IN PRESENCE OF COOLING USING SMOOTHED PARTICLE HYDRODYNAMIC SIMULATIONS

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We use the Smoothed Particle Hydrodynamics (SPH) method to simulate the behavior of inviscid flow accreting on a neutron star. For black holes, the lack of any hard surface allows matter to advect in supersonically. For neutron stars, however, the presence of a hard surface requires matter to settle down on the surface with zero radial velocity, essentially making the flow subsonic. Apart from this, near the compact object, the flow should be similar in both the cases. During the hard spectral state, the incoming flow has a negligible viscosity, leading to the absence of any disk blackbody emission. In such a state, the flow can be assumed to be purely inviscid for the computational purpose. We show that for a purely inviscid advective flow having angular momentum, the solution allows two shocks in the flow. The outer one, forms due to strong centrifugal barrier and is called CENtrifugal pressure dominated Boundary Layer or CENBOL, which is a common feature for both neutron stars and black holes. The inner shock forms very close to the surface of a neutron star, due to the presence of the physical boundary. We study 1) the formation of steady shocks in 2D, in absence of any cooling process, 2) the formation and variation of winds from the post-shock region when the angular momentum of the flow varied, 3) shock formation in strong winds, 4) the radial oscillation of shocks when cooling effects are added, 5) formation of asymmetries w.r.t. the Z=0 plane and instabilities due to the interaction of inflow and outgoing strong winds which leads to vertical oscillations,

6) the oscillation of NBOL and the variation of effective surface temperature when stronger cooling effects are present and accretion rate is varied. Our results capture both the low and high-frequency quasi-periodic oscillations observed in the power density spectra for the case of accretion around a neutron star.

E1.10-0020-18 IGR J17329-2731: THE BIRTH OF A SYMBIOTIC X-RAY BINARY

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I will report on the results of the multi-wavelength campaign carried out after the discovery of the INTEGRAL transient IGR J17329-2731. The optical data collected with the SOAR telescope allowed us to identify the donor star in this system as a late M giant at a distance of 2.7(+3.4,-1.2) kpc. The data collected quasi-simultaneously with XMM-Newton and NuSTAR showed the presence of a modulation with a period of 6680±3 s in the X-ray lightcurves of the source. This unveils that the compact object hosted in this system is a slowly rotating neutron star. The broad-band X-ray spectrum showed the presence of a strong absorption (10^{23}cm^2) and prominent emission lines at 6.4keV, and 7.1keV. These features are usually found in wind–fed systems, with the emission lines resulting from the fluorescence of the X-rays from the accreting compact object on the surrounding stellar wind. The presence of a strong absorption line around ~ 21 keV in the NuSTAR spectrum suggests a cyclotron origin, thus allowing us to estimate the neutron star magnetic field as ~ 2.4×10^{12} G. All evidence thus points to IGR J17329-2731 being a symbiotic X-ray binary. As no X-ray emission was ever observed from the location of IGR J17329-2731 by INTEGRAL during the past 15 yr in orbit and considering that symbiotic X-ray binaries are known to be variable but persistent X-ray sources, we concluded that IGR J17329-2731 was most likely caught by INTEGRAL when the source shined as a symbiotic binary in X-rays for the very first time. The Swift XRT monitoring performed up to ~3 months after the discovery of the source, showed that it maintained a relatively stable X-ray flux and spectral properties. This supports the idea that IGR J17329-2731 might have become a persistent X-ray source in our Galaxy.

E1.10-0021-18 LOW ENERGY X-RAY LINE EMISSION FROM HER X-1: XMM-NEWTON/RGS OBSERVATIONS AROUND THE TURN-ON

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Her X-1 is a bright intermediate-mass X-ray binary system consisting of a pulsar with a 1.24- s rotational period and a 1.7-d orbital period. The neutron star accretes matter from its A/F donor through an accretion disk. The accretion disk is warped, tilted, and precessing causing a 35-d variation cycle that affects the emission from the central source. This 35-d cycle is characterised by states of high X-ray flux (main-on and short-on) and low-states with intensity of 3% of the main-on intensity. During the turn-on of the main-on the accretion disk completely opens up our view onto the neutron star. During this time we are able to observe emission directly from the central source, and scattering and absorption features caused by an atmosphere. We observed Her X-1 four times during this phase. We will present RGS data analysis, showing the detected lines at specific stages before, during, and after the turn-on. Measurements of the line evolution at each stage enables us to constrain the emission region and measure the structure and geometry of the disk atmosphere.

E1.10-0022-18 REVISITING SCO X-1 WITH KEPLER, MAXI AND HERMES

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Sco X-1 has been the subject of many multi-wavelength studies in the past, being the brightest persistent extra-solar X-ray source ever observed. Here I will revisit Sco X-1 and present simultaneous short cadence Kepler optical photometry, MAXI X-ray photometry and highresolution optical spectroscopy obtained with HERMES, over a continuous 78-day period. By characterising the highly variable nature of the dataset, I will show how the optical fluxes display a clear bimodality associated to two distinct optical states. These states display substantially different optical power spectral densities, and can be associated to the known flaring/normal branch X-ray states. Furthermore, by performing an optical/X-ray cross-correlation, I will show how a broad 12.5 hour optical lag is detected in the dataset, and discuss this in terms of a possible disk thermal reprocessing mechanism. This scenario is also supported by an echo detection in the optical lightcurve alone using the Cepstrum, which will also be introduced.

E1.10-0023-18 FALLBACK DISKS IN NEUTRON STAR EVOLUTION

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Evolution of neutron stars with fallback disks could produce rather different source properties due to the differences in the initial conditions of the systems (magnetic dipole moment, initial period, and disk mass). In addition, sources with similar initial conditions could exhibit dissimilar properties in different phases of the long-term evolution. We summarize the fallback disk model illustrating the effects of the initial conditions and the transitions between the accretion and the propeller phases on the long-term X-ray luminosity and the rotational properties of the neutron stars. We also present the results of the model applications to individual sources from different neutron star populations.

E1.10-0024-18 ON THE OPTICAL EXCESS OF DIM ISOLATED NEUTRON STARS

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The large optical excess in the spectrum is one of the defining characteristics of dim isolated neutron stars (XDINs). We have studied the optical excess of XDINs in the context of the fallback disk model. In this model, XDINs are neutron stars that evolve in the propeller phase, slowing down by the magnetic torques resulting from the disk-field interaction. In this work, we have shown through spectral fits that the optical excess of XDINs can be produced from the inner disk being heated by magnetic stresses. The blackbody temperature of the heated inner rim of the disk is higher than the temperatures sustained by X-ray irradiation and viscous dissipation alone. Since XDINs are in similar evolutionary phases, it is expected that they have similar torque mechanisms and ratios of the magnetic work that heats up the inner disk. Consistently with this idea, we have found that a similar and significant fraction of the work done by the magnetic torques can explain the optical excess of all XDINs. We have also found that heating by X-ray irradiation is negligible compared to the effects of magnetic heating. We propose that this is a common property of the systems with rotational power to LX ratios greater than about 10−2.

E1.10-0025-18 NEUTRON STARS AND THEIR ENVIRONMENTS IN THE INFRARED: THE INTRIGUING CASE OF RX J0806.4-4123

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Most of our current constraints on neutron star structure and evolution are obtained from radio and high-energy observations. Few pulsars have been detected so far at optical or infrared wavelengths. Yet, these observational windows can provide valuable insights into the physical properties of neutron stars and their environments. At these wavelengths, in addition to studying magnetospheres and pulsar wind nebulae, one can also find and characterize (stellar and substellar) companions, or investigate circumpulsar disks. After an overview of the current observational constraints on neutron star properties from infrared observations, I will present our recent discovery and interpretation of extended near-infrared emission at the position of a nearby isolated neutron star. Finally, the talk will include an outlook on future infrared instrumentation capabilities and their relevance for neutron star exploration.

E1.10-0026-18 MAGNETARS' EVOLUTION

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I will review the latest results on magnetars' observations with particular attention to their outburst activity. I will show how their emission is in line with magneto-thermal evolution models, as well as connected with other classes of neutron stars.

E1.10-0027-18 RETURN CURRENT HEATING OF NEUTRON STAR ATMOSPHE

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Rotation-powered X-ray pulsars display pulsed emission originating from polar caps heated by incident particles from the magnetic return current. We model the atmospheric conditions in the polar caps under the influence of this energetic particle flux. We calculate the temperature profile of the atmosphere as well as the beaming function and spectrum of the emission. Highenergy particles penetrate to large optical depths, leading to a typical deep-heating radiative equilibrium atmosphere, while low-energy particles heat the upper regions of the atmosphere, leading to a temperature inversion. The resulting beaming patterns can significantly affect observed pulse profiles.

E1.10-0028-18 ATMOSPHERE OF MAGNETARS UNDER PARTICLE BOMBARDMENT

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Transient or persistent magnetars have strong surface magnetic fields B 1014 1015 G, and these fields could sustain large currents of charged particles in the star's magnetosphere. The charged particles attain very large Lorentz factors and they will flow back to the stellar surface moving along the magnetic field lines. The bombardment of these energetic particles lead to energy deposition, which in turns heats the stellar atmosphere. As such the radiation from the star would be substantially enhanced, surpassing the power expected for the radiation from a passively cooling neutron star. In this talk I will discuss radiation transport in an atmosphere heated by particle bombardment. Our calculations assume that the charged particles are stopped via magneto-coulomb interaction within the atmospheric layer. The particular case of a magnetized, grey (frequency integrated) atmosphere and the observational implications for magnetars will be addressed.

E1.10-0029-18 MULTIPOLAR ELECTROMAGNETIC FIELDS AROUND NEUTRON STARS: GENERAL-RELATIVISTIC VACUUM SOLUTIONS

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Magnetic fields inside and around neutron stars are at the heart of pulsar magnetospheric activity. Strong magnetic fields are responsible for quantum effects, an essential ingredient to produce leptonic pairs and the subsequent broadband radiation. The variety of electromagnetic field topologies could lead to the observed diversity of neutron star classes. Thus it is important to include multipolar components to a presumably dominant dipolar magnetic field. Exact analytical solutions for these multipoles in Newtonian gravity have been computed in recent literature. However, flat spacetime is not adequate to describe physics in the immediate surrounding of neutron stars. We generalize the multipole expressions to the strong gravity regime by using a slowly rotating metric approximation such as the one expected around neutron stars. Approximate formulas for the electromagnetic field including frame dragging are computed from which we estimate the Poynting flux and the braking index. Corrections to leading order in compactness and spin parameter are presented. As far as spindown luminosity is concerned, it is shown that frame dragging remains irrelevant. For high order multipoles starting from the quadrupole, the electric part can radiate more efficiently than the magnetic part. Both analytical and numerical tools are employed.

E1.10-0030-18 NONEQUILIBRIUM DYNAMICS AND THE EVOLUTION OF SUPERFLUID NEUTRON STARS

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The interior crust and the liquid core of neutron stars are predicted to be a mixture of neutron and proton superfluids and a liquid of relativistic electrons and muons. Quantized vortices in the neutron superfluid and quantized flux lines in the proton superconductor are topological defects of these hadronic condensates. I discuss the roles of nucleation, interaction and evolution of topological defects under non-equilibrium conditions in the context of our current understanding and models of the rotational dynamics of pulsars, as well as thermal and magnetic field evolution of neutron stars. I include some ideas on possible turbulent vortex states in neutron star interiors.

E1.10-0031-18 LARGE GLITCHES IN SUPERFLUID NEUTRON STARS

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Issues involving nuclear superfluidity are though to play key roles for neutron star phenomenology. In particular pulsar glitches (sudden jumps in the period of otherwise steadily spinning down pulsars) offer a glimpse into the superfluid interior of a neutron star: within the currently accepted scenario these timing irregularities are explained in terms of an expulsion of the quantized vortex lines that permeate the superfluid region. Vortex pinning to ions in the crust can provide the mechanism for storing the angular momentum which can be eventually released during a glitch. A consistent model for the angular momentum reservoir of pinned vorticity gives a general and quantitative inverse relation between size of the maximum glitch and the pulsar mass, allowing to put some limits on the mass of a pulsar.

E1.10-0032-18 INFLUENCE OF CRUSTAL MUTUAL FRICTION ON THE GLITCH RISE

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Probing neutron star matter under extreme conditions relies on understanding the connection between macroscopic observables and microphysics. This plays an important role for pulsar glitches, where the post-glitch behaviour is typically modelled within a large-scale hydrodynamical framework. Physics on small scales enter the model in the form of vortex-averaged mutual friction, which directly controls the hydrodynamical coupling timescales. We address the frictional dynamics in the inner crust as a result of one specific mechanism, the excitation of kelvin vortex waves. We subsequently calculate the corresponding mutual friction strength for a set of realistic microscopic parameters and find it to be strongly density-dependent. Using a simple toymodel, we illustrate the implications of a strong and non-constant drag on the rotational evolution of the different neutron star components. We also highlight several uncertainties in our understanding of the microphysics and discuss how future observations of glitching pulsars could help to constrain these.

E1.10-0033-18 PROBING THE DYNAMICS OF NEUTRON STARS WITH PULSAR GLITCHES

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Pulsars are spinning very rapidly with extremely stable periods, thus providing the most accurate clocks in the Universe. Nevertheless, sudden spin ups have been detected in some of them such as the emblematic Vela pulsar. These abrupt changes in the pulsar's rotation period have long been thought to be the manifestation of a neutron superfluid permeating the inner crust of neutron stars. However, this superfluid has been recently found to be so strongly coupled to the crust due to non-dissipative entrainment effects that it does not carry enough angular momentum to explain the Vela timing data. After reviewing the physical origin of entrainment, the extent to which pulsar-timing observations can be reconciled with the standard glitch theory will be explored.

E1.10-0034-18 THE UNENDING PUZZLES OF NEUTRON STAR GLITCHES

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More than 500 glitches have been observed from the conventional radio pulsars, binary pulsars, millisecond pulsars, Anomalous X-ray Pulsars (AXPs) and other manifestations of neutron stars. These glitches have continued to exhibit new features, thus making the understanding of the glitch processes and mechanisms quite intriguing and challenging. This paper discusses some of these features such as glitch size evolution, glitch signatures and recovery from glitches. The implications of these on the stability of neutron stars are discussed.

E1.10-0035-18 POINT VORTEX SIMULATIONS OF PULSAR GLITCHES

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Pulsar glitches may be caused by a sudden collective unpinning of many superfluid vortices in a decelerating neutron star. This vortex avalanche model is similar to other systems in nature exhibiting “self-organised criticality” (SOC), such as sand piles and earthquakes. We have developed an N-body code that simulates the motion of many vortices in classical hydrodynamics. I present the results of the first simulations of a simple model decelerating neutron star and discuss how they compare to those expected by SOC. I also present a statistical analysis of the observed glitch size and waiting time distributions in the context of SOC.

E1.10-0036-18 MODELLING PULSAR GLITCHES

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Pulsar glitches are thought to be a macroscopic, astrophysical, manifestation of the quantum nature of the neutron star interior. Nevertheless producing theoretical models that can link the small scale quantum behaviour of the fluid to the large scale astrophysical observables is computationally challenging and still an open problem. In this talk I will review recent advances in our theoretical understanding of the problem, from the microscopic scale of vortex-cluster interactions and pinning, to vortex motion and the large scale behaviour of the star. I will also discuss future directions and how upcoming observations can constrain our models.

E1.10-0037-18 LONG-TERM GLITCH EFFECTS

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Glitches are discrete positive steps in spin frequency (ν) that occasionally interrupt the smooth rotation of pulsars. Observations show a broad variety of glitch sizes, covering more than seven decades, and exhibiting a clear bimodal distribution. The largest events gather closely at around

$\Delta\nu/\nu$ 10−6, show different occurrence rates to the small glitches and more regular times between glitches. Furthermore, large glitches are followed by significant negative changes in slowdown rate ($\dot{\nu}$), with sizes $\Delta\dot{\nu}/\dot{\nu}$ 10−3. Enhanced spin-down rate regimes, known as glitch recoveries, are seen to last for months and slowly evolve towards pre-glitch values over years,

or even decades. We have recently characterized the long-term (>20 yr) evolution of a number of pulsars with 3 or more large glitches and found that all of them evolve with particularly low frequency second derivatives, leading to low long-term braking indices $n = \nu\ddot{\nu}/\dot{\nu}2$ 2. Such findings strongly suggest that large glitches and their transient recoveries are perturbations that can largely affect the observable spin evolution of pulsars over long periods of time. I will review the main consequences of this result and will present ongoing measurements that explore the properties of the large glitches and their recoveries.

E1.10-0038-18 MINIMUM GLITCH SIZE AND CRUSTQUAKE IN THE NEUTRON STARS

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Glitches are likely triggered by crust breaking. The critical strain is the significant quantity determining the size of the broken plate. The minimum glitch size is related with the inertial moment of the region, in which the crustquake takes place, and the size of the broken plate. The broken crust plate size in turn determines the number of vortices involved in the unpinning avalanche that effects the size of the amplified glitch. This number, N 1013, is typical of all small and large glitches from Vela, Crab and PSR J1119-6127 analysed so far in terms of vortex unpinning, indicating a particular scale of the glitch trigger. The coincidence of the number of vortices is highly suggestive and is explained in terms of crust breaking with a typical plate size and critical strain angle which is found to be in agreement with theoretical and computational estimates ϑcr 0.1, corresponding to the unscreened Coulomb lattice in the neutron star crust.

The minimum glitch size and the regularity in the number of vortices involved in glitches are due to the large critical strain angle, ϑcr∼0.1, of the neutron star crust.

E1.10-0039-18 NEUTRON STAR ROTATIONAL EVOLUTION WITH TIME DEPENDENT EXTERNAL TORQUES

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The two-component model describes neutron star dynamics under the combined action of internal superfluid and external braking torques. Conventional applications involve only constant decelerating external torques, appropriate for steady braking of pulsars among life-time. However, in recent years there is growing evidence that magnetars, high magnetic field pulsars and some canonical radio pulsars display bursting activity and apparent variations in the spin-down rates on observational timescales. This fact indicates time dependent variability in the external torque of pulsars. We present the general solution of two-component neutron star dynamics under arbitrary time-dependent external torques, including the coupling with internal torques due to vortex creep against nuclei in the inner crust and flux tubes in the outer core. The two-component model can now be applied not only to canonical radio pulsars but also to magnetars and to neutron stars in binary systems showing variability and noise in the spin-down or spin-up rates. The methods extracting information about neutron star internal structure from such observations are also discussed.

E1.10-0040-18 NEUTRON STAR EVOLUTION

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The evolutionary paths of neutron stars post-supernova are not fully understood. Questions of cooling, magnetic field evolutions, spin down both steady and via glitches, evolving emission behaviour, environmental influences and more besides are each highly complex, and at the same time intertwined. Deciphering the full evolutionary picture is thus a messy job. Thankfully the discovery rate of neutron stars in comparison to that of said problems is respectable, and looks set to continue to increase so that such problems will hopefully be tractable and testable with observational data. Here I will present a few 'corner cases', neutron stars that one might think would be the same that exhibit radically different behaviours. I will argue that some studying such cases, with tests I will describe, can give insight into the overall evolutionary picture.

E1.10-0041-18 EVOLUTION OF HIGH-B RADIO PULSARS IN THE FALLBACK DISK MODEL

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We have investigated the X-ray luminosity and the rotational evolutions of the so-called “highmagnetic-field neutron stars” (HBRPs) in the frame of the fallback disk model that was also applied earlier to anomalous X-ray pulsars/soft gamma repeaters (AXPs/SGRs), and dim isolated neutron stars (XDINs). The estimated supernova ages and the measured braking indices of the three HBRPs, namely PSR J1734–3333, PSR J1119–6127 and PSR B1509-58, provide significant constraints on the models. We have shown that the individual source properties (period, period derivative, braking index and X-ray luminosity) can be reproduced simultaneously in the fallback disk model, consistently with the estimated supernova ages. Our results indicate that HBRPs are currently spinning down in the propeller phase without any accretion onto the star, while the X-ray luminosities are produced by the intrinsic cooling of the neutron star. This is in agreement with the observed pulsed radio emission of the sources. The strength of the dipole fields of HBRPs indicated by our simulations are one or two orders of magnitude smaller than the fields inferred from the dipole-torque formula. Furthermore, our results imply evolutionary connections of HBRPs with AXPs/SGRs and normal radio pulsars. We also discuss the initial conditions responsible for the evolutions producing these different neutron star populations.

E1.10-0042-18 INFERRING NEUTRON STAR'S MASS WITH PULSAR GLITCHES

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In the interior of a neutron star, the differential rotation of the neutron superfluid component with respect to the normal component is believed to provide the angular momentum necessary to cause a pulsar glitch. We provide a relativistic generalization in the slow-rotation approximation of a previous Newtonian model that has been recently used to obtain maximum glitch amplitudes and to estimate upper bounds on the masses of glitching pulsars. We show that the Newtonian upper bounds on the masses of large glitchers obtained from observations of their largest recorded event differ by less than a few percent from those calculated within the relativistic framework. Finally, we present some preliminary results of a new analytical model for the raise of the angular velocity during a glitch event.

E1.10-0043-18 LOW-MASS X-RAY BINARIES IN THE LOW-LUMINOSITY REGIME

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The spectra of a select group of neutron star (NS) low-mass X-ray binaries exhibit a significant softening compared to black hole (BH) binaries in the low-luminosity phase. This 'divergence' effect between the two groups appears in their spectral index Γ-Lx correlation at or near a threshold luminosity of a few x 1034 erg/s, a luminosity that represents a small fraction of Eddington, and one that is typically associated with the Low-Hard/quiescent states. We report on the spectral analysis of 27 X-ray binaries for which data are available in the Chandra and XMM-Newton archives. We present our results in the context of a correlation between the spectral index and the 0.5-10 keV X-ray luminosity and its possible interpretation in terms of Comptonization of seed photons via the hot corona in the vicinity of the central compact object.

E1.10-0044-18 X-RAY REPROCESSING: THROUGH THE ECLIPSE SPECTRA OF HIGH AND LOW MASS X-RAY BINARIES WITH XMM-NEWTON

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Study of X-ray reprocessing is one of the key diagnostic tool to probe the environment in Xray binary systems. Difficult aspect to study X-ray reprocessing is the presence of primary radiation from the compact star along with the reprocessed radiation. Eclipsing X-ray binaries make an ideal condition to study reprocessed X-rays, as the X-rays detected during eclipse are purely reprocessed while the primary X-rays are blocked by the companion star. We carried out first comprehensive studies of X-ray reprocessing with a number of eclipsing High Mass X-ray Binary and Low Mass X-ray Binary (HMXB and LMXB) systems during and outside eclipse with XMM-NEWTON EPIC pn. Comparing eclipse and out-of-eclipse spectra of these sources we have found ample diversity in the X-ray reprocessing characteristics in HMXBs, even in the same source at different epochs the variation is quite large. In spite of having much weaker wind environment, the flux ratio of out-of-eclipse to eclipse in LMXBs is in a range comparable to the HMXBs. The analysis shows very strong Iron k emission line during eclipse phases in most of the HMXBs and week or no Iron emission lines in LMXBs. Equivalent width of Iron emission lines in Supergiant Fast X-ray Transients (SFXTs) are large during eclipse, similar to that in Supergiant HMXBs (SgHMXBs). There are some significant system to system differences. For example low equivalent width of Iron k emission line in HMXB Cen X-3 during eclipse, very week Iron emission line in HMXB SMC X-1, comparable out-of-eclipse to eclipse flux ratio in LMXB AXJ 1745.6-2901 irrespective of intensity state etc. Overall we try to infer the wind and accretion disk characteristics, which are the reprocessing agents in the HMXB and LMXB systems respectively.

E1.10-0045-18 THE FAINT 2016 OUTBURST OF MAXI J0556-332

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MAXI J0556–332 is a neutron star X-ray binary discovered by its first detected outburst in January 2011. Since its initial outburst it has remained in quiescence until a new outburst in January 2016. The source has a number of rare properties. It is one of the few transient Z-sources, has a strongly heated neutron star during quiescence, has partial X-ray eclipses suggesting a high inclination system, and has been suggested to lie at a large distance of sim45 kpc (this should soon be refined by Gaia).

Here we present optical monitoring observations of the 2016 outburst of MAXI J0556–332 with the 2-m Faulkes and 1-m Las Cumbres Observatory telescopes. We also analyse X-ray, UV and optical Swift data of the outburst. We find that the 2016 outburst was less luminous than the 2011 discovery outburst, at both X-ray and optical wavelengths. We detected the initial outburst rise with the Faulkes Telescopes eight days before the first X-ray detection by MAXI, and constrain the date of the onset of the outburst to be between 19 December and 29 December 2015. After the initial rise, several prominent dips and flares are evident in all optical filters, and there is a fairly tight correlation of Fopt F 0.5 between the optical and X-ray fluxes. The correlation slope and the optical spectral energy distributions are both consistent with a thermal origin to the optical emission from the accretion disc, with no evidence for a red excess from synchrotron emission in the optical data. The optical emission is likely due to reprocessed X-rays reflected on the accretion disc surface, with a characteristic temperature of 8,000 - 11,000 K during outburst. From the optical / X-ray ratio alone we favour a distance to the source greater than 3 kpc, whereas a 45 kpc distance would imply MAXI J0556–332 is one of the most luminous neutron star X-ray binaries at optical and X-ray wavelengths.

E1.10-0046-18 NEUTRON STAR COOLING

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The cooling behavior of neutron stars (NSs) is a key observational test of the physics of their interiors, which can be probed through X-ray observations. While NSs are hot enough to be studied in the X-ray, their long-term cooling is dominated by neutrino emission from the core. This enables us to constrain the neutrino emission processes in NS cores by studying their thermal X-rays.

Young NSs, cooling after their birth in supernovae, provide the most straightforward tests of cooling theories. The diversity in their cooling tracks requires some variation in e.g. envelope composition. The youngest Galactic NS, in Cassiopeia A, may show evidence for rapid cooling, which if correct may indicate that neutrons in its core are transitioning to a superfluid state. However, monitoring its cooling taxes the limits of our observational capabilities, and it is not certain that the apparent flux decline actually indicates cooling.

Old NSs in X-ray binaries can also be used to probe cooling, by comparing their thermal surface emission (heat going out from the surface) with their long-term time-averaged accretion history (heat deposited inside), to determine the rate at which neutrinos must be removing heat from the core. Note that NSs also experience short-term cooling after episodes of intense accretion, which reveals information on the properties of the crust (see Cumming's talk). Intriguingly, a wide range of neutrino emission rates appear to be present within NSs in X-ray binaries. This wide range can be most easily explained if NSs have a wide range of masses, and if the most massive, and thus densest, NSs can access faster neutrino cooling mechanisms (such as the direct Urca process) in their cores.

E1.10-0047-18 A NEW PERSPECTIVE ON NEUTRON STAR COOLING

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Cooling of neutron stars has long been recognized as a way to investigate the physics of dense matter in neutron star interiors. Because cooling depends on the heat capacity and neutrino emissivity of the matter, it is sensitive to both the particle content, for example the proton fraction, and state of matter, for example whether the particles are paired to form a superfluid. The traditional way to study neutron star cooling is to compare theoretical models with the observed population, either the population of young isolated neutron stars with detected X-ray emission, or with neutron stars accreting from a companion in binary systems. However, there are significant uncertainties in this comparison and degeneracies in the inferred neutron star properties.

In this talk, I will focus on the new opportunity to probe neutron star interiors that comes from the ability to follow cooling of individual neutron stars on timescales of months to decades using long term monitoring with X-ray observatories. This has primarily been done for accreting neutron stars which are heated by nuclear reactions in their crust during accretion outbursts, and then cool afterwards. Models of the cooling allow us to determine how much energy was deposited and then observe the response of the core to the energy input (they also provide a way to determine the envelope composition, a significant uncertainty in population studies). I will describe how this has provided the first independent constraints on heat capacity and the neutrino emissivity of neutron star cores, and the implications for the physics of the interior: how it provides a way to break the degeneracies in the models and begin to untangle the different contributions such as the dependence of pairing gap with depth. These studies are very much continuing, so I will emphasize the future constraints that we expect to obtain, and discuss how they relate to other information about neutron stars coming up (e.g. radius or moment of inertia measurements).

E1.10-0048-18 HEATING AND COOLING OF THE CRUST OF ACCRETING NEUTRON STARS

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The composition and structure of the 1 km thick, solid crust of neutron stars is responsible for many of their observable properties, and plays a fundamental role in the emission of gravitational waves and the evolution of their magnetic field. When residing in an X-ray binary, a neutron star accretes gas from a companion star. As matter accumulates on the neutron star surface, the underlying crust is compressed and heated due to nuclear reactions induced by this compression. These heating processes may have an important role in the observable properties of thermonuclear bursts and rapid variability (mHz QPOs) observed from accreting neutron stars.

Once accretion switches off, sensitive X-ray satellites can be employed to observe the thermal glow of the accretion-heated crust and how it cools in absence of accretion. Comparing these observations with theoretical simulations provides very valuable insight into the structure and composition of neutron star crusts, as well as the heating processes that occur during accretion episodes. One of the current puzzles is that the observations seem to point to much more heat generation than is currently accounted for in theoretical models. I will provide an overview of the various lines of evidence pointing to such "shallow heating" and describe what recent observational efforts seem to teach us about its properties and origin.

E1.10-0049-18 AN UPDATE ON THE X-RAY SPECTRAL EVOLUTION OF THE CENTRAL COMPACT OBJECT IN CAS A

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The Central Compact Object (CCO) in the Cassiopeia A supernova remnant (SNR) is a very young (300 years) neutron star. The temperature evolution of such a young neutron star is of great interest because of its implications for models of neutron star cooling. Heinke Ho 2010 reported a substantial drop of the CCO's X-ray flux within nine years based on Chandra ACIS observations of the SNR. Assuming that the observed thermal X-ray emission emerges from a carbon atmosphere of the neutron star, the drop was interpreted as a fast decrease of the effective surface temperature. The X-ray data of the CCO, however, were strongly affected by instrumental effects since the Chandra observations were optimized for the investigation of the SNR. Using a more suitable observational setup, Posselt et al. 2013 did not find any statistically significant temperature decrease over a time span of 5.5 years. Here, we present an update on the evolution of the CCO's spectral properties based on additional new Chandra data and improvements of the ACIS calibration.

E1.10-0050-18 PHASE-RESOLVED SPECTROSCOPY OF THE LOWER KHZ QPO IN 4U1608- 52

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Kilohertz quasi-periodic oscillations (kHz QPOs) are the most rapid (quasi-)coherent kind of variability that have been detected in the light curves of accreting neutron star X-ray binaries. Previous spectral-timing work using the rms spectrum revealed that the QPO emission is a Comptonized blackbody, consistent with that expected from the boundary layer between the accretion flow and neutron star surface. Furthermore, the lag-energy spectra and covariance spectra indicate that the lower kHz QPO arises from a more complex energy-dependent variability than just an overall modulation in the flux normalization. To better interpret the spectral variability, we present phase-resolved spectroscopy of a kHz QPO for the first time, using a method based on the energy-dependent cross-correlation function (CCF). The bestfitting spectral parameterisation requires the power-law index, high-energy cut-off temperature and seed blackbody temperature of the Comptonized emission to vary with QPO phase. Additionally, the variations in these three parameters show small but non-zero phase differences, which together can explain the previously observed lag-energy dependence. We suggest that these spectral variations could be explained by a "breathing" oscillation in the Comptonizing boundary layer; this possibility can be explored in greater detail with current and future X-ray missions such as AstroSat, NICER, eXTP, and STROBE-X.

E1.10-0051-18 THE HIGHEST FREQUENCY KHZ QPOS IN NS-LMXBS

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We investigate the detections with RXTE of the highest-frequency kHz QPOs in neutron star low mass X-ray binaries. In particular, we compare recent findings on 4U 0614+09 and 4U 1728–34 to the properties of high frequency kHz QPOs detected in other sources. We find that the highest-frequency kHz QPO detected in 4U 0614+09 exceeds 1267 Hz with 3σ (99.73%) confidence, which is the highest 3σ lower limit on a kHz QPO frequency reported to date. This number is of direct physical interest as it can be used to constrain the supra-nuclear density equation of state (EoS). We compare our measured frequencies to maximum orbital frequencies predicted by models of rotating neutron stars with different realistic EoS.

E1.10-0052-18 AN ENIGMATIC HUMP AROUND 30 KEV IN SUZAKU SPECTRA OF AQUILA X-1

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In Neutron Star Low Mass X-ray Binaries (NS-LMXBs), the matters accreting on the NS are compressed, heated, and eventually undergo thermonuclear flashes called Type-I bursts. Because the accreting materials mainly consist of hydrogen, the NS atmosphere is expected to be in a proton-rich environment. When type-I bursts ignite under such a condition, the rapidproton capture process (rp-process) should occur. The NS atmosphere is hence a promising site of the rp-process.

The typical NS-LMXB, Aquila X-1, was observed with Suzaku seven times in the decay phase of an outburst in 2007 September-October. Among them, the second to the fourth observations were performed 10 to 22 days after the outburst peak, when the source was in the Low/Hard State with a luminosity of 1036 erg/sec. In general, the Low/Hard state spectrum of an NS-LMXB is represented by a hard X-ray continuum up to 100 keV arising when blackbody photons from the NS surface is Comptonized, plus an optically thick disk emission appearing below a few keV (Sakurai et al. 2014). This model was able to approximately reproduce the Aqlila X-1 spectra obtained in the 2nd to the 4th observations. However, these three spectra all exhibited an enigmatic hump-like excess around 30 keV above the Comptonized continuum.

A similar feature is found in an RXTE spectrum of this object observed in the Low/Hard state (Lin et al. 2007). We quantify this feature, and attempt to interpret it in the context of rp-process products.

The excess feature was successfully represented by a Gaussian centered at 29–34 keV, with a width (sigma) of 3-11 keV and an equivalent width of about 8 keV. Alternatively, the feature can also be explained by a recombination edge (redge) model, that produces a quasi-continuum above an edge energy of 26 ± 1 keV with a plasma temperature of 6–32 keV.

Considering that the feature is K-shell structures of highly-ionized heavy elements produced via the rp-process, and taking into account the gravitational redshift on the NS surface, the Gaussian centroid energy indicates the atomic number of Z = 59 - 63, or Pr to Eu. Whereas the redge model results indicate Z = 47 and 48, namely, Ag and Cd. We discuss these results in the context of rp-process in X-ray bursts, and examine whether this scenario if feasible or not.

E1.10-0053-18 WHAT WILL THE SKA DO FOR NEUTRON STARS?

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In this poster I will give an overview of the Square Kilometre Array (SKA), its science case, and the status of its design and construction. Very briefly, the SKA will be the largest radio observatory on the planet, consisting of two telescopes each at different sites (one in Australia, one in South Africa). At present we are in the middle of a series of critical design reviews for SKA Phase 1, marking the final part of the pre-construction phase which has been running since 2013. I will describe what the SKA will do for neutron star science. The impact should be substantial with pulsar searches and timing amongst the top priority science goals which have driven the design.

E1.10-0054-18 LONG-TERM QUASI-PERIODICITY OF 4U 1636-536 RESULTING FROM ACCRETION DISC INSTABILITY

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We present the results of a study of the neutron star low-mass X-ray binary 4U 1636-536. We have performed temporal analysis of all available RXTE/ASM, RXTE/PCA, Swift/BAT and MAXI data collected until 2017. We have confirmed the previously discovered quasi-periodicity of 45 d present during 2004, and we have found it continued to 2006. At other epochs, the quasi-periodicity is only transient, and the quasi-period, if present, drifts from 32 to 72 days. We have applied a time-dependent accretion disc model to the interval with the significant X-ray quasi-periodicity. Although 4U 1636-536 is persistent, the observed quasi-periodicity can be well modelled by the hydrogen thermal-ionization instability occurring in outer regions of the accretion disc. For our best model, the period and the amplitude of the theoretical light curve agree well with those observed.

E1.10-0055-18 MORPHOLOGY AND EVOLUTION OF THE 20 DAY SUPERORBITAL MODULATION IN THE HIGH-MASS X-RAY BINARY IGR J16493-4348

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We report on Nuclear Spectroscopic Telescope Array (NuSTAR), Swift X-ray Telescope (XRT) and Swift Burst Alert Telescope (BAT) observations of IGR J16493-4348, a wind-fed Supergiant X-ray Binary (SGXB) showing significant superorbital variability. From a discrete Fourier transform of the BAT light curve, we refine its superorbital period to be 20.058 0.07 days. The BAT dynamic power spectrum and a fractional root mean square analysis both show strong variations in the amplitude of the superorbital modulation, but no observed changes in the period were found. The superorbital modulation is significantly weaker between MJD 55,700 and MJD 56,300. The joint NuSTAR and XRT observations, which coincide near the minimum and maximum of the superorbital modulation, reveal no significant changes in the 1093 s neutron star rotation period on superorbital timescales. We do not observe any significant changes in the pulse profiles in the 3–50 keV band and the 3–40 keV spectral continuum between superorbital minimum and maximum, suggesting a similar accretion regime. At superorbital maximum, we find a possible Fe K emission feature at 6.4 keV. The 6.4 keV emission feature is not significant at superorbital minimum. The spectral continuum shows no significant changes as a function of neutron star rotation period. We discuss different mechanisms that might drive the observed superorbital modulation.

E1.10-0056-18 TRANSPORT COEFFICIENTS OF LEPTONS IN SUPERCONDUCTING NEUTRON STAR CORES REVISITED

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I consider thermal conductivity and shear viscosity of electrons and muons in the nucleon NS cores where protons are in the superconducting state. The charged lepton collision frequencies are mainly determined by the transverse plasmon exchange and are mediated by the character of the plasma screening. When protons are in the paired state, they give the dominant contribution to the transverse screening. In previous works [Shternin, Yakovlev, Phys. Rev. D. 75, 103004 (2007); Phys. Rev. D. 78, 063006 (2008)] this contribution was considered in the Pippard limit Δ nqvF p, where Δ is the proton pairing gap, vF p is the proton Fermi velocity, and nq is the typical transferred momentum in collisions. However, for large critical temperatures Tcp (large Δ) and relatively small densities in the outer NS cores (small q), the Pippard limit may become invalid. Restricting the consideration for not too high temperatures (T ;S 0.3Tcp), when the lepton-proton collisions can be neglected, and employing the BCS expression for transverse screening, I revisit the transport coefficients calculations. It is found that older calculations indeed severely underestimated the screening in a certain range of parameters appropriate to NS core conditions. As a consequence, values of the transport coefficients at T Tcp are smaller than previously thought.

E1.10-0057-18 THE HIGH STATISTIC STUDY OF X-RAY EMISSION OF THE CRAB PULSAR

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Using the Rossi X-Ray Timing Explorer (RXTE)observations of the Crab pulsar, we have systematically studied the pulsed X-ray emission from this pulsar, including the phase-resolved spectra, profile evolution, flux evolution and the phase lag between the X-ray and radio pulses. The phase resolved X-ray spectroscopy shows that the spectrum softens from the beginning of the first pulse, turns to harden right at the pulse peak and becomes the hardest at the bottom of the bridge, softens gradually until the second peak, and then softens rapidly. The X-ray profiles, as characterized by a few parameters, changed slightly, but with high statistical significance in the more than 10 years of observations: the separation of the two peaks increased with a rate of 0.88±0.20 degree per century, the flux ratio of the second pulse to the first pulse decreased by (3.64 0.86)×10−2per century, and the pulse widths of the two pulses represented by their full widths at half maxima decreased by 1.44 0.15 and 1.09 0.73 per century, respectively. The pulsed X-ray flux in 5-60 keV obtained by RXTE/PCA decreases with a rate of

(-2.4 0.4)×10−14 erg cm−2 s−1 per day, and it is significantly correlated with the spin-down power Lsd by LX Lsd1.6±0.3. Detail comparisons of the X-ray pulse phases and the radio ones show that their is no significant long time evolution, with a rate is (-0.3 1.8)×10−7period per day, which show that the distance of the X-ray and radio emission regions on the Crab pulsar does not change above the measured limit, and the timing-noises are unlikely resulted from any unique physical processes in the radio or X-ray emitting regions.

E1.10-0060-18 X-RAY STUDY OF VARIABLE GAMMA-RAY PULSAR PSR J2021+4026

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Variable gamma ray pulsar PSR J2021+4026 showed a glitch around 2011, October 16. After the glitch, the pulsar stayed a low gamma ray flux state for 3 years, and then returned to the state before the glitch. To investigate any change in the X-ray emissions in low-gamma-ray flux state and after the relaxation, we analyze XMM-Newton data. We find no significant change in the X-ray emission in the two stages. We fit the X-ray light curve with the heated polar cap model, and discuss half hemisphere of the magnetosphere is less active.

E1.10-0061-18 EVOLUTION OF LOW-MASS X-RAY BINARIES: THE INFLUENCE OF DONOR EVAPORATION

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Millisecond pulsars (MSPs) are thought to originate from low-mass X-ray binaries (LMXBs). The discovery of eclipsing radio MSPs, including redbacks and black widows, indicates that evaporation of the donor star by the MSP's irradiation takes place during the LMXB evolution. In this work, we investigate the effect of donor evaporation on the secular evolution of LMXBs, considering different evaporation efficiencies and related angular momentum loss. We find that for widening LMXBs, the donor star leaves a less massive white dwarf than without evaporation; for contracting systems, evaporation can speed up the evolution, resulting in dynamically unstable mass transfer and possibly the formation of isolated MSPs.

E1.10-0062-18 A MULTI-WAVELENGTH VIEW OF THE INTRIGUING PULSAR WIND NEBULA AROUND PSR J0855-4644

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We present results from X-ray and radio observations of the region surrounding PSR J0855- 4644. PSR J0855-4644 is a nearby, fast spinning, and energetic radio pulsar in the south-eastern rim of the supernova remnant RX J0852.0-4622. X-ray observations with XMM Newton have shown an arcmin scale extended emission, the pulsar wind nebula (PWN), around the X-ray counterpart of the pulsar. Recent Chandra observations have revealed a further compact PWN (arcsecond scale) associated with the pulsar showing a possible double 'torus+jet 'morphology. This makes it only the third source of its kind, and being a nearby object provides us the golden opportunity to investigate the physics of equatorial and polar outflows in PWNe. We use the double torus PWN morphology and the radio light curve to constrain the geometry of the pulsar. Further using radio observations with GMRT at 1.4 GHz we have discovered the radio counterpart of the PWN. We model the radio PWN to study the energetics and the magnetic field strength of the PWN surrounding PSR J0855-4644.

E1.10-0063-18 THE INSIGHT-HXMT OBSERVATION OF THE NEWLY DISCOVERED TRANSIENT X-RAY PULSAR SWIFT J0243.6+6124

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Since the discovery of the Be/X-ray binary Swift J0243.6+6124 in an outburst showing up around 2017 October 3, Insight-HXMT has continuously monitored on this source in a broad energy band covering roughly 1-250 keV. With these observations the orbital ephemeris of the system are derived and refined later on, according to the variability of the spin frequency, which denotes a canonical Doppler effect endorsed by the orbital motion in a NS binary system. We therefore estimate the orbital ephemeris of Swift 0243.6+6124, thanks to the long term observations from Insight-HXMT. The orbital parameters are then obtained by us with a period around 27.35 days, a semi-major axis around 199 light-seconds, an eccentricity around 0.0842. We find from Insight-HXMT data that, both the pulse profile and phase-resolved spectrum evolve strongly with luminosity, which points to the complexity of the outburst exhibited by Swift J0243.6+6124.

E1.10-0064-18 ORBITAL PERIOD AND BREAKING LUMINOSITY RELATION IN LMXBS

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It has been long debated that whether the sharp luminosity drop in X-ray binaries is due to the transition from accretion to the propeller stage or is the result of the ionization of the disc due to irradiation from the central source. The latter model predicts a positive correlation between the critical luminosity at which transition to rapid decay stage occurs and the size of the disc which depends on the binary separation and hence the orbital period of the binary system. We have searched for such a relation among the 5 black hole and 9 neutron star hosting low mass X-ray binary systems. We find no correlation between the critical transition luminosity and the orbital period.

E1.10-0065-18 CLEAR ANTI-CORRELATION BETWEEN X-RAY LUMINOSITY AND PULSED FRACTION IN THE SMALL MAGELLANIC CLOUD PULSAR SXP 1323

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We report the anti-correlation between pulsed fraction (PF) and luminosity of the X-ray pulsar SXP 1323, found for the first time in a luminosity range 1035–1037 erg s–1 from observations spanning 15 years. The phenomenon of a decrease in X-ray PF when the source flux increases has been observed in our pipeline analysis of other X-ray pulsars in the Small Magellanic Cloud (SMC). It is expected that the luminosity under a certain value decreases as the PF decreases due to the propeller effect. Above the propeller region, an anti-correlation between the PF and flux might occur either as a result of an increase in the un-pulsed component of the total emission or a decrease of the pulsed component. Additional modes of accretion may also be possible, such as spherical accretion and a change in emission geometry. At higher mass accretion rates, the accretion disk could also extend closer to the neutron star (NS) surface, where a reduced inner radius leads to hotter inner disk emission. We will discuss the implication of the accretion model and the beam configuration.

E1.10-0066-18 STUDY OF HIGH MASS X-RAY BINARY PARAMETERS: SAMPLE DEFINITION AND PHYSICAL PROPERTIES

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The variability of measured cyclotron resonant scattering features (cyclotron lines) are of fundamental importance to understanding the physics of magnetized X-ray systems. We investigate the statistics of available data sets of cyclotron lines for several High-Mass X-ray Binaries (HMXBs). An application of the presence of observational data of cyclotron lines allow the formation mechanism of magnetic field strengths to be analyzed and studied through their X-ray spectra. Thus, we divide the data into transient and persistent sources, since the comparison of these sources would provide useful information on their origin and evolution. The orbital parameters of these systems are also investigated. Among the persistent sources, 75long spin period (Pspin 100 s) suggesting that all the persistent sources are supergiant HMXB systems and most of them wind-fed when they feature long spin periods. The transient sources exhibit rapidly rotating main-sequence stars which are deep inside their Roche lob, and thus exhibit emission phases associated with long orbital periods, during which they eject mass from their equatorial regions. Furthermore, a plot of magnetic field against orbital period shows that the transient systems occupy separate regions of the parameter space, akin to the separated regions on the Corbet diagram, suggesting that their accretion rates are changed due to variations in the stellar wind, or possibly associated with the formation of a temporary accretion disk. We briefly discuss the implications of these results on our understanding of the properties of neutron stars and the accretion geometry in these sources.

E1.10-0068-18 CLUMPY WIND ACCRETION IN SUPERGIANT X-RAY BINARIES

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Supergiant X-ray Binaries (SgXB) host a neutron star (NS) accreting a fraction of the intense wind from an evolved O/B Supergiant companion. The X-ray emission associated to accretion displays photometric and spectroscopic variability in time which has partly been attributed to overdensities (aka clumps) in the stellar wind. Recently, the micro-structure of the wind mass and dimension of these clumps. To evaluate the impact of the serendipitous a has been computed by Sundqvist et al (2017), shedding new light the on the mass and dimension of these clumps. To evaluate the impact of their serendipitous accretion on the time variability of the mass accretion rates, we plunge the NS into the wind and performed 3D simulations of the accretion process. We follow the inhomogeneous flow over several orders of magnitude, from the hydrodynamical bow shock down to the NS magnetosphere, and identify the conditions favorable to the formation of a transient disc-like structure within the shocked region. We also account for the variable absorption due to unaccreted clumps passing by the line-of-sight and estimate the final effective variability of the mass accretion rate for different orbital separations. By confronting our results to observations of Vela X-1 by Grinberg et al (2017), we conclude that, if the variability at low luminosity is essentially due to clumps, they can not explain, per se, the flaring activity which must find its origin within the NS magnetosphere.

E1.10-0069-18 DISCOVERY OF THE MISSING LINK BETWEEN THE GLITCH AND RECOVERY PROCESSES IN THE CRAB PULSAR

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Glitches are typical events of pulsars, observed as sudden jumps in rotational frequency nu, usually followed by a stage of recovery, in which nu and its derivative dotnu evolve to the preglitch value gradually. The recovery is interpreted as the result of angular momentum transfer between the inner superfluid and the outer crust. However, exactly how the recovery starts has never been observed before. Here we report the discovery of the missing link

between the glitch and recovery processes in the Crab pulsar, during the first-light observation of sl InsightHXMT, China's first X-ray astronomy satellite launched on June 15th, 2017. This missing link could be used to probe the equation of state and the structure of the material inside a neutron star.

RESEARCH IN ASTROPHYSICS FROM SPACE (E)

ACTIVITY OF THE SUPER-MASSIVE BLACK HOLE AND OTHER ENERGETIC PROCESSES AT THE GALACTIC CENTER (E1.11)

E1.11-0001-18 RECENT RESULTS FROM OBSERVATIONS OF SGR A* VARIABILITY WITH THE SPITZER & CHANDRA SPACE TELESCOPES

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Among the many exotic objects at the center of our Galaxy is the closest supermassive black hole, weighing in at 4 million solar masses. Our proximity to it provides the best opportunity to closely study it as a proxy for the physical conditions and phenomenology around supermassive black holes in galactic nuclei. Sagittarius A* (Sgr A*) is the fluctuating source of electromagnetic radiation associated with the accretion of matter onto the black hole. In the NIR, the brightness of Sgr A* is dramatically changing. At times, it can become 30 times brighter than average within 10 min (and in the X-rays even up to 500 times). Its variable emission has been routinely detected with ground-based observatories in the NIR, radio, and submm during the last 15 years. However, many basic questions about this extraordinary source have not been answered yet because of the time limitations of ground-based observations.

We will report the results of a recent multi-wavelength study of Sgr A*. New NIR observations with Spitzer Space Telescope/ IRAC between 2013 and 2017 opened an unexpected window to continuous measurements of variability timescales up to 24-hours - unobservable with ground-based observatories. We observed together with the Chandra Space Telescope and ground-based telescopes like SMA, ALMA, the VLT, and the Keck telescopes. As a result we obtained a rich dataset that provides new insights into the correlation between the wavelengths, and thus into the origin of the variability and the radiative processes. Our eight 24-hour NIR Spitzer datasets in concert with the massive amount of historic ground-based NIR light curves from Keck and the VLT enabled us to determine the characteristic variably timescale with unprecedented precision, and to characterize the NIR spectral properties of the variability. Additionally, We will report our latest results on G2, the putative gas cloud that 3 years ago passed through periapsis in its orbit around the back hole, and its impact on the variability of Sgr A*.

E1.11-0002-18 RADIATION PHYSICS FROM EVENT HORIZON SCALE BLACK HOLE IMAGES

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The ongoing VLTI GRAVITY and Event Horizon Telescope experiments resolve event horizon scales around Sgr A*. I will discuss what we expect them to see, and what it might teach us about low-luminosity accretion, plasma physics, and strong gravity.

E1.11-0003-18 ALMA POLARIMETRY OF SAGITTARIUS A*: PROBING THE ACCRETION FLOW ON SCALES FROM THE EVENT HORIZON TO THE BONDI RADIUS

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Polarization of millimeter wavelength emission from Sagittarius A* provides a unique probe of thermal and non-thermal gas in the accretion flow, jet, and outflow on scales as small as the event horizon and as large as the Bondi radius. The large degree of Faraday rotation seen towards Sgr A* has demonstrated conclusively the presence of a radiatively inefficient accretion flow (RIAF) and provided a strong constraint on the mass accretion rate. Intrinsic variability of the linear polarization fraction and angle probe the synchrotron-emitting gas close to the event horizon. New observations with ALMA provide an exquisite and complex picture of the Faraday rotation and intrinsic polarization. For the first time, we are able to conclusively separate intrinsic and Faraday effects, providing insights into the radial profile of the accretion flow including the magnetic field, the distribution of thermal and non-thermal electrons, and the degree of turbulence on a range of spatial scales not accessible to any other technique. Interpretation of these results is essential for providing the boundary conditions of physical models that will be used to evaluate images and models obtained by the Event Horizon Telescope.

E1.11-0004-18 MULTI-WAVELENGTH COVERAGE OF A POWERFUL FLARE FROM SGR A* CONFIRMS THE SYNCHROTRON ORIGIN OF THE X-RAY EMISSION

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The origin and radiative mechanism of the flares of Sgr A* are still not completely understood. Indeed, even though 15 years have passed since the discovery of the flaring activity of Sgr A*, simultaneous X-ray and NIR spectra of flares are scarce. I will present the first fully simultaneous fits to the NIR and X-ray spectral slope (and its evolution) during a very bright flare from Sgr A*. The difference in spectral slopes (=0.57±0.09) between the NIR and X-ray slopes strongly supports synchrotron emission with a cooling break. The spectral variations are consistent with the evolution of the high energy cut-off in the electron distribution that induces an initial cut-off in the optical-UV band that evolves slowly into the X-ray band. I will also report hints for a variation of the cooling break that might be induced by an evolution of the magnetic field. I will conclude that synchrotron emission with a cooling break is a viable process for Sgr A*'s flaring emission.

E1.11-0005-18 PROBING GENERAL RELATIVITY WITH HORIZON-RESOLVING IMAGES OF SGR A*

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In April, 2017, the full Event Horizon Telescope, a global millimeter-wavelength interferometer capable of resolving the horizons of nearby supermassive black holes, observed Sgr A* for the first time. This new capability promises to transform our understanding of black hole astrophysics and provide a window onto the structure of spacetime itself around astrophysical black holes. I will describe what we already know from a set of precursor experiments with a smaller array, and discuss some of the opportunities for probing the nature and strong gravity of black holes presented by these observations in the future.

E1.11-0006-18 RECENT RESULTS FROM EVENT HORIZON TELESCOPE OBSERVATIONS OF SGR A*

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The Event Horizon Telescope (EHT) is a global interferometric array operating at 1.3mm. The EHT currently achieves an angular resolution of approximately 10 microarcseconds – comparable to the angular size of the Schwarzschild radius of Sgr A*. Previous EHT observations of Sgr A* have demonstrated that the 1.3mm emission region subtends only a few Schwarzschild radii, and they have detected image asymmetry and substructure on these scales. The EHT also discovered ordered magnetic fields with vigorous activity near the event horizon. With the 2017 expansion to eight sites, including the ALMA array, the EHT now has the potential to directly image the black hole and its surrounding magnetic fields. I will discuss recent EHT progress and results, including the emerging capabilities of the EHT to study relativistic dynamics of accretion flows, to elucidate the role of magnetic fields in jet launching, and to track structural evolution during flares of Sgr A*.

E1.11-0007-18 INTERACTING STELLAR WINDS: CLUMP FORMATION AND ACCRETION ONTO SGR A*

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The central parsec of the Milky Way is one of the most intriguing environment in the galaxy. The presence of enigmatic G2-like objects as well as the rate and way in which the gas travels towards Sgr A* are remaining unknowns that have attracted special attention in the last decade. The region is populated by tens of Wolf-Rayet stars whose strong outflows fill the ISM with hot, diffuse plasma. Therefore, it is expected that multiple stellar wind collisions are constantly taking place. In this context, we aim to study: i) the hypothesis of G2 being a clump formed in any of the known massive binaries, ii) properties and final fate of clumps formed in unstable wind interactions. Based on analytical analyses and test-particle simulations we found that the properties and dynamics of the clumps produced in the binaries are not consistent with G2's. Thus, an origin in such systems is not possible. On the other hand, we performed adaptive-mesh refinement hydrodynamical simulation of colliding winds in order characterize the clump formation process. Currently, we are conducting a parameter study of wind velocity and stellar separation. Our preliminary results show that clumps are about a thousand times less massive compared with the theoretical upper limit. Furthermore, the ejection velocity from the system is about one third of the terminal speed of the wind. These results combined with our knowledge of the stellar orbits of the Wolf-Rayet stars will allow us to quantify the amount of cold, dense material, and its chances of being accreted.

E1.11-0008-18 IMAGING BLACK HOLES NOW AND IN THE FUTURE

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One of the most fundamental predictions of general relativity are black holes. Their defining feature is the event horizon, the surface that even light cannot escape. So far, we have never seen the event horizon, but this is about to change. Advanced computer simulations make clear predictions of how the shadow of black holes should look like and global interferometric radio observations with the Event Horizon Telescope are now trying to image the supermassive black hole in the center of our own Milky Way and the radio galaxy M87 for the very first time. To improve the imaging quality further more telescopes should be added to the array, in particular in Africa. The more distant future will belong to higher frequencies and space-based interferometry. The talk will give an overview of the ongoing research to image and simulate black holes, as well as of plans for future expansions.

E1.11-0009-18 GRAVITY IN THE GALACTIC CENTER

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The GRAVITY interferometer will have finished more than a full year of repeated Galactic Center observations by the time of the conference, including the peri-passage of the fast orbiting star S2 in May 2018. With its unprecedented angular resolution of only few milliarcseconds, GRAVITY overcomes the crowding limit of single telescope observations, thereby revealing the infrared counterpart of SgrA* at all times and directly measuring the orbit of S2 to better than hundred microarcsecond precision. We will present the results from the ongoing GRAVITY observations, and give an outlook on what to expect in the next years from ever deeper imaging and a longer astrometric timeline.

E1.11-0010-18 STELLAR ORBITS AT THE GALACTIC CENTER

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In this talk I will review the work of the Galactic Center Orbits Initiative, a two decade long program of high angular resolution imaging and spectroscopy measurements from W. M. Keck Observatory of stellar orbits at the Galactic Center. The orbits of the shortest period stars have provided the best evidence to date for the existence of supermassive black hole holes and have become unique probes of the laws of gravity. While these probes become more powerful with time, the closest approach of S0-2 during the summer of 2018 provides the first opportunity to test Einstein's theory of General relativity in the unexplored regimes near a supermassive black hole. The orbits of longer period stars have revealed the dynamical structures within the nuclear star cluster, including the unexpected populations of young stars and stars experiencing tidal interactions.

E1.11-0011-18 THE INNER PARSEC OF THE GALACTIC CENTER: HYDRODYNAMICS, X-RAY MODELING, AND 360-DEGREE VIDEOS

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The Galactic Center's inner parsec is a hotbed of astrophysical activity, with the injection of wind material from 30 Wolf-Rayet (WR) stars orbiting the supermassive black hole (SMBH) playing an important role. We compute the thermal X-ray emission from a suite of Galacticcenter hydrodynamic simulations that have various SMBH feedback mechanisms, which are compared to Chandra X-ray Visionary Program observations of the region. Over a 2-5″ ring centered on our galaxy's SMBH (Sgr A*), the spectral shape is well matched, indicating that the WR winds are the dominant source of the thermal X-ray emission. Furthermore, the X-ray flux depends on the SMBH feedback due to the feedback's ability to clear out material from the central parsec. A moderate outburst is necessary to explain the current thermal X-ray flux, even though the outburst ended ~100 yr ago. We will report on our efforts to expand this modeling by including the ~100 O stars and the 'S' stars in the region.

Additionally, we will present our 360-degree videos of the aforementioned Galactic-center simulations. These movies render an image over all 4π steradian, and therefore provide a unique and immersive way to visualize astrophysical simulations. Viewed from the perspective of Sgr A*, the most striking aspect of our latest video, which renders column density, is the inspiraling and stretching of clumps of WR-wind material as they make their way towards the SMBH. Video sharing sites such as YouTube allow these videos to be shared with the masses; they can be viewed in their 360-degree nature on computer screens, with smartphones, or, best of all, in virtual-reality (VR) goggles. Our latest video, powered by a Chandra press release, went viral and has been viewed on multiple platforms over 1.2 million times!

E1.11-0012-18 ESTIMATION OF ACCRETING GAS MASS AROUND SGRA* USING DEEP SPECTRO-IMAGING OBSERVATIONS OF NIR RECOMBINATION LINE BRY

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The accretion rate of hot gas through the Bondi radius of the central supermassive black hole at the center of our Galaxy (Sgr A*) can be estimated from X-ray observations, but the amount of cooler gas very near the black hole is not strongly constrained. Murchikova (2016, IAUS 322, 21) placed an upper limit on the gas mass within 0.015 pc around Sgr A*, of 2 Jupiter masses using the H30α radio recombination line. The UCLA Galactic center group has been gathering data on this region (2 arcseconds around Sgr A*) with the near-infrared integral field spectrograph OSIRIS at Keck for over 12 years, for a total of more than 20 epochs of deep observations. These observations have been taken with the primary goal of determining radial velocities of the young stars orbiting Sgr A*. With this large dataset we propose to investigate emission in the Brγ recombination line at 2.166 μm arising from the immediate vicinity of Sgr A* (0.06 arcseconds). The line in this region is expected to be very broad (several thousand km/s) but the width of the observed band, Kn3, is large enough to cover the extent of a potentially broad Brγ line (+-7000 km/s). We are in the process of carefully aligning and combining these 12 years of observations to produce the highest signal-to-noise spectrum of the immediate vicinity of SgrA *. Foreground and background gas components detected in this direction can be easily disentangled from Sgr A* because of their limited velocity extent. An upper limit on the accreting gas mass will be reported and compared with previous estimates of the accretion rate and with Murchikova's limit.

E1.11-0013-18 STUDYING AGN FROM THE MILKY WAY TO Z=4 WITH SOFIA

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I will review the extensive work on SOFIA with imaging and spectroscopy of the central 5pc of the Milky Way from 5 to 250 microns. A comparison will be make with other AGN which are 5 to 10 orders of magnitude brighter, but show similar structure in the dust. Observations of AGN that are gravitationally lensed now have been observed with SOFIA to z 4 and will be discussed.

E1.11-0014-18 DIFFUSE X-RAY EMISSION FROM THE CENTRAL DEGREES OF THE MILKY WAY

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Sensitive X-ray observations of the center of our Galaxy have revealed the presence of warm and hot plasma associated with energetic energy releases and particle acceleration. I will present the deepest X-ray maps of the central few degrees of the Galaxy, discussing newly-discovered extended features, such as supernova remnants, super-bubbles and X-ray filaments. In addition, I will also discuss the discovery of warm plasma at high Galactic latitude, showing a sharp edge to its distribution that correlates with the location of known radio/mid-IR features such as the "GC Lobe". These features might be associated with an inhomogeneous hot "atmosphere" over the GC, perhaps fed by continuous or episodic outflows of mass and energy from the GC region.

E1.11-0015-18 ORIGINS OF THE GALACTIC CENTER DIFFUSE X-RAYS

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Galactic diffuse X-ray emission (GDXE) is unresolved X-rays prevailing over the Galactic center and ridge. Its origin, whether from unresolved point sources, or truly diffuse plasma, has been under debate for a long time. In the point source scenario, the candidate active X-ray stars (AXSs) have been mainly cataclysmic variables (CVs) and coronally active binaries. One of the most remarkable features of the GDXE is strong K-shell iron lines: FeI-Kα, FeXXV-Heα, and FeXXVI-Lyα lines. For the examination of the GDXE origin, we focus on the three iron lines. We measured spatial distributions of the three iron lines associated with the GDXE and confirmed that the GDXE is decomposed into the Galactic Center X-ray Emission (GCXE;

e-folding scales of Δl = 0.°62 0.°72 and Δb = 0.°22 0.°26) and the Galactic Bulge X-ray Emission (GBXE; Δl = 8° 10° and Δb = 1° 2°) as well as the Galactic Ridge X-ray Emission (GRXE; Δl = 45° 57° and Δb = 0.°5 1.°0) [1, 2]. The scale heights of the three lines in the

GCXE are similar to the central molecular zone (CMZ). We also constructed the global spectra of the GDXE in the iron K-shell band and fit them with a combination of the mean spectra of AXSs. The GBXE spectrum is reproduced by a combination of AXSs, and the most fraction is occupied by non-magnetic CVs. On the other hand, the GCXE spectrum shows large excesses in the three iron lines [3]. Together with the fact that the scale heights of the iron lines are similar to that of the CMZ, the excess components would be related to high-energy activity in the Galactic center, such as the past big flares of Sgr A*.

[1] Uchiyama et al., 2013, PASJ, 65, 19 [2] Yamauchi et al., 2016, PASJ, 68, 59 [3] Nobukawa et al., 2016, ApJ, 833, 268

E1.11-0016-18 HIGH FREQUENCY PULSED RADIO EMISSION VARIABILITY FROM THE GALACTIC CENTER MAGNETAR PSR J1745-2900

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Radio observations of the Galactic Center (GC) magnetar, PSR J1745-2900, provide valuable insight into the missing population of pulsars near the GC and the turbulent environment near Sgr A*. We present simultaneous high frequency radio observations at S-band (2.3 GHz) and Xband (8.4 GHz) between 2015 July 30 and 2016 August 20 from the NASA Deep Space Network (DSN) 70 m antenna (DSS-43), located in Tinbinbilla, Australia. The radio spectrum steepened between 2.3 GHz and 8.4 GHz, compared to measurements performed approximately 5 months prior, and then flattened considerably towards the end of our observations. We carried out a search for single pulses at S-band and X-band, which revealed bright X-band events displaying multiple emission components with significant temporal variability between the components. The structure of the single pulse events changed on substantially shorter time scales than the pulsar rotation period, with some events showing strong evidence of pulse broadening. Unusual frequency dependent behavior was also observed in the dynamic spectra of the X-band single pulse emission components. We will discuss the pulse morphology observed from this magnetar, possible mechanisms that could explain the variability, and the implications of these observations on multipath scattering near the GC through the interstellar medium.

E1.11-0017-18 SIGNIFICANT DUST SCATTERING EFFECTS FOR X-RAY SOURCES IN THE GALACTIC CENTRE

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The Galactic Centre (GC) region contains many bright X-ray sources and has a high column density of foreground gas and dust. This suggests that X-ray dust scattering should be ubiquitous and intensive in the GC direction. In this presentation, I will report our recent major progress in discovering various significant effects of dust scattering for GC X-ray sources. As an example, I will show that X-ray dust scattering can severely bias the observed spectrum of the GC LMXB AX J1745.6-2901 at 1.45 arcmin away from Sgr A*, and explain its peculiar eclipse light curves. This study also allows us to put constraints on the GC foreground dust distribution, which indicate that most of the dust along the line-of-sight should reside in the Galactic disk rather than in the GC. I will also show that dust scattering halo is commonly observed around many GC sources, and so its spectral timing effects should be seriously considered for all these sources, including Sgr A*. Finally, I will introduce our Xspec models for the spectral correction of GC foreground dust scattering.

E1.11-0018-18 A NEW CHANDRA PERSPECTIVE OF X-RAY SOURCE POPULATIONS IN THE NUCLEAR STAR CLUSTER

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Based on decade-long, ultra-deep Chandra observations towards the Nuclear Star Cluster (NSC), we have catalogued about 3600 X-ray sources down to a luminosity of 1E31 erg/s, which are presumably close binaries that evolve in the most dynamic environment in our Galaxy. The unprecedented X-ray data allow us to revisit the global (temporal, spectral and spatial) properties of these X-ray sources and obtain new insights on the constituent stellar populations.

E1.11-0019-18 A REVIEW ON THE DISTRIBUTION OF GAS AND YOUNG STARS IN THE INNER 500 PC OF THE GALAXY

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I will give a review of recent progress on our understanding of the mass flows and energy cycles in the Central Molecular Zone – the inner 500pc of the Galaxy – focusing on the distribution of molecular/ionised gas and the star formation history over the last few Myr.

E1.11-0020-18 JOINT VENTURE OF SGR A*'S X-RAY FLARES AND MOLECULAR CLOUDS IN THE GALACTIC CENTER REGION

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Thanks to the ubiquity of molecular clouds in the Galactic Center region that can reflect Xrays, we have learned that Sgr A* experienced short and powerful flares in the recent past. In turn, these flares offer a truly unique opportunity to probe the properties of the molecular clouds themselves, namely their 3D location (at 100 pc scales) and inner structure (down to 0.1 pc scales), statistics of the gas density distribution, and potentially properties of the velocity field. Short duration of the flare(s), combined with X-rays high penetration power and insensitivity to the thermoand chemo-dynamical state of the gas, makes such X-ray probing almost free of the projection and opacity effects. Currently available data already provide us with (i) an estimate of the flare age, (iii) an estimate of the total emitted during it energy,

(ii) upper limit on its duration and a lower limit on the mean luminosity. The same data also allow one to determine the line-of-sight positions of the brightest reflecting clouds and measure statistics of the molecular gas density distribution over a 3.5 pc thick slice inside them. Future X-ray observatories featuring polarimeters and cryogenic bolometers will be able to measure velocities and polarization degrees of the reflected emission, allowing to model-independently reconstruct 3D geometry of the problem, probe velocity fields and cross-match the X-ray data with velocity-resolved emission of various molecular species.

E1.11-0021-18 MAGNETIC FIELD LINES DISTORTED BY COLLIMATED OUTFLOWS FROM THE GALACTIC CENTER

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Images of the Sgr A radio complex made by combining continuum data from multiple configurations of the Jansky Very Large Array at 6cm wavelength show two bundles of strongly curved nonthermal filaments on opposite sides of the central parsec at average distances of 10 pc. While numerous nonthermal filaments have been reported throughout the Galaxy's central molecular zone, most are only gently curved, the curled filaments ("curls") that we report here have unusually small radii of curvature. Furthermore, both curls are concave toward the central parsec. We interpret these features as distortions in the ambient magnetic field caused by collimated winds from the central parsec, with the most likely source of the winds being the Galactic Black Hole. The intensity of synchrotron emission from the curls correlates roughly with their local curvature, suggesting either that the collimated wind carries relativistic particles that illuminate the compressed field lines at the magnetopause, or that the impact of the wind on the magnetopause drives a shock acceleration process that generates the relativistic particles.

E1.11-0022-18 RESULTS OF THE PAST ACTIVITY OF SGR A* FROM X-RAY OBSERVATIONS OF THE GALACTIC CENTER DIFFUSE EMISSION

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X-ray observations of the diffuse emission at the Galactic center have been performed for more than two decades, revealing an intense and highly-variable non-thermal component spatially correlated with the main molecular complexes. This reflection signal has been identified as echoes created by the past activity of the central supermassive black hole, Sagittarius A*. In particular, the time behaviors and spectra characterized across the whole central molecular zone are successfully explained by several short outbursts during which the black hole was at least a million times brighter than it is today. However, the precise description of the corresponding past catastrophic events is difficult to assess, mainly because the properties of the reflection features that they create while propagating away from Sgr A* depend on the line-of-sight distance, the size, and the morphology of the reflecting clouds, all of which are poorly known. I will review the different attempts to reconstruct Sgr A*'s past activity from the constraints obtained through the observation of the reflection features in the Galactic center, including the 2015-2017 Chandra monitoring and recent NuSTAR observations.

E1.11-0023-18 NUSTAR'S VIEW OF THE GALACTIC CENTER DIFFUSE EMISSION

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The Galactic diffuse X-ray emission, an unresolved X-ray emission that fills the Galactic center and extends over 100° along the Galactic plane, has been extensively studied since its discovery over 30 years ago. The NuSTAR observatory, due to its angular resolution of 18// for focused photons (< 1 pc at the Galactic center) and its wide aperture for unfocused photons, provides the unique ability to separately measure the diffuse emission of the inner 10 pc, 100 pc, and several hundreds of parsecs of the Galaxy using the same instrument. Conclusions about the dominant underlying stellar remnant populations in the innermost parsecs have already been updated by NuSTAR observations, which indicate that the Galactic center is dominated by intermediate polar systems with heavier white dwarfs than previously assumed. In this contribution, we exploit the wide NuSTAR solid angle aperture for unfocused photons to add to this picture the broad-band measurement of the diffuse emission in the inner 1 3° of the Galactic bulge. This allows for a picture of the changing nature of the high-energy X-ray stellar remnant population on various length scales from the Galactic center. In addition, these same NuSTAR observations constrain possible X-ray line signatures from the radiative decay of sterile neutrino dark matter. In most of the mass range 10-50 keV, these (along with those derived from NuSTAR blank-sky observations) are now the strongest limits on this leading dark matter candidate.

E1.11-0024-18 DIVERSE ORIGIN OF GALACTIC CENTER NON-THERMAL X-RAY FILAMENTS

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A unique phenomenon of the Galactic center region is the existence of numerous non-thermal filamentary structures, whose source nature has been under debate. The NuSTAR Galactic center and Galactic plane observation campaign allowed us to detect four non-thermal X-ray filaments above 10 keV: G359.89-0.08 or Sgr A-E, G359.97-0.038, G0.13-0.11 and G359.950.04. These hard X-ray filaments are among the brightest in soft X-ray band of 2-8 keV, with luminosities above 8e32 erg/s at a distance of 8 kpc. The broadband 3-79 keV NuSTAR data points to a diverse origin for these filamentary structures: Sgr A-E is best explained by a magnetic flux tube trapping 100 TeV cosmic-ray electrons; G359.97-0.038 can be best interpreted as Sgr A East shell interacting with the 50 km/s cloud; G0.13-0.11 and G359.950.04 are pulsar wind nebula candidates. Future deeper X-ray Galactic center surveys will be able to detect more X-ray filaments and reveal whether there is dominant source origin for this unique type of sources.

E1.11-0025-18 RECONSTRUCTING THE PAST LIGHT CURVE OF SGR A* WITH DETAILED SPECTRA OF X-RAY ECHOES

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The bygone activity of the supermassive black hole Sgr A* is traced by the ongoing reflection of past X-ray flares off molecular clouds located within the central molecular zone of the Galaxy. However, until recently, no proper reconstruction of the light curve of Sgr A* was possible since the exact positions of the clouds, and hence the propagation delay of the echoes, remained unknown. With the development of Monte Carlo-simulated reflection spectra, we are now able to place the best constraints to date on the line-of-sight positions of the bright clumps and, consequently, to provide an estimation of the outburst ages. A detailed study of the main subregions of the molecular complex Sgr C based on Chandra and XMM-Newton observations collected between 2000 and 2014 will be presented. The extension of this approach to other nearby regions, such as Sgr A, B and D, will also be discussed.

E1.11-0026-18 DISCOVERY OF A RECOMBINING PLASMA IN SAGITTARIUS A EAST: A RELIC OF PHOTO-IONIZATION BY THE PAST ACTIVITY OF SAGITTARIUS A*?

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Sagittarius (Sgr) A∗ is a supermassive black hole located at the Galactic Center (GC). Recent observations suggest that Sgr A∗ exhibited bright X-ray flares in the past (e.g., the X-ray reflection nebula located at the GC region, Sunyaev et al. 1993, ApJ, 407, 606; Koyama et al. 1996, PASJ, 48, 249; the recombining plasma in the south of the GC, Nakashima et al. 2013, ApJ, 773, 20). Sgr A East is a supernova remnant (SNR) with a high temperature plasma

(Maeda et al. 2002, ApJ, 570, 671; Koyama et al. 2007, PASJ, 59, 237). Sgr A∗ is located inside of the SNR.

Using the Suzaku archive data, we have obtained a high quality X-ray spectrum upto 12 keV. As a result, we have discovered a recombination continuum feature of Fe at 9 keV, indicating the recombining plasma (RP). The electron temperature, the initial ionization temperature and recombination parameters (plasma density multiplied by the recombination time) are 1.5 keV, 13 keV and 7×1011 s cm3, respectively. In the RP spectrum, we discovered Heα lines of Cr and Mn for the first time. We found a hint that the ionization temperature in the near side from

Sgr A∗ is larger than that of far side. Then one possible origin of the RP is photo-ionization by past X-ray flares of Sgr A∗. Using the mean distance of Sgr A East from Sgr A∗, best-fit initial ionization temperature and recombination parameter, we estimate the flare luminosity of Sgr A∗ in the past to be ~1042 erg s–1.

E1.11-0027-18 TIDAL DISRUPTION EVENTS: SHORT-LIVED LUMINOUS FLARES AND LONG-LASTING TRACES

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Tidal disruption events (TDEs) happen in the centers of galaxies, where stars that pass too close by are destroyed by the tidal force from the central supermassive black holes. In a TDE, a large amount of stellar material is fed to the black hole in only a few years, forming a transient accretion disk and sometimes a relativistic jet. A bright flare is produced, the luminosity of which can change by two orders of magnitude in one year following a deterministic decline pattern. Moreover, as the stellar material is accreted onto the black hole at a rate largely exceeding the Eddington accretion rate, a thick super-Eddington disk forms, which launches wide-angle, ultra-fast outflows. These allow TDEs to be a unique probe to the inner regions of galaxies. The luminous flare and powerful outflows can help us map out the inner regions of galaxies through signatures such as radio signals produced when outflows shock the circumnuclear gas, emission line echoes and dust echoes produced by photoionization, and echoes by molecular clouds in the central region. While (fortunately) we have not seen a bright TDE from our Galactic Center, we have possibly observed several traces from past TDEs, including an X-ray echo which might be due to a TDE happened a hundred years ago.

E1.11-0028-18 DARK MATTER AT THE GALACTIC CENTER AND THE GALACTIC CENTER GAMMA-RAY EXCESS

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Over the last seven years, Fermi-LAT observations have convincingly found an excess in gammaray emission emanating from the center of the Milky Way galaxy. The excess has three definitive properties: (1) it has a hard spectrum that peaks at an energy of 2 GeV, (2) it extends from within 0.1 degrees to more than 10 degrees from Sgr A* with a three-dimensional intensity that falls roughly as r–2, (3) it is approximately spherically symmetric. Several models for this excess have been formulated, including the collective emission from a population of individually dim gamma-ray pulsars, outbursts of cosmic-ray electrons from the central molecular zone, or potentially dark matter annihilation. In this talk, I will discuss the arguments for and against each model, focusing specifically on constraints from multi-wavelength observations. Additionally, I will discuss the future observations that are critical for understanding the origin of the gamma-ray excess.

E1.11-0029-18 UNIVERSAL ENERGY SPECTRUM OF COSMIC RAYS IN DIFFUSE MOLECULAR CLOUDS: EFFECT ON GAMMA-RAY EMISSION

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We propose a generic model of CR penetration into molecular clouds through their diffuse envelopes, and identify the leading physical processes controlling their transport on the way from a highly ionized interstellar medium to a dense interior of the cloud. The model allows us to describe a transition between a free streaming of CRs and their diffusive propagation, determined by the scattering on the self-generated disturbances. We demonstrate a remarkable mutual complementarity of different mechanisms leading to the onset of the diffusive regime, which results in a universal energy spectrum of the modulated CRs. The model is applied to estimate the expected gamma-ray emission from molecular clouds. In particular, it can provide insights into the origin of the so-called GeV excess of diffuse gamma-ray emission from the Galactic center.

E1.11-0030-18 POSSIBLE CONSEQUENCES OF STELLAR CAPTURE AND TIDAL DISRUPTION BY SUPERMASSIVE BLACK HOLES

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Stars captured by the supermassive black holes in the galactic centers are common phenomena. Capture events occurred in distant galaxies have been observed by various of X-ray satellites. The capture rate is roughly once every tens to hundreds thousand years for normal galaxies. These capture events should also occur in the past of Milky Way. In this talk we will review some observed high energy phenomena in the galactic centers, which may be the consequences of the stellar capture events including Fermi Bubbles, positron annihilation lines, X-ray emission from Swift 1644+57 etc.

E1.11-0031-18 VERY HIGH ENERGY EMISSION FROM THE GALACTIC CENTRE

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Very High Energy (VHE) gamma-rays offer a very rich perspective of the Galactic centre (GC) and the surrounding 300 pc. We review observational results at VHE and discuss their physical implications. In particular, we discuss the nature of the gamma-ray source at the GC and its possible connection with the supermassive black hole. We also present the measurements of the interstellar emission and their impact on our knowledge of the cosmic-ray population production and propagation in the region. We finally discuss perspectives, in particular with the Cherenkov Telescope Array.

E1.11-0032-18 VERY HIGH ENERGY GAMMA RAY EMISSION FROM THE GALACTIC CENTER WITH VERITAS

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The Galactic Center (GC) is an energetic and exciting region that is host to various forms of nonthermal gamma-ray emission in the very-high-energy regime above 100 GeV. Among the possible origins of the central gamma-ray emission are point sources such as the central supermassive black hole Sagittarius A*, supernova remnants, and pulsar wind nebulae. The mechanism of emission from Sgr A* is unknown, and many candidate models have been proposed for this important astrophysical process. A study of the spectrum, morphology, and potential variability of emission in this region can help to discriminate between models capable of creating such high energy particles, and may give hints about the past activity in the region. The GC also has a large diffuse component of gamma-ray emission that correlates with large molecular clouds such as Sgr B2. Examining the combined spectral behavior of Sgr A* and the surrounding diffuse emission could indicate the presence of a significant source of Galactic cosmic rays. The GC has undergone deep observations by VERITAS, an array of atmospheric Cherenkov telescopes designed to detect very high energy gamma rays. When observing the Galactic Center, VERITAS is sensitive to gamma rays with energies between 2 and 30 TeV, among the highest of any gamma ray observatory. Here we will provide an overview of the spectral and morphological results of VERITAS observations of the Galactic Center taken between 2008 and 2017. These results will be used to confront the various models available for the different forms of observed emission.

E1.11-0033-18 DETAILED STUDY OF THE DIFFUSE EMISSION IN THE CENTRAL 200 PC OF OUR GALAXY WITH H.E.S.S.

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H.E.S.S. Collaboration

H.E.S.S.S Collaboration

In 2006 a diffuse emission was discovered around the Galactic Center (GC) by the High Energy Stereoscopic System (H.E.S.S.) array and interpreted as the result of an overabundance of cosmic-rays interacting with the dense matter distribution of the Central Molecular Zone (CMZ). Since then, the GC region has been constantly monitored by the H.E.S.S. I array accumulating more that 200 hrs of additional data. We report the results of a detailed spectral and morphological analysis of the diffuse emission and discuss the implications on the existence and origin of a cosmic-ray excess in the region.

E1.11-0034-18 ACTIVITY OF THE SMBH AND OTHER ENERGETIC PROCESSES AT THE GC: HIGHLIGHTS AND CONCLUDING REMARKS

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P. N. Lebedev Institute, Moscow, Russia Andrea Goldwurm, andrea.goldwurm@cea.fr CEA/Saclay & APC, Gif Sur Yvette, France

The scientific organizers of the event provide in this talk a summary of the highlights presented during the conference, proposing to the audience a number of issues for comments and discussion.

E1.11-0035-18 SEARCH FOR TRANSIENT RADIO SOURCES NEAR GALACTIC CENTRE REGION

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Galactic centre region is best suited to search for transient radio sources. Transient radio sources are mostly compact objects. Dynamic radio sky is not properly studied due to various reasons. There are different kind of compact sources which show highly variable radio emission from nano second to month time scale for different kind of physical reasons. We are systematically searching transient sources in Galactic centre region using Giant Meterwave Radio Telescope (GMRT) and Janskey Very Large Array (JVLA). We have already discovered few transient sources, most of which are characterised with high spectral index and presence of circular polarization. In this paper we will summarize different methods to search transient radio sources and will summarize our effort to search transient sources. We will also summary different properties of newly discovered transient sources and multi-wavelength followup of these sources.

E1.11-0036-18 AN OUTBURST FROM A NEW GALACTIC BULGE INTERMEDIATE POLAR CANDIDATE IN THE XMM-NEWTON GALACTIC CENTER LOBE SURVEY

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For the past decades a rare subclass of cataclysmic variables, with magnetized white dwarfs (WD) as accretors has been studied and called intermediate polars (IP). IPs are very numerous but mostly faint X-ray sources in the Galactic center and bulge (GC/GB) region and there is evidence that they are responsible for a large fraction of the diffuse X-ray emission due to unresolved sources in the GB. In an ongoing deep X-ray survey (0.5-10 keV energy band) of 3x3 deg around the GC with the XMM-Newton observatory we conducted a systematic search for transient X-ray sources. Promising systems were analyzed for spectral, timing, and multi-wavelength properties to constrain their nature. We discovered a new highly variable (factor >20) X-ray source about 1.25 deg south of the GC. We found evidence making the newly discovered system a candidate IP. The X-ray light curve shows a period of 511 10 s which can be interpreted as the spin period of the WD. The X-ray spectrum is well fit by a bremsstrahlung model with a temperature of 13.9 2.5 keV, suggesting a WD of 0.4-0.5 solar masses. High X-ray absorption and absence of an optical counterpart are evidence that the source is most likely located in the GB. This system will help to understand the population of rarely observed IPs in the GB. In extension of this work a full study of the diffuse X-ray emission and point source population in the ongoing (to be completed this year) XMM-Newton GC survey is currently under way.

E1.12-0001-18 X-RAY SURVEYS OF DISTANT ACTIVE GALACTIC NUCLEI: DEEP TO WIDE

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I will review the results from cosmic X-ray surveys of active galactic nuclei (AGNs) over the past 20 yr that have dramatically improved our understanding of growing supermassive black holes over most of cosmic time. The relevant X-ray surveys range from ultradeep ones, such as the Chandra Deep Fields, to much wider field surveys covering 1-10 square degrees or more. I will briefly describe these surveys, the essential roles of complementary multiwavelength data, and how AGNs are selected and identified. I will then highlight selected key results on the AGN population and its evolution ("demographics"), the physical processes operating in AGNs ("physics"), and the interactions between AGNs and their hosts/environments ("ecology"). I will conclude by describing some significant unresolved questions and prospects for advancing the field with new observations and future missions.

E1.12-0002-18 X-RAY SURVEYS: SOFT TO HARD - PROBING OBSCURED BLACK HOLE GROWTH OVER COSMIC TIME

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I will review recent results from large X-ray surveys that probe the evolution of Active Galactic Nuclei (AGNs) at both soft and hard X-ray energies and provide crucial insights into obscured black hole growth over cosmic time.

Chandra and XMM-Newton have provided the most sensitive X-ray surveys to date, probing from 0.5-8 keV in energy. However, these surveys still suffer complex selection effects against obscured AGNs. A number of recent studies have developed new techniques, exploiting the soft-to-hard energy coverage of Chandra and XMM-Newton, to address these selection biases and provide accurate measurements of the evolution of the AGN luminosity function and the distribution of obscuring column densities (the "NH function"). These studies show that the bulk of black hole growth took place at high redshifts (z>1) and is obscured, although the fraction of the most heavily obscured, Compton-thick AGNs and its evolution remains somewhat uncertain.

Moving to harder energies, the NuSTAR observatory is providing the first high-sensitivity Xray surveys at >8keV, enabling new studies of the evolution of obscured AGN to high redshifts. I will give an overview of the results from the NuSTAR survey program, including the first measurements of the evolution of the AGN luminosity function at >8keV, constraints on the fraction of obscured and Compton-thick AGNs, and studies of the spectral properties of AGNs at these hard energies.

Finally, I will briefly discuss future missions, in particular the Athena X-ray observatory that will probe obscured black hole growth out to very high redshifts.

E1.12-0003-18 X-RAY SURVEY'S SPECTRAL ANALYSIS

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X-ray surveys are a fundamental tool for characterising the AGN population. They simultaneously provide accretion luminosities and line-of-sight column densities, but more importantly a well-understood selection function. After detecting X-ray sources crucial steps include 1) finding multi-wavelength counterparts, 2) constraining redshifts (spec-z/photo-z/XZ) and 3) X-ray spectral analysis; each step however has pitfalls. In this talk I will focus on characterising the X-ray spectra in the low/high-count, low/high-z and Compton-thin/thick regimes with spectral models of realistic complexity. Care has to be taken with choosing the right methods, including: fitting statistic, background handling, redshift uncertainty propagation, parameter space exploration methods and model comparison technique. Finally, I discuss how to rigorously infer population distributions from a limited, biased sample with uncertain properties using hierarchical Bayesian inference.

E1.12-0004-18 AGN OBSCURATION, EDDINGTON RATIO DISTRIBUTION AND CLUSTERING: DEEP AND WIDE X-RAY SURVEYS WITH NUSTAR AND CHANDRA IN THE UKIDSS-UDS AND BOOTES FIELDS

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X-ray surveys are one of the most efficient ways to detect active galactic nuclei (AGN) and perform statistically meaningful population studies. In the past decade, important results in this field came from both wide and deep X-ray surveys of the sky performed by the Chandra and XMM-Newton observatories. The launch of NuSTAR in 2012 allowed to extend such sensitive surveys to higher energies, starting a fruitful synergy between soft and hard X-rays. On one side, recent deep hard X-ray surveys confirmed the presence of a population of heavily obscured AGN: related to this, I will present the results coming from a deep NuSTAR survey of the UKIDSSUDS field, as well as the aggregated results in the COSMOS, ECDFS and UDS fields obtained exploiting three new hard NuSTAR bands, focusing on an interesting source in the COSMOS field barely detected by Chandra due to heavy obscuration, but standing out in the NuSTAR 8- 16 keV band. On the other side, the first steps and perspectives for a new Chandra survey in the central 6 deg2of theBootesf ield(theChandraDeepW ideF ieldSurvey, CDW F S)willbediscussed.T heCDW scaleclusteringof AGN andtheirEddington – ratiodistribution.

E1.12-0005-18 THE ELUSIVE AGN POPULATION

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X-ray surveys conducted in the previous 20 years with both Chandra and XMM-Newton have provided large samples of Active Galactic Nuclei spanning a large range of intrinsic properties. To perform astrophysics studies of these sources, it is vital to couple X-ray with multiwavelength observations, providing key properties and enabling us to fully characterize them. I will give an overview of the multiwavelength findings about X-ray selected AGN and the unexpected difference with optical selected sources.I will focus on the discovery of the elusive AGN population, not recognized as such at other wavelength and the importance of X-ray surveys to obtain a complete census of active SMBH in the Universe.

E1.12-0006-18 REVEALING RARE AGN THROUGH THE STRIPE 82X SURVEY

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Stripe 82X is a 31 deg2 survey in the legacy SDSS Stripe 82 field, which harbors a rich investment of multiwav date, and on−going projects to unveil how these AGN evolve over cosmic time, typical environments that host this AGN population, and planned catalog releases and value added products that will be made available to the community.

E1.12-0007-18 A HARD X-RAY VIEW OF THE AGN POPULATION WITH THE NUSTAR SERENDIPITOUS SURVEY

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New insights into AGN are being provided by NuSTAR, the first focusing telescope with high sensitivity at hard X-ray energies (E>8 keV), and therefore close to the peak of the cosmic X-ray background (CXB). The NuSTAR serendipitous survey is the largest blind survey performed with NuSTAR, with 13 sq. degrees of coverage (over the first 40 months), and has yielded a large sample of 500 hard X-ray sources (primarily AGNs). I will present X-ray and multiwavelength properties of the NuSTAR survey sources, comparing to local hard X-ray samples (e.g., from Swift BAT). An important part of the AGN census is to identify and characterise the most highly obscured (Compton-thick) AGNs, which may contribute a large fraction of the overall cosmic growth of black holes, but are normally hidden from view by gas and dust. The NuSTAR survey is beginning to uncover new Compton-thick AGNs which were elusive at other wavelengths, thus informing AGN population models.

E1.12-0008-18 HUNTING HEAVILY OBSCURED AGN: THE X-RAY MULTI-OBSERVATORY APPROACH

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According to the different models of Cosmic X-ray Background (CXB), the diffuse X-ray emission observed in the 1 to 200-300 keV band, is mainly caused by accreting supermassive black holes, the so-called active Galactic Nuclei (AGN). Particularly, at the peak of the CXB (30 keV) a significant fraction of emission (10-25%) is expected to be produced by a numerous population of heavily obscured, Compton thick (CT-) AGN, having intrinsic column density

NH 1024 cm−2. Nonetheless, in the nearby Universe (z 0.1) the observed fraction of CTAGN with respect to the total population appears to be lower than the one expected on the basis of the majority of CXB model predictions (20-30%), being between 5 and 10%. This discrepancy between data and models is one of the open challenges for X-ray astronomers, and needs to be solved to get a complete understanding of the AGN population. In this presentation, I will discuss a multi-observatory X-ray approach to find and characterize heavily obscured AGN. Candidate sources are first selected in the 100-month Swift-BAT catalog, the result of a 7 years all-sky survey in the 15-150 keV band. These objects are then targeted with snapshot (5-10 ks) observations with Chandra andSwift-XRT, which allow us to constrain the intrinsic absorption value within a 20-30% uncertainty. Finally, deep (25-50 ks) observations with XMM-Newton and NuSTAR allow us to study the physics of these complex and elusive sources.

E1.12-0009-18 OBSCURATION PROPERTIES OF AGN

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Most of the accretion onto supermassive black holes (SMBHs) happens during a phase in which the AGN is obscured. However, to date it is not clear what is the mechanism regulating the amount of obscuration around supermassive black holes, and how obscuration is related to the host galaxy and to the accretion properties of the SMBH. In my talk I will review our current understanding of obscuration in AGN from an X-ray perspective, and discuss recent studies aimed at understanding the origin of obscuration, and its relation with the accretion properties of the black hole.

E1.12-0010-18 THE BAT AGN SPECTROSCOPIC SURVEY (BASS) SECOND DATA RELEASE

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The Burst Alert Telescope (BAT) instrument on the Swift satellite has surveyed the sky to unprecedented depth, increasing the all sky hard X-ray sensitivity by a factor of more than 20 compared to previous satellites. The goal of the BAT AGN Spectroscopic Survey (BASS) is to complete the first large (>1000) survey of hard X-ray selected AGN with optical spectroscopy. This work will place constraints on the growth and structure around nearby black holes and provide a baseline for future European X-ray missions, such as ATHENA, that will perform deeper observations of more distant AGN. Here we present an overview of the 11 recent papers published by our collaboration using the first data release and an overview of the second data release which includes redshift determination, absorption and emission line measurements, and black hole mass and accretion rate estimates via broad lines and velocity dispersion for over 1000 AGN.

E1.12-0011-18 THE COMPLETE IR VIEW OF THE SWIFT/BAT 70 MONTH AGN CATALOG

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We systematically investigate the nearto far-infrared (FIR) photometric properties of a nearly complete sample of local active galactic nuclei (AGN) detected in the Swift/Burst Alert Telescope (BAT) all-sky ultra-hard X-ray (14-195 keV) survey. Out of 606 non-blazar AGNs in the

Swift/BAT 70 month catalog at high galactic latitudes of $b > 10°$, we obtain IR photometric data of 604 objects by cross-matching the AGN positions with catalogs from the WISE,

AKARI, IRAS, and Herschel infrared observatories. We find a good correlation between the ultra-hard X-ray and mid-IR luminosities over five orders of magnitude ($41 < \log L14{-}195 < 46$). Informed by previous measurements of the intrinsic spectral energy distribution of AGNs, we find FIR pure-AGN candidates whose FIR emission is thought to be AGN-dominated with low star-formation activity. We also demonstrate that the X-ray obscuration fraction always exceeds the dust covering factor above the peak of log Lbol > 42.5. We also show that the completeness of the WISE color-color cut in selecting Swift/BAT AGN increases strongly with 14-195 keV luminosity.

E1.12-0012-18 THE NON-THERMAL SKY ABOVE 15 KEV

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We are living in prosperous times for high-energy astronomy with many missions currently keeping watch of the non-thermal sky. After more than a decade of observations, Swift/BAT and INTEGRAL/IBIS still perform surveys. Their shallowness is largely complemented by deep surveys of NuSTAR, which are driven by its one-of-a-kind focusing optics. Yet, to study the evolution of AGNs in the local universe we rely on wide-field surveys with the coded-mask detectors of BAT and IBIS. However, coded-mask technology suffers from an inevitable low sensitivity due to the optics. In this talk I will show how the sensitivity of the wide-field surveys with BAT and IBIS can be boosted by combining their independent observations. Especially the INTEGRAL mission has performed with IBIS deep observations to allow this technique reaching unmatched survey sensitivity. I will review this observing technique and show how the combined observations of BAT and IBIS tie in well with deep NuSTAR surveys.

E1.12-0013-18 MILDLY OBSCURED ACTIVE GALAXIES AND THE COSMIC X-RAY BACKGROUND

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The diffuse cosmic X-ray background (CXB) is the sum of the emission of discrete sources, mostly massive black-holes accreting matter in active galactic nuclei (AGN). The CXB spectrum differs from the integration of the spectra of individual sources, calling for a large population, undetected so far, of strongly obscured Compton thick AGN. Such objects are predicted by unified models, which attribute most of the AGN diversity to their inclination on the line of sight, and play an important role for the understanding of the growth of black holes in the early Universe. The fraction of obscured AGN at low redshift can be derived from the observed CXB spectrum assuming AGN spectral templates and luminosity functions. We show that high signal-to-noise average hard X-ray spectra, derived from more than a billion seconds of effective exposure time with the Swift/BAT instrument, imply that mildly obscured Compton thin AGN feature a strong reflection and contribute massively to the CXB. A population of Compton thick AGN larger than that effectively detected is not required, as no more than 6% of the CXB flux can be attributed to them. The stronger reflection observed in mildly obscured AGN suggests that the covering fraction of the gas and dust surrounding their central engines is a key factor in shaping their appearance. These mildly obscured AGN are easier to study at high redshift than Compton thick sources.

E1.12-0014-18 A SEMI-EMPIRICAL MODEL FOR THE LARGE-SCALE DISRIBUTION OF ACTIVE GALACTIC NUCLEI

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I will combine cosmological dark-matter simulations with the latest observational results on the galaxy occupation of active supermassive black holes to construct a semi-empirical model for the large-scale distribution of Active Galactic Nuclei. Using forward-modeling techniques I will then compare the semi-empirical model against observational results on the clustering and halo-occupation distribution of Active Galactic Nuclei. I will discuss the results in the context of black-hole fueling modes and comment on claims that the environment of AGN is related (or not) to the physics of black-hole growth.

E1.12-0015-18 AGN EVOLUTION FROM WIDE EXTRAGALACTIC SURVEYS: WITNESSING THE IMPACT OF THE LARGE SCALE ENVIROMENT

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Extragalactic X-ray surveys with XMM-Newton and Chandra have revealed the evolution of active galactic nuclei (AGN) across time and space. The analysis of X-ray fields targeted on galaxy clusters have shown that AGNs tend to be abundant in the outskirts of clusters, and their surface density drops towards the centers of galaxy clusters. This observation is similar to the transition galaxies under go as they fall into clusters. Namely, the removal of interstellar medium from galaxies depletes the cold gas reservoir essential for star-formation.

With a combined 60 sq. deg. sky coverage and X-ray flux limit of about 10–15erg/s/cm² the XXL and the X-COP surveys are unique laboratories to assess the transformation of AGN. Due to the large collecting area of XMM, ideal for providing extended sky coverage, and the ancillary multiwavelength photometric and spectroscopic data we are in position to probe the AGN population across different environments, from the field all the way into galaxy cluster cores. Our sample consists of 200 clusters with masses 1014-1015 solar masses up to redshift of one and several thousands of AGN. In this talk, I will present the first direct determination of the X-ray luminosity function of AGN inside clusters and the field up to redshift of one and discuss the implications on the unified model of AGN.

E1.12-0016-18 PROBING CLUSTERING OF X-RAY AGN USING CHANDRA COSMOS LEGACY

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The presence of a SMBH in almost all galaxies in the Universe is an accepted paradigm in astronomy. How these BHs form and how they co-evolve with the host galaxy is one of the most intriguing unanswered problems in modern Cosmology and of extreme relevance to understand the issue of galaxy formation. Clustering measurements can powerfully test theoretical model predictions of BH triggering scenarios and put constraints on the typical environment where AGN live in, through the connection with their host dark matter halos. In this presentation I will talk about the clustering properties of X-ray AGN from both an observational and theoretical point of view, using the new catalog of AGN detected by Chandra in COSMOS and semi-empirical models. The Chandra COSMOS-Legacy catalog is the largest available sample of X-ray AGN for clustering studies, allowing clustering measurements as a function of obscuration, luminosity and AGN host galaxy properties. I will also present mock catalogs of galaxies and BHs assigned via semi-empirical relations to large samples of dark matter halos and how BH/galaxy properties drive the AGN clustering measurements, via detailed comparisons of the predictions from the mocks with the AGN clustering at different scales and redshifts.

E1.12-0017-18 PAST TO FUTURE: ROSAT TO EROSITA

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MPI Extraterrestrische Physik, Garching, Germany eROSITA (extended ROentgen Survey with an Imaging Telescope Array) is the core instrument on the Russian/German Spektrum-Roentgen-Gamma (SRG) mission which is current scheduled for launch in 2018. In the soft band (0.5-2 keV), the deep All-sky survey will be 30 times more sensitive than the previous ROSAT All-sky survey, while the first ever true all-sky survey will be mapped in the hard band (2-8 keV). Although its design driving science is the detection of large samples of galaxy clusters for studying the large scale structure in the Universe and test cosmological models, eROSITA will yield a sample of around 3 million active galactic nuclei. This is bound to revolutionize our view of the evolution of supermassive black holes and their impact on the process of structure formation in the Universe. The talk reports on the eROSITA scientific prospect and how the German eROSITA consortium is activated for ensuring an adequate follow-up of the sources to be discovered. The talk will also reports the work in progress in the follow-up and scietific exploitation of those AGN that ROSAT have already discovered and eROSITA will revisit.

E1.12-0018-18 UNCOVERING OBSCURED AGN WITH X-RAY AND MID-INFRARED SURVEYS

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Providing a complete census of the obscured Active Galactic Nuclei (AGN) is crucial to fully understand the cosmological growth of supermassive black holes (SMBH). Nevertheless, the majority of the highly obscured accretion phenomenon still evades our census.

Hard X-ray surveys (>few keV) are the most efficient and effective method to trace accretion onto SMBHs, but miss Compton-thick AGNs. Since most of the absorbed AGN energy is reemitted in the mid-infrared (mid-IR), surveys at these wavelengths can potentially trace, at least in part, the elusive highly obscured accretion phenomenon.

In this talk I will review recent progress on the identification of obscured AGN at infrared wavelengths using photometric data from Spitzer/IRAC and the Wide-field Infrared Survey Explorer. I will also discuss how AGN selection at mid-IR wavelengths can allow us to complete our census of AGN activity.

E1.12-0019-18 MULTIWAVELENGTH STUDIES OF ACTIVE GALACTIC NUCLEI OVER DIVERSE TIMESCALES

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Active galactic nuclei (AGNs) are generally characterized by extremely high luminosities as they are powered by accretion of matter onto a super massive black hole (SMBH) surrounded by an accretion disk. The accretion of matter onto SMBHs yields high radiative efficiencies. They also show significant rapid variability over diverse timescales i.e. from 100 s to months and years. To probe the location of the emission processes taking place in the targets in different electro-magnetic bands, we first use variability over diverse timescales which includes analysis of observational data using different statistics. As flux variations are often followed by spectral changes, we also examine their colour - magnitude relationship on diverse timescales which helps us to understand the origin of variability. Presence or absence of correlation among multiple frequencies, characteristic variability timescales in the light curves or a quasi-periodic oscillation can be used to infer the origin of variability, constraint the size of emitting region and also derive SMBH mass. As a part of this, we have developed a suite of time series analysis techniques consisting of the Structure Function, Discrete Correlation Function, Lomb Scargle Periodogram, Wavelet analysis and Power Spectral Density which are applied to analyze light curves of our source sample. Although with the advent of large telescopes, the numbers of known AGNs have grown considerably in the past decade, nevertheless, many aspects remain uncertain. The mechanism under play for their active nature, their formation, evolution, taxonomy and their interaction with its immediate environment requires systematic studies. Thus we explore complex phenomena governing AGNs through the analysis of observational data and its applications using various theoretical models which further helps us to understand the physics of the inner regions of AGNs.

E1.12-0020-18 OBSCURATION AND HOST GALAXY STAR FORMATION FOR AGNS IN DEEP AND WIDE X-RAY SURVEYS

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The wealth of multiwavelength observations and the discovery of different AGN populations led to the paradigm of AGN unification, in which the unobscured and obscured AGN populations are similar in nature, and the observed differences are simply caused by the dust in the smallscale "torus" that only enters the line-of-sight for the obscured AGNs. With the advances in recent X-ray surveys and the launch of Herschel Space Observatory, there have been increasing evidence suggesting that in addition to the small-scale torus, galactic star-forming dust is also connected to AGN obscuration. I will review recent studies on this topic using data from both deep and wide X-ray surveys. I will also describe results from the latest "deep-wide" XMM-Newton survey in the XMM-LSS field. With 1.3 Ms new XMM-Newton observations,

the central 5.3 deg2 region of XMM-LSS has uniform X-ray coverage reaching < 2 10–15 erg s–1 cm–2 in the 0.5 2.0 keV band for 90% of the survey area. XMM-LSS is the first part of the XMM-SERVS survey, which is comprised of three separate extragalactic fields: XMMLSS, W-CDF-S, and ELAIS-S1. With the uniform X-ray coverage, wide survey area, and excellent ancillary multiwavelength observations, I will also describe how XMM-SERVS will enable detailed studies on the connection between obscuration and host galaxy star formation in the next few years.

E1.12-0021-18 A REVIEW OF RECENT INSIGHTS IN AGN RESEARCH GAINED THROUGH COMBINING X-RAY SURVEY DATA WITH OTHER MULTIWAVELENGTH DATA

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I will present a review of what I consider to be the most important developments in AGN research that have come from combining X-ray survey data with that collected from other parts of the electromagnetic spectrum. My talk will largely focus on "population studies", considering general trends within the AGN population, with an emphasis on the relationship between AGNs and their host galaxies. I will finish with a consideration of key outstanding questions, and how future observing technologies will help to address these.

E1.12-0022-18 AGN FEEDBACK: LESSONS LEARNED FROM X-RAY SURVEYS AND MULTIWAVELENGTH SYNERGIES

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Outflowing winds are now revealed routinely in Active Galactic Nuclei and Quasars across the entire electromagnetic spectrum and are invoked in many co-evolutionary models to link the growth of SMBH and galaxies through feedback phenomena. Both numerical simulations and observations have shown that the nature of AGN outflows is multiphase, and that each gas phase embeds a fundamental piece of information on the driving mechanism and on the effect on the host galaxy.

I will review recent results on the detection of strong winds at different scales through dedicated NIR infrared and ALMA follow-ups of luminous obscured AGN, and the implications for AGNgalaxy co-evolution. I will also discuss the unique power of AGN X-ray surveys in selecting the most promising targets, and the perspectives for future high-energy missions to advance in our understanding of these important phenomena.

E1.12-0023-18 INTERMEDIATE-MASS BLACK HOLES IN DWARF GALAXIES OUT TO REDSHIFT=2 IN THE CHANDRA COSMOS LEGACY SURVEY

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How supermassive black holes form is still one of the long-standing questions in astronomy. In order to reach 109 solar masses when the Universe was less than 1 Gyr old, they should have started as seed intermediate-mass black holes (IMBHs) of 100-106 Msun. The presence of IMBHs at z>7 is difficult to prove; however, those seed IMBHs that did not grow into supermassive black holes should be found in local dwarf galaxies resembling the first galaxies formed at early epochs. I will present observational evidence that a population of IMBHs exists in dwarf galaxies based on the X-ray stacking analysis of low-mass galaxies in the Chandra COSMOS-Legacy survey and on the finding of AGN X-ray emission in 40 dwarf galaxies at redshifts 2. One of the dwarf galaxies has a stellar mass of 7e7 Msun and is the least massive galaxy found so far to host an AGN. Unlike massive galaxies, the AGN fraction of lowmass galaxies is found to decrease with redshift, suggesting that AGN in dwarf galaxies evolve differently than those in high-mass galaxies. The future large, deep, multiwavelength surveys that will result from the synergy of next decade missions such as Athena with major optical/IR facilities will allow us to detect IMBHs in fainter (less massive) and more distant galaxies and thus to better understand how supermassive black holes in the early Universe formed.

E1.12-0024-18 PHYSICAL PROPERTIES OF THE HIGHEST REDSHIFT SUPERMASSIVE BLACK HOLES

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I will review the current understanding of key physical properties of some of the first generation of growing supermassive black holes (SMBHs). This includes their accretion rates and history, their host galaxies, and the large-scale environments that enabled their emergence about a billion years after the big bang. The available multi-wavelength data show that these SMBHs are consistent with Eddington-limited, radiatively efficient accretion that had to proceed almost continuously since very early epochs. New ALMA data confirms high SFRs and gas content in the host galaxies, and moreover a high fraction of companion, interacting galaxies, separated by 10-50 kpc. This clearly supports the idea that the first generation of luminous SMBHs grew in overdense environments, and that major mergers are important drivers for rapid early SMBH and host galaxy growth, although other fueling processes and accretion modes may still be required. Current X-ray surveys cannot access the lower-mass counterparts of these rare massive quasars, which would elucidate the earliest stages of BH formation and growth. Such low-mass nuclear BHs will be the prime targets of the deepest surveys foreseen for the next generation of X-ray space observatories, such as the upcoming ESA Athena mission and the NASA Lynx mission concept.

E1.12-0025-18 INVESTIGATING THE EVOLUTION OF SUPERMASSIVE BLACK HOLES (SMBHS) AS A FUNCTION OF REDSHIFT

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We aim to establish a new database to obtain a large statistical sample of SMBH in QSOs at different values of redshift, the database having the width of an emission line (e.g., H, Mg II and C IV). These advantages allow us to obtain many of L (5100 Acirc) and MBH estimates of QSO to show significant evolution for any value of MBH as a function of redshift and cosmic time. We also, investigated the evolution and distribution of SMBH masses over cosmic time with concentration on SMBH at high redshift. We aimed to answer the question: how does the black hole grow with cosmic time and how does the mass of SMBHs correlate to other QSO properties, such as their luminosity and optical line FWHM to show the existence of any significant evolution over cosmic time. This study may provide a useful way to probe for tracing the history of BH growth in distant Compton-thin QSOs; and in the universe and also display the birth and growth of the first Black Hole. We found poor correlations between H FWHM and Mg II FWHM and also between Mg II and C IV FWHMs interesting, as this implies different MBH for the same object. The fact of the matter is that MBH (H) are the most reliable of these measurements, MBH (Mg II) are slightly less reliable and MBH (C IV) are not reliable due to the effects of winds and reddening. Our research found that the maximum peak of the mass of QSOs (BHs) grows with increased redshift. Here, we found that the more massive BHs achieve most of their growth at a very early epoch in high redshift, such as Z > 5.5, while QSOs tend to have a lower mass black hole at lower redshift. This process is called Downsizing. We find the maximum peak in the mass of QSOs for all samples of QSOs is 109 M, with a few exceptionally massive objects reaching 1010 M. So, a SMBH containing between a million and a billion times the mass of the Sun gives off as much as 10 billion times the Sun's energy. One of the most interesting results from this work is the relatively poor correlations between H and Mg II FWHM and between Mg II and CIV FWHMs. This implies different M BH for the same object.

E1.12-0027-18 X-RAY SELECTED AGNS BEHIND THE SMC

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Finding Active Galactic Nuclei (AGNs) behind the Magellanic Clouds is difficult because of the high stellar density in these fields. Although the first AGNs behind the Small Magellanic Cloud (SMC) was reported in the 1980's, it is only recently that the number of AGNs behind the SMC has increased by several orders of magnitude. AGNs behind the SMC are of several scientific interests, including an astrometric reference system needed to derive precise coordinates, especially for proper motion studies. The mid-infrared color selection technique has been proven to be an efficient mean of identifying AGNs, especially obscured sources. The X-ray regime is also complimentary in this regard. We present a catalog of AGNs behind the SMC by correlating the XMM-Newton X-ray point source catalog of the SMC with already known AGNs from literature, as well as candidates obtained from the ALLWISE mid-infrared color selection criterion. The redshift and luminosity distribution of the sample indicate that we detect sources from nearby Seyfert galaxies to distant and obscured quasars. The X-ray hardness ratios are compatible with those typically expected for AGNs. The near-infrared colors and variability are also consistent in this regard. We also present a sample of new candidate AGNs and candidates for highly obscured AGNs. All of these make an interesting subset for further follow-up studies.

E1.12-0029-18 EXPLORING THE AGN OBSCURER GEOMETRY WITH NUSTAR COMPTON HUMPS

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Thick gas and dust obscures most active galactic nuclei. However, little is currently known about its geometry, origin and why the covering factors are so high. With NuSTAR spectroscopy, we can now probe the geometry of the obscurer through its X-ray reprocessing effects at 8-40keV. We quickly learn that current models have severe difficulties, and do not produce the observed spectral shapes. To highlight this, I present a new hard X-ray color-color diagram, contrasting Compton-humps of observations and existing models. We also illuminate new physically-motivated AGN obscurer geometries. The observed colors that are difficult to reach by models allow general conclusions about the arrangement of gas and dust around AGN, and directions for future models.

E1.12-0030-18 A GLOBAL MILLIMETER VLBI ARRAY SURVEY OF COMPACT EXTRA GALACTIC RADIO SOURCES AT 86 GHZ

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Very Long Baseline Interferometry (VLBI) Observations at 86 GHz reach a resolution of about 50 µas and sample the scales as small as 103 - 104 Schwarzschild radii of the central black hole in Active Galactic Nuclei (AGN), and uncover the jet regions where acceleration and collimation of the relativistic flow takes place. We present the results from a large global VLBI survey of 162 ultra compact radio sources at 86 GHz conducted in 2010-2011. This survey has contributed an increase of 2 on the total number of AGN imaged with VLBI at 86 GHz. The survey data attained a baseline sensitivity of 0.1 Jy and a typical image sensitivity of 5 mJy/beam.

We have used Gaussian model fitting to represent the structure of the observed sources and to estimate the flux densities and sizes of the core and jet components. The model fitting yields estimates of the brightness temperature (Tb) of the VLBI bright core (base) of the jet and inner jet components of AGN, taking into account the resolution limits of the data at 3 mm. The modelfit-based estimates of Tb were compared to the estimates of brightness temperature limits made directly from the visibility data, demonstrating a good correlation between the two methods.

We have applied a basic population model with a single value of intrinsic brightness temperature, T0, in order to reproduce the observed distribution of Tb. Our data are consistent with a population of sources that have T0 = (3.77 0.14)×1011 K in the VLBI cores, implying that the inverse Compton losses dominate the emission and T0 = (1.42 0.19)×1011 K in the jets, which is slightly higher than the equipartition limit of 5.0×1010 K expected for these jet regions. For objects with sufficient structural detail detected, we also investigated the effect of adiabatic energy losses on the evolution of brightness temperature along the jet.

Under the equipartition condition between the magnetic field energy and particle energy density, the absolute distance of the VLBI core from the central engine can be estimated. The brightness temperature measurements obtained from this survey at 86 GHz are combined with the database of VLBI survey at lower frequencies (2, 8 and 15 GHz) to study the brightness temperatures in source frame in the sub-parsec scale of the ultra compact radio sources. From the vicinity of the central engine, the brightness temperature increases slowly and then rises with a steeper slope and then slow down. This gives a strong implication that the jets are accelerated and collimated by the magnetically driven force, as predicted by the relativistic inner jet models for the magnetic acceleration.

E1.13-0001-18 PULSATING ULXS: HIGHLY MAGNETISED NEUTRON STARS AT EXTREME MASS ACCRETION RATES

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X-ray pulsars (XRPs) form a special class in a family of accreting neutron stars (NSs). They stand out from the other classes due to their strong magnetic field, which typically exceeds 1012 G and affects even fundamental properties of matter. Magnetic field funnels the accretion flow and its gravitational energy is released in the form of X-rays coming from the compact area on the NS surface. Recent discoveries of pulsations from ultra-luminous X-ray sources (ULXs) have opened a new chapter in studies of XRPs. The classical theoretical limitation for luminosity is given by the Eddington value, which is about 2 1038 erg/s for NSs. Discovery of ULXs powered by accreting NSs is a challenge for theoretical astrophysics opening new questions on how accreting NSs can exceed the Eddington limit by at least two orders of magnitude.

I will discuss the features of XRPs, which arise and become essential at extremely high mass accretion rates: (1) accretion columns, which arise at super-critical mass accretion rates and provide a principal possibility to exceed the Eddington value, (2) optically thick envelopes, which are formed by hot accretion flow at the magnetospheric surface and can affect the spectral and timing properties of ULX pulsars, and (3) possibly strong neutrino emission at extreme mass accretion rates.

E1.13-0002-18 MAGNETIC FIELD STRENGTH OF A NEUTRON-STAR-POWERED ULTRALUMINOUS X-RAY SOURCE

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The discovery that some ultraluminous X-ray sources (ULXs) are powered by accretion on to neutron stars has revolutionized the field of super-Eddington accretion. Given their observed luminosities, these neutron stars are exceeding their Eddington limits by factors of up to 500. Much debate has taken place regarding the strength of their magnetic fields, which may provide the answer as to how these compact objects can shine so brightly. We have recently discovered a cyclotron resonance scattering feature in the X-ray spectrum of a ULX. Not only does this identify the source as another neutron-star-powered ULX, but it offers us a direct measurement of the magnetic field strength of the neutron star. I will present the observational constraints on the feature and what interpretations can be drawn from it.

E1.13-0003-18 NUMERICAL SIMULATIONS OF SUEPER-EDDINGTON ACCRETION FLOWS AND OUTFLOWS AROUND BLACK HOLES AND NEUTRON STARS

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By performing multi-dimensional radiation-MHD simulations, we reveal the inflow-outflow structure around the black holes (BHs) and the neutron stars (NSs). In both cases, the quasisteady, super-Eddington disk forms around the central objects. The disk is supported by the strong radiation pressure and the radiatively-driven outflows are launched from the disk surface. The hot outflow produces the high-energy X-ray photons via Comptonization. In addition, powerful outflows fragments into many gas clouds by the radiation RT instability. Such gas clouds would lead to the X-ray time variation with several seconds for the stellar mass black holes. Our results basically consistent with the recent observations of ultraluminous X-ray sources.

E1.13-0004-18 SUPER-EDDINGTON X-RAY PULSAR SWIFT J0243.6+6124 AS SEEN WITH ASTROSAT

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Swift J0243.6+6124 is a newly discovered X-ray pulsar, with a spin period of 9.85 sec, that went into outburst in October 2017. This system is of particular interest because it exhibited a super-Eddington X-ray luminosity (Lx 5x1038 erg/sec, assuming a source distance of 4 kpc) within a month of outburst onset. In contrast to what is seen in other similar sources (like 4U 0115+63), a radio jet was observed at peak Lx. I will present results of a 50,000 sec observation made by the Large Area X-ray Proportional Counter (LAXPC) and Soft X-ray Telescope (SXT) onboard Astrosat at the beginning of the outburst, when Lx 3x1037 erg/sec. The LAXPC data shows clear pulsations at around 9.85 seconds and a pulse-profile that varies significantly with energy. Our analysis of SXT and LAXPC data finds the broadband spectrum is well-fit by a two-component model (an absorbed blackbody plus cut-off power-law model). Finally, I will discuss the link between the pulse-profile characteristics and broadband spectrum.

E1.13-0005-18 DISK OUTFLOWS AND X-RAY SPECTRAL APPEARANCE OF NEUTRON STAR VERSUS BLACK HOLE ULXS

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The standard model for super-Eddington accretion flows (based on analytical work and GRMHD simulations) consists of a lower-density polar funnel and a thick disk outflow. SuperEddington sources viewed down the funnel are predicted to have harder X-ray spectra and higher apparent luminosity; the same sources viewed at higher inclination would have a softer spectrum (due to Compton down-scattering in the wind) and appear fainter. Although this scenario is probably applicable to some individual sources, we will argue that it is not consistent with the observed statistical properties of the ULX population. It is also difficult to reconcile this collimated scenario with the quasi-spherical ionized bubbles observed around several ULXs.

The reason why the funnel/outflow scenario struggles against the observations may be that it is only applicable to black holes and to weakly magnetized neutron stars. No strong outflows and funnels are expected for strongly magnetized, super-Eddington neutron stars, whose X-ray spectra would appear harder even at high inclination. If so, it means that the majority of ULXs are neutron stars (consistent with the shape of the cumulative luminosity distribution of this population). We will briefly discuss other tests to identify a neutron star ULX when X-ray pulsations are not detected.

E1.13-0006-18 SUPER-EDDINGTON PULSARS AND ULTRALUMINOUS X-RAY SOURCES

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Ultraluminous X-ray sources are an enigmatic population of X-ray binary with luminosities that exceed the Eddington limit for a standard 10 Msun stellar remnant black hole. Following a series of remarkable recent discoveries, primarily led by the NuSTAR X-ray observatory, we now know that some of the most luminous members of this population are actually powered by highly super-Eddington pulsars. These remarkable sources can reach apparent X-ray luminosities of 500 Eddington, making them the most extreme persistent accretors known! I will discuss the broadband X-ray characteristics of the known pulsar ULXs and their connection with the broader ULX population, focusing in particular on the implications for the demographics of the accretors powering these sources.

E1.13-0007-18 DISCOVERY OF A RELATIVISTIC JET IN A SUPER-EDDINGTON X-RAY PULSAR

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Relativistic jets are a universal phenomenon in accreting systems, yet the physical process underlying their formation is poorly understood. A key approach to understanding jet formation is constraining the conditions in which jets are launched. We present the discovery of a relativistic jet in the newly-discovered transient X-ray pulsar Swift J0243.6+6143 with the Very Large Array. While no radio emission is detected at the start of the outburst, optically thin radio emission emerges as the source accretes at super-Eddington rates. Subsequently, it transitions into optically thick emission as the outbursts decays below the Eddington limit, suggesting that the jet transitions from discrete ejecta into a steady, compact jet. This jet detection disproves the long-standing paradigm that strong neutron star magnetic fields (B > 1012 G), as in Swift J0243.6+6143, inhibit the formation of jets. It also constitutes the first monitoring of the evolution of a super-Eddington accretor jet and the first detection of disk-jet coupling in such a system. We will discuss the implications of these results for the formation of jets in accreting NSs specifically and super-Eddington accreting compact objects in general.

E1.13-0008-18 CHANDRA/HETGS OBSERVATIONS OF SMC X-3 AT A LUMINOSITY OF 10 L_EDD.

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The discovery that 3 ultra luminous X-ray sources are powered by accretion onto highly magnetized neutron stars has been a breakthrough in our understanding of super-Eddington accretion. These results suggest that neutron stars contribute to a large fraction of the observed ULX population. The sample of local high magnetic field neutron stars present an opportunity to study such high luminosity accretion flows. The Be/X-ray binary systems are excellent targets, with large magnetic fields (>1e12 G) and quasi-regular outbursts that reach values far in excess of the Eddington limit for a canonical neutron star (Lx 2e38 erg/s). We will present the re- sults of a high spectral resolution Chandra/ HETGS observation of the Small Magellanic Cloud Be/X-ray binary SMC X-3 during a giant/type-II outburst in 2016. The source was observed at a luminosity of Lx 2e39 erg/s or approximately 10 times the Eddington limit. The high quality grating data reveal numerous highly ionized emission lines. We will discuss the constraints these spectra place on our understanding of models for the super Eddington accretion flow onto a highly magnetized neutron star.

E1.13-0009-18 TIME-DEPENDENT NUMERICAL SIMULATION OF EDDINGTON AND SUPEREDDINGTON ACCRETION FLOWS ONTO BLACK HOLES AND NEUTRON STARS USING SMOOTHED PARTICLE HYDRODYNAMICS

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We use Smoothed Particle Hydrodynamics (SPH) technique to simulate the formation of TwoComponent Advective Flow (TCAF) for accretion onto black holes and neutron stars in presence of cooling and viscous effects. We vary the accretion rates from sub-Eddington to superEddington for flows having different values of injected angular momentum and viscosity. We study the time-dependent variation of the accretion disk and the outflow geometry for such cases when the radiative pressure of the flow (for both BHs and NSs) and of the normal boundary layer (NBOL, for NS) is included. We show 1)for black holes and neutron stars, super-Eddington accretion is highly likely when strong outflows are present, 2)how the value of viscosity limits the accretion rate, 3)how the limiting value is decreased for the case of NS due to the presence of NBOL. We also compare our findings from the numerical simulation with the observed X-ray data for a few black holes and neutron stars.

E1.13-0010-18 DISK-OUTFLOW COUPLING: MAGNETIZED SUBTO SUPER-EDDINGTON ACCRETION FLOWS AROUND BLACK HOLES

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Symbiotic description of accretion and outflow/jet appears to be indispensable, when there are lots of evidence that accretion and outflow influence each other. The most self-consistent approach towards this venture is the coupled 2.5-dimensional disk-outflow system, which we explore in the presence of large-scale magnetic field enabling angular momentum transport, when the magnetic field plays an indispensable role in order to generate vertical flux. Here, we discuss the importance of large scale strong magnetic field in the removal of angular momentum outward, as well as the possible origin of different kinds of magnetic barrier in advective, geometrically thick, sub-Keplerian accretion flows around black holes. The origin of this large scale strong magnetic field near the event horizon is due to the advection of the magnetic flux by the accreting gas from the environment, say, the interstellar medium or a companion star, because of flux freezing. In this circumstance, the accreting gas either decelerates or faces the magnetic barrier near the event horizon by the accumulated magnetic field depending on the geometry. We suggest that these types of flow are the building block to produce jets and outflows in the accreting system. We also find that in some cases, when matter is trying to go back to infinity after knocking the barrier, it is prevented being escaped by the cumulative action of strong gravity and the magnetic tension, hence by another barrier. In this way, magnetic field can lock the matter in between these two barriers and it might be a plausible explanation for the formation of episodic jet. Note that generally the episodic jets occur during the transition from hard to soft states, while the continuous jets only in the hard state. Finally, we try to reproduce the observed luminosity in various accretion/jet cases: from AGNs, Blazars to ultra-luminous X-ray sources (which often are argued to be super-Eddington accretors), at different combinations of mass and spin of the black holes, ratio of specific heats and accretion rate.

E1.13-0011-18 PROPERTIES OF THE 2015 OUTBURST OF V404-CYGNI FROM SPECTRAL ANALYSIS WITH THE TCAF SOLUTION

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Galactic black hole candidate V404-Cygni went through a violent outburst on June 2015 after 26 years of inactivity. Several radio and X-ray flare were observed during the 2015 outburst. We have analyzed rising phase of the outburst using 0.5-150.0 keV Swift/XRT and Swift/BAT data with two component advective flow (TCAF) model fits file in XSPEC. We have also analyzed two NuSTAR data available during our analyzing period. We find that the accretion flow during the outburst was dominated by sub-Keplerian matter. Shock was found to move closer to the black hole as outburst progressed. We did not observe a constant value of normalization, since there were high jet activity. We find the source was in hard state during the initial phase of the outburst. It become softer as outburst progressed but we could not conclude if there is any state transition due to the violent, i.e., rapidly changing accretion nature of the outburst. Spectral state was found softer after radio flare indicating mass ejection from the base of the jet or post-shock region. From the spectral analysis with the TCAF solution, we also obtain mass of the central black hole in the range of 9 – 12 M0.

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E1.13-0012-18 RAPID OPTICAL VARIABILITY IN THE 2015 OUTBURSTS OF V404 CYGNI

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V404 Cyg is one of black-hole X-ray transients, which are characterized by sporadic outbursts lasting for a few hundreds days (Tanaka & Shibazaki 1996). This object entered outbursts twice in 2015 after the 26-years quiescence, and we performed their optical photometry through the Variable Star Network (VSNET) team. We detected its optical short-term and large-amplitude variations for the first time in the 2015 June-July outburst. Some of them have repetitive patterns with amplitudes of 0.1-2.5 mag on timescales of 5-150 min, and we found these optical variations chased the simultaneous X-ray variations by comparing the simultaneous optical data and X-ray data which were taken by Swift/INTEGRAL satellites. Additionally, their optical flux were not explained only by Synchrotron emission expected by the radio flux. We thus concluded that the X-ray reprocessing was dominant in these variations (Kimura et al. 2016). Also in the 2015 December outburst, the rapid and high-amplitude optical variations were observed, and we confirmed the dominant X-ray reprocessing in these variations by the 30-s optical delay against the simultaneous X-ray variations (Kimura et al. 2017). Repetitive variability is also observed in a few other X-ray binaries. It was always observed when the luminosity was close to the Eddington luminosity, and hence, existing theory assumes the Eddington luminosity is a key condition. V404 Cyg sometimes exceeds the Eddington luminosity in the June outburst, but the repetitive patterns of optical variability in this object were detected even at low luminosity. In this presentation, we focus on the violent variability in this system and discuss its mechanism.

E1.13-0013-18 GRS 1915+105 AND MAXI J1535-571 OBSERVED BY ASTROSAT

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I will present the results of the analysis of Astrosat observations of the two bright blackhole binaries GRS 1915+105 and MAXI J1535-571, concentrating on the data from the laxpc instrument. For GRS 1915+105 the detection of a high-frequency QPO will be presented and compared with the previous results from RXTE. For MAXI J1535-571, which was observed at a flux increasing from 2 to 3 Crab, the evolution of the low-frequency QPO and its relation to spectral and fluc changes will be analyzed.

E1.13-0014-18 THE STRANGE CASE OF IGR J17091-3624: A SUB-EDDINGTON GRS 1915+105?

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IGR J17091-3624 is a Low Mass X-ray Binary. This object shows highly complex X-ray variability over timescales of seconds to minutes, strongly reminiscent of that seen in GRS 1915+105. The mechanism behind this variability is poorly understood, but has generally been described as being caused by the near-Eddington accretion rate of GRS 1915. We have analysed RXTE data of the 2011 outburst of IGR J17091-3624 to compare and contrast this object with GRS 1915, and have found that IGR J17091 is likely accreting at a significantly sub-Eddington rate. As such, we conclude that Eddington-limited accretion can no longer be considered a sufficient or necessary criterion for GRS 1915+105-like variability to occur in Low Mass X-Ray Binaries. We discuss the implications of these results on our understanding of these enigmatic objects.

E1.13-0015-18 SPECTRAL EVOLUTION AND SUPER EDDINGTON ACCRETION OF THE NEW BLACK HOLE CANDIDATE MAXI J1535-571 DURING ITS 2017 OUTBURST

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The black hole candidate MAXI J1535-571 is a recently discovered X-ray transient. We report on the observations with Insight-HXMT and other X-ray telescopes during the outburst. We present the state transition from the hard state to the soft state overall observation duration. When the source is not in the hard state, detailed spectral analyses using a multi-temperature disk model reveal that the disk luminosity is flatter than the inner disk temperature to the fourth power, and the disk temperature profile varies as the disk radius raised to the power of −0.5, consistent with the behavior of a slim disk, implying that the disk structure has been modified due to the high luminosity of ∼ 1039 erg s−1.

E1.13-0016-18 SUPER-EDDINGTON DRIVEN WINDS IN ULTRALUMINOUS X-RAY SOURCES

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The detection of fully-grown supermassive black holes powering active galactic nuclei at high redshift, when the Universe was young, challenges the theories of black holes growth, requiring long periods of high accretion, most likely above the Eddington limit. This is a focus of the next generation large missions, such as ATHENA, but cannot be done with the current instrumentation due to the large distances. Therefore, we need to study objects accreting at high Eddington rates in the nearby Universe. Most ultraluminous X-ray sources (ULXs, luminosities above 1039erg/s) show X-ray spectra that are consistent with stellar mass black holes or neutron stars accreting at or above Eddington and provide the best workbench to study super-Eddington accretion and fast growth rates. The detection of pulsations in a few ULXs confirms that some of them must be powered by neutron stars and support their compact nature and extreme accretion rates. It is not clear though how strong are their magnetic fields and what are their effects on the accretion discs. For instance, do magnetic fields inhibit radiationpressure driven winds? In this talk I will discuss our recent discoveries of relativistic outflows in archetypal ULXs and the most recent results obtained with high-resolution X-ray spectroscopy of ultra-luminous X-ray pulsars.

E1.13-0017-18 THE VERTICAL PROFILE OF ACCRETION DISKS CLOSE TO THE EDDINGTON LIMIT

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I will describe a simple analytic argument concerning the vertical profile of accretion disks close to the Eddington limit, and its implication on the observed SED and possibly on the onset of winds.

E1.13-0018-18 MODIFIED VISCOSITY AND WINDS IN ACCRETION DISKS

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Black holes surrounded by accretion disks are present in the Universe in different scales of masses, from microquasars, up to Active Galactic Nuclei. Standard geometrically thin optically thick disks based on alpha description leads to disk thermal and viscous instability when the radiation pressure dominates.

This could result in a limit-cycle behaviour operatating in this broad mass scale range. Such behaviour is observed in sources like like GRS1915+105 and IGR 17091-3624, having high (close to 1) value of Eddington ratio, with the timescales of order of ten to hundreds of seconds. In AGN the timescales are from hundreds of thousand of years, and the arguments are indirect. We will discuss the dependence of the outburst parameters on the description of the viscosity and the presence of strong winds. For example, in IGR J17091-3694 the limit-cycle oscillations are supressed by the wind launch, visible via spectral observations. We examined large grid of accretion disk models with generalized description of viscosity, which allows for an easy comparison of the theoretical model parameters and the measured observables.

As an example, we show the application of the model to determine the mass of the intermediate mass black hole of HLX-1 and its accretion rate from the observed flares, detected by the Swift X-ray satellite.

E1.13-0019-18 SUPER-EDDINGTON DISK WINDS IN BLACK HOLE OUTBURSTS

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One of the great revelations of the last 20 years, and one of the great legacies of RXTE, is the discovery of the “disk-jet connection,” a strong coupling between the behavior of accretion disks and relativistic jets around stellar mass BHs. But it has also become clear that this picture of black hole accretion is incomplete, as we have amassed a growing body of evidence from high-resolution spectroscopy with Chandra that accretion disk winds play a critical role in black hole outbursts. Once thought to be simple ionized disk atmospheres, we now know that X-ray absorption lines represent outflowing winds that carry away the vast majority of the infalling matter. Focusing on observations of GRO J1655-40, I will argue that these massive winds don’t merely regulate the accretion rate at the event horizon: they can control the course of black hole outbursts. I will discuss the implications for wind driving mechanisms and, time permitting, highlight some open questions illustrated by NICER and NuSTAR observations of the recent super-Eddington outburst of MAXI J1535-571.

E1.13-0020-18 OPTICAL INTERFEROMETRY OF A MICROQUASAR: RESOLVING SUPEREDDINGTON OUTFLOWS IN SS 433

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SS 433 rose to astrophysical stardom in the late 1970s with the discovery of its moving optical emission lines of hydrogen and helium which were shown to originate in a mildly relativistic (0.26c), precessing baryonic jet and which established it as the first microquasar. It remains the only known super-Eddington accretor in the Galaxy, possibly an edge-on Galactic ULX. The connection between SS 433 and ULXs, the latter discovered through X-ray observations since the 1980s, has been strengthened by the recent discovery of massive outflows in ULXs akin to those seen in SS 433 and even a second system containing a baryonic relativistic jet. The VLTI instrument GRAVITY achieves sub-milliarcsecond spatial resolution in the nearinfrared, sufficient to spatially resolve both SS 433's optical massive winds and baryonic jets for the first time. Over multiple epochs, we find evidence for both a circumbinary disk and polar outflow. The jet structures are emitted closer to the compact object than predicted from optical spectroscopy, but with a consistent exponential emission profile. Using spectro-interferometry, we can further isolate discrete jet ejections and resolve the activity of the central jet in both space and time. We will also present the first XSHOOTER observations of SS 433, which for the first time provide up to 20 pairs of jet lines simultaneously and allow to constrain the conditions and heating mechanism of the optical emitting jet gas as it travels through a dense surrounding medium. We will discuss the implications of these measurements for the accretion-ejection structure of SS 433.

E1.13-0021-18 SEARCHING FOR OUTFLOWS IN ULTRALUMINOUS X-RAY SOURCES THROUGH HIGH-RESOLUTION X-RAY SPECTROSCOPY

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Ultraluminous pulsars are a definite proof that persistent super-Eddington accretion occurs in nature. They support the scenario according to which most Ultraluminous X-ray Sources are super-Eddington stellar mass accretors rather than intermediate mass black holes. An important prediction of theories of supercritical accretion is the existence of powerful outflows of moderately ionized gas at relativistic speeds (0.2-0.3c). In practice, the spectral resolution of X-ray gratings such as RGS onboard XMM-Newton is required to resolve their observational signatures in ULXs. Using RGS, the outflows have been discovered in the spectra of 3 ULXs (none of which are currently known to be pulsars). We studied a sample of 10 ULXs and found one which shows evidence (3σ) for a relativistic jet with a projected speed of 0.34c, another feature widely predicted by the models of super-Eddington accretion. The rest do not have high enough data quality for a significant detection but most show signatures similar to those of ULXs with known outflows. A majority also exhibits narrow emission lines which could originate in photoionized, or shocked gas (as the potential outflow hits the surrounding medium). Most recently, the 4th ultraluminous pulsar was discovered in NGC 300. I will present the results of a rigorous, in-depth search for a relativistic wind in the spectrum of this object using all available X-ray data.

E1.13-0022-18 A NEW, CLEAN CATALOGUE OF ULXS IN NEARBY GALAXIES

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Study of the wider population of super-Eddington accreting objects is facilitated by the existence of catalogues of ultraluminous X-ray sources (ULXs). We have created a new, clean catalogue of extragalactic non-nuclear X-ray sources by correlating the 3XMM-DR4 data release of the XMM-Newton Serendipitous Source Catalogue with the Third Reference Catalogue of Bright Galaxies and the Catalogue of Neighbouring Galaxies, using an improved version of the method presented in Walton et al. (2011). Our catalogue contains 1,467 sources, of which 381 are candidate ULXs. Our resulting catalogue improves upon previous catalogues in its handling of contaminants by taking into account XMM-Newton quality flags, and we estimate the contamination of ULXs by background sources to be 19%. We define a 'complete' subsample as those ULXs in galaxies for which the sensitivity limit is below 1039 erg s1 and use it to examine the hardness ratio properties between ULX and non-ULX sources, and ULXs in different classes of host galaxy. We find that ULXs have a similar hardness ratio distribution to lower-luminosity sources, consistent with previous studies. We also find that ULXs in spiral and elliptical host galaxies have similar distributions except for a hard subpopulation found in spirals, which we postulate is due to high levels of absorption within the host galaxy rather than any intrinsic difference in the spectral shape of the ULXs. Our catalogue contains further interesting subpopulations for future study, including Eddington Threshold sources and highly variable ULXs, and we give an overview of science that has been performed with these subsamples so far. We also examine the highest-luminosity ULXs in our catalogue in search of IMBH candidates, and find eight new possible candidates.

E1.13-0023-18 COMPARE SUPER-EDDINGTON ACCRETION DISKS ONTO STELLAR MASS AND SUPERMASSIVE BLACK HOLES

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Supper-Eddington accretion is expected to happen for both stellar mass black holes as in some ULXs and supermassive black holes as for tidal disruption events. Structures of accretion disks are normally expected to be similar for the two types of black holes. However, one important difference is the ratio between radiation pressure and gas pressure, which significantly affects the properties of MRI turbulence and disk structures. I will describe a series of 3D global radiation magneto-hydrodynamic simulations for super-Eddington accretion disks for the two types of black holes with a wide range of accretion rates. I will show the importance of density waves in the supermassive black hole case due to the strong radiation pressure. Flow structures, outflow properties, radiative efficiencies and observational properties of super-Eddington accretion disks in the two regimes will also be compared.

E1.13-0024-18 RELATIVISTIC BARYONIC JETS FROM AN ULTRALUMINOUS SUPERSOFT X-RAY SOURCE

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While ultraluminous supersoft X-ray sources (ULSs) bear features for intermediate mass black holes or very massive white dwarfs possibly close to Chandrasekhar mass limit, our recent discovery of processing relativistic baryonic jets from a prototype ULS in M81 demonstrate that they are not IMBHs or WDs, but black holes accreting at super-Eddington rates. This discovery strengthens the recent ideas that ULXs are stellar black holes with supercritical accretion, and provides a vivid manifestation of what happens when a black hole devours too much, that is, it will generate thick disk winds and fire out sub-relativistic baryonic jets along the funnel as predicted by recent numerical simulations.

E1.13-0025-18 THE DONOR STARS OF ULTRALUMINOUS X-RAY SOURCES

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Ultraluminous X-ray sources (ULXs) are the most extreme X-ray binaries in the Universe. As the large majority of ULXs are extragalactic objects and their optical emission is in most cases dominated by the accretion disc, spectroscopic identification of ULX donors is challenging. Many ULXs are believed to have high mass donor stars as they are found in or near star forming regions. This makes them possible progenitors for the black hole mergers discovered by LIGO. To learn where they fit in the picture of massive binary star evolution, knowledge of the donor stars in these systems is crucial. Detecting stellar absorption lines is also necessary to obtain dynamical mass measurements, which is the only direct way to determine the mass of any black hole accretors in ULXs.

Of the five ULX donor stars that have been identified spectroscopically, three are red supergiants discovered in our near-IR survey of nearby ULXs. The photometric part of this survey is now finished and our spectroscopic follow-up campaign, to classify the counterparts and monitor the ones that are confirmed to be stellar, is well underway. I will show the latest results of this campaign and discuss the opportunities afforded by upcoming facilities such as JWST and 30-m class telescopes.

E1.13-0026-18 A SPITZER TIME-DOMAIN INVESTIGATION OF MID-INFRARED COUNTERPARTS OF ULTRALUMINOUS X-RAY SOURCES

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We present mid-infrared (IR) light curves of the Ultraluminous X-ray Sources (ULX) taken by the Spitzer Space Telescope at 3.6 and 4.5 m in the Spitzer Infrared Intensive Transients Survey. We highlight the observations of the well-studied ULX Holmberg II X-1, which exhibits variability in the mid-IR. The mid-IR emission from Holmberg II X-1 is determined to arise primarily from dust emission rather than from a jet or an accretion disk outflow. A comparison of Holmberg II X-1 with a sample of spectroscopically identified massive stars in the Large Magellanic Cloud on a mid-IR color-magnitude diagram suggests that the mass donor in X-1 is a supergiant (sg) B[e]-star. The sgB[e]-interpretation is consistent with the derived dust properties and the presence of the [Fe II] (= 1.644 m) emission line revealed from previous near-IR studies of X-1. We attribute the mid-IR variability of X-1 to the increased heating of dust located in a circumbinary torus. It is unclear what physical processes are responsible for the increased dust heating; however, it does not appear to be associated with the X-ray flux from the ULX, given the constant X-ray luminosities provided by serendipitous, nearcontemporaneous X-ray observations around the first mid-IR variability event in 2014. Our results highlight the importance of mid-IR observations of luminous X-ray sources traditionally studied at X-ray and radio wavelengths.

E1.13-0027-18 SPECTRAL PREDICTIONS FROM SUPER-EDDINGTON ACCRETION SIMULATIONS

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The study of super-Eddington accretion is essential to our understanding of the growth of supermassive black holes in the early universe, the accretion of tidally disrupted stars, and the nature of ultraluminous X-ray sources. Unfortunately, this mode of accretion is particularly difficult to model because of the multidimensionality of the flow, the importance magnetohydrodynamic turbulence, and the dominant dynamical role played by radiation forces. However, recent increases in computing power and advances in algorithms are facilitating major improvements in our ability to model radiation in numerical simulations of astrophysical plasmas. I will briefly describe our new radiation transfer modules and discuss our efforts to model super-Eddington accretion flows around stellar mass and supermassive black holes. I will focus on the predictions of the spectrum from these simulations generated using Monte Carlo radiation transfer methods to post process the numerical simulations.

E1.13-0028-18 SUPER-EDDINGTON ACCRETION IN TIDAL DISRUPTION EVENTS

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In a tidal disruption event (TDE), a star is disrupted close to a supermassive black hole by the overpowering tidal force. Stellar debris is fed to the black hole at a rate determined by the black hole mass and spin as well as the stellar structure and orbital parameters. This rate can be as high as hundred times of the Eddington accretion rate of the black hole. As compared to the scenario in Active Galactic Nuclei or X-ray binaries, a TDE disk is formed at a much closer distance to the black hole. Therefore, TDEs likely provide the best environment to study superEddington accretion onto supermassive black holes in the local universe. I will talk about our general-relativistic radiation magnetohydrodynamics simulation of a compact super-Eddington disk resembling disks assembled in TDEs. Wide-angle, optically thick winds are produced from the radiation pressure dominated thick disk, and a relativistic jet can be produced when conditions are optimal. Emissions produced from the inner disk are reprocessed in the outflows, and the observed emissions sensitively depend on the viewing angle of the observer. I will also discuss how this leads to a unified model for TDEs, which can explain various classes of TDEs that have been observed.

E1.13-0029-18 THE EFFECTS OF RADIATION PRESSURE ON DUSTY GAS: SUPER-EDDINGTON OUTFLOWS IN NORMAL AGN

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The force due to UV radiation acting on gas with a typical Galactic dust content is about 1000 times greater than the radiation force on ionized hydrogen due to Thomson scattering of electrons. If we consider that the Eddington limit occurs when the radiation force of an object equals its gravitational attraction, then AGN which exceed 0.1% of the Eddington limit for ionized gas alone can be Super-Eddington for dusty gas. The UV absorption is rapidly absorbed however so the effective limit is a function of the column density of the gas. An outflow region is defined in the Eddington fraction - column density plane. Observational evidence for this will be presented and discussed together with modelling of the dynamics of momentum-driven outflows seen in many AGN. Much that is learned from dusty outflows should be relevant to all Super-Eddington outflows.

E1.13-0030-18 MULTI-WAVELENGTH OBSERVATIONS OF THE SUPER-EDDINGTON ACCRETION FLOW IN NARROW-LINE SEYFERT 1 GALAXIES

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The most powerful accretion and radiation processes in the Universe can be found in superEddington AGN. Among them, super-Eddington Narrow-line Seyfert 1 Galaxies (NLS1s) are the most ideal targets for observations with current instruments. This is because they are both bright and highly variable, and so can provide high-quality data for detailed investigation of the accretion flow. In this talk, I will present multi-wavelength spectral-timing properties and the broadband spectral energy distribution of unobscured super-Eddington NLS1s. I will show that these observational results can be explained in a unified accretion flow scenario, which contains a standard outer disc, a puffed-up inner disc with strong disc wind and/or advection (which suppresses the radiation efficiency), an extended soft X-ray corona region, and a compact hard X-ray corona region. By considering the inclination angle effect, such a scenario has the potential to explain the X-ray complexity of all super-Eddington NLS1s, without requiring a large spin parameter. I will also show that super-Eddington NLS1s are most likely to be the low-redshift analogies of super-Eddington quasars at high redshifts. Finally, I will mention future observations that can bring new information about the super-Eddington accretion flow in AGN.

E1.13-0031-18 WHAT'S IN THE WIND? SPECTRAL SYNTHESIS FOR BROAD ABSORPTION LINE QUASARS

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Despite years of study, physical constraints on broad absorption line quasar outflows have been obtained from only a handful of objects. We introduce SimBAL, a spectral synthesis fitting method for broad absorption line quasars (BALQSOs), which uses Bayesian model calibration to compare synthetic spectra computed from photoionization model results with observed spectra. We have found that SimBAL allows us to study BALQSOs in new ways. We present results from SDSS 0850+4451, a low-ionization BALQSO, where we were able to map the physical parameters of the outflowing gas (ionization parameter, column density, covering fraction) as a function of velocity. We present results from a sample of iron low-ionization BALQSOs, where we found that the distances of the outflows from the central engine range from sub parsec to kiloparsec scales, as well as a dearth of objects with large line widths at kiloparsec distances. We discuss future prospects, and speculate on the relationship between accretion and the power source of the outflows.

E1.13-0032-18 HOW DOES THE EDDINGTON LIMIT AFFECT THE MULTIWAVELENGTH VARIABILITY OF AGN?

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AGN emit a significant fraction of their power as a variable X-ray continuum, which is usually observed to correlate with variability in UV/optical emission. However, such correlations are not always observed. For example, the recent 40 day long XMM-Newton large programme on IRAS 13224-3809 showed no correlation between X-ray and W1-band variability. This source is believed to be accreting at around the Eddington limit and other discoveries in the new dataset, such as a variable Ultra-Fast Outlow, demonstrate that more than the thin accretion disc and corona structure of sub-Eddington AGN is present in this source. Other highly accreting AGN also lack correlations between the observed X-ray and optical emission, suggesting that changes to the accretion flow at around the Eddington limit may be responsible for the lack of correlation. We will present results from the IRAS 13224-3809 campaign and compare these with findings from other AGN monitoring campaigns to show what such campaigns can teach us about differences in the accretion structure between moderately and highly accreting systems.

E1.13-0033-18 LONG-TERM BEHAVIORS OF THE ULTRALUMINOUS X-RAY SOURCE NGC1313 X-1

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Ultraluminous X-ray sources (ULXs) are known to vary X-ray luminosities with one order of magnitude. However, the behavior in just rising and decaying phases during outbursts is still unclear due mainly to the sparse data sampling. Here, we analyzed a long-term monitoring data set (since 2013 June) of NGC1313 X-1 obtained with Swift/XRT. We found that X-1 has experienced the low luminosity state (about 7 1039 erg/s, a quiescent stable phase) and two types of outbursts: One is month-scale outbursts with relatively modest brightening (to

9 1039 erg/s) and spectral softening. Contrastingly, the other type shows day-scale, remarkable brightening (to 4 1040 erg/s) with spectral hardening; such an extreme luminosity has been observed only once, with Suzaku reported by Mizuno et al. (2007). We also found a distinctive behavior just before some outbursts.

Based on best-fit parameters of each phase and the hysteresis variation of NGC1313 X-1, we suggest a super-critical accretion flow model composed of two parts: a moderately massive inner disk and a highly massive outer one. The luminosity and spectral variations of X-1 may be caused by moves of the transition radius which separates these two disk regions. In addition, we will mention a notable behavior during a more long period by many archival data sets with other satellites.

E1.13-0034-18 ASTROSAT OBSERVATIONS OF MAXI J1535-571 DURING ITS BRIGHT 2017 OUTBURST

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MAXI J1535-571 (J1535) is a hard X-ray transient recently discovered by the Monitor of All-sky X-ray Image (MAXI) and Swift/BAT. Radio and X-ray follow up observations showed that this system is a Low-Mass X-ray binary containing a Black Hole. This source is of particular interest, as the outburst was very bright, reaching a maximum flux of 2 Crab as seen by Swift/BAT (15- 50 keV). As a part of several multi-wavelength campaigns on J1535, AstroSat observed J1535 for a total of 5 consecutive days (between 12-17 September, 2017). The observations made with the Large Area X-ray Proportional Counter (LAXPC) instrument on-board AstroSat revealed the presence of a strong and sharp Quasi Periodic Oscillation (QPO) at 2.4 Hz. Assuming a source distance of 8 kpc, we measure the source luminosity of about 6e38 ergs/s which is close to the Eddington luminosity measured for a 10 solar mass black hole. In this talk, I will present results on this 5-days observation of the brightest LMXB transient observed with Astrosat, including a detailed analysis of the powerand lag-spectrum and the interpretation of these results, in the context of the 0.5-80 keV broadband spectra as seen by the Soft X-Ray Telescope (SXT) and LAXPC.

E1.13-0035-18 NUMERICAL SIMULATIONS OF TIME-VARYING VISCOSITY INSIDE A TWO COMPONENT ADVECTIVE FLOW STUDYING CREATION AND ANNIHILATION OF KEPLERIAN DISC DURING AN OUTBURST

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Accretion process around compact objects needs a considerable amount of viscosity to transport angular momentum and maintain the flow at a steady rate. If the viscosity is inadequate, the rates can be time dependent. X-ray outbursts are believed to be the effect of sudden rise in viscosity which transports angular momentum efficiently and increases the accretion rates causing higher X-ray flux. As the viscosity is reduced, the outburst subsides and the object returns back to its pre-outburst quiescence stage. We perform numerical simulations considering the rise and the fall of the viscosity parameter at the outer injection grid, assumed to be located at the accumulation radius where matter from the companion is piled up before being released by enhanced viscosity. Since X-ray spectra of a black hole candidate can be explained by a Keplerian disc component in presence of a post-shock region of an advective flow, we want to understand if the flow configurations required to explain spectral states of an outbursting source could be obtained by time varying viscosity. We present our simulation results to prove that low-angular momentum (sub-Keplerian) advective flows do form a Keplerian disc in the pre-shock region when the viscosity is enhanced which disappears at a much longer time scale after the viscosity is withdrawn. From the variation of the Keplerian disc inside an advective halo, we have successfully explained the two component advective flow dynamics during an entire X-ray outburst. We also claim that the hysteresis effect of an outburst is mainly due to the difference in creation and annihilation times of the Keplerian component.

E1.13-0036-18 RELATIVISTIC ACCRETION HYDRODYNAMICS AROUND ROTATING BLACK HOLES.

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Using this relativistic equation of state(EOS) in which the adiabatic index Gamma(=Cp/Cv), varies smoothly from 5/3 to 4/3 as a function radius, we re-investigate the issue of the formation of the shocks in accretion and wind solutions once again. We find that except for the region very nearby the compact object, Gamma does not change significant from its non-relativistic value and therefore the EOS mostly remains non-relativistic in nature. As a consequence the existence of two saddle type critical point becomes a rare possibility indicating that it is an artifact of the choice of the constant ultra-relativistic (Gamma =4/3). Therefore, the formation of shocks in the flow (which require the presence of two saddle type points) becomes unlikely.

E1.13-0037-18 EVOLUTION OF FLOW PARAMETERS OF THE PERSISTENT X-RAY SOURCE CYGNUS X-1 USING THE TWO COMPONENT ADVECTIVE FLOW SOLUTION

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Cygnus X-1 is one of the brightest persistent galactic black hole (BH) binaries. It dwells most of the time in its hard state although it also exhibits soft-states as well as 'failed-transitions'. Because of its persistence, brightness and proximity Cygnus X-1 is a very important source to study the physics of accretion processes around black holes. In this work, we investigate the spectral behavior of the persistent black hole candidate Cygnus X-1 from December 10, 1997 to May 12, 1998 when it was in its persistent hard state as well as during one of its flaring phases, between March 12, 2003 to October 7, 2003 when the object entered into the soft/intermediate state. We use the RXTE/PCA data and apply Two-Component Advective Flow (TCAF) solution for this purpose. We classify the spectral states based on the nature of the TCAF model fitted flow parameters, namely, the disk and the halo rates, the location, size and the density of the Compton cloud produced by the post-shock flow and the accretion rate ratio (the ratio between the halo rate and the disk rate). This gives us an idea of the underlying accretion flow dynamics and provides us with evolution of the aforementioned accretion flow parameters. This is the first time that explicit flow parameters of Cygnus X-1 are obtained from the spectral analysis. From the behavior of the accretion flow parameters during the flaring phase, i.e., the dynamical evolution of the Keplerian and the sub-Keplerian rates, we conclude that the free-fall time scale is comparable to the viscous time-scale which further enables us to infer that the Keplerian disk of Cygnus X-1 is possibly quite small.

E1.13-0038-18 ACCRETION TORI AROUND KERR SMBHS: CONSTRAINTS ON RETROGRADE AND PROGRADE DOUBLE ACCRETING TORI

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We provide constraints on formation and interaction of coupled coplanar accreting tori orbiting a central Kerr SMBH, independence on its dimensionless spin. This is a comparative investigation of the prograde versus retrograde tori properties. We demonstrate that two accretion tori orbit around the central Kerr attractor only under very specific conditions. These configurations could be directly linked to the current models featuring the obscuration of galactic BHs X-ray emission. The emergence of instability phases of a torus couple, consisting in a super-Eddington accretion stage, is discussed, tori collision has been also investigated. The first evaluation of the center-of-mass energy and the accretion rates proves that the collisional energy efficiency increases with the dimensionless black hole spin, being very high for near-extreme black holes. Dynamics of the unstable phases of the double tori systems becomes significant for the high energy phenomena which could be observable in the X-ray or γ-ray emission in active galactic nuclei and quasars.

E1.13-0039-18 X-RAY OBSCURERS: BRIDGING THE GAP BETWEEN WARM ABSORBERS AND ULTRA-FAST OUTFLOWS

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Outflows from active galactic nuclei are found over a broad range of distances from the supermassive black hole and with a large range of velocities. The so-called "warm absorbers" cover a broad range of ionization parameters but at modest velocities of a few hundred to thousand km/s and relatively modest column densities of typically less than 1% of the Thomson depth. On the other extreme, ultra-fast outflows with speeds of order 0.1c have column densities up to a Thomson depth but are almost fully ionized.

In this contribution, we discuss a newly discovered component, the X-ray obscurers which occupy the velocity gap and likely also the distance gap between warm absorbers and ultra-fast outflows. These obscurers have been studied in detail using deep joint monitoring observations with XMM-Newton, HST, Swift and NuSTAR in for example NGC 5548 and NGC 3783. The gas is generally lowly ionized, has high column densities up to 10% of the Thomson depth and is outflowing at speeds of several thousands of km/s. They block a significant fraction of the ionizing radiation from the central regions, are likely due to a strong accretion disk wind, and occur more frequently than previously anticipated. We discuss the impact of these obscurers on their environment, their frequency and the observational challenges to study them.

E1.13-0040-18 ORBITAL RESOLVED SPECTROSCOPY OF GX 301-2: WIND DIAGNOSTICS

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GX 301-2, a bright high-mass X-ray binary with an orbital period of 41.5 days, exhibits stable periodic orbital intensity modulations with a strong pre-periastron X-ray flare. Several models have been proposed to explain the accretion at different orbital phases, invoking accretion via stellar wind, equatorial disc, and accretion stream from the companion star. From the orbital resolved spectroscopic study of GX 301-2 with the X-ray all sky monitor MAXI, we found a very large equivalent width of the iron line for a small value of the column density in the orbital phase range 0.1-0.3 after the periastron passage. The orbital dependence of the spectral parameters favours accretion on to the neutron star occurring via a high density accretion stream plus stellar wind of the companion. We further investigate the characteristics of the accretion stream with an ASTROSAT LAXPC and SXT observation of the system.

E1.13-0041-18 THE FULL CYCLE OF SIMULATING BLACK HOLE SHADOWS: FROM RAY TRACING TO SPECTRUM-SPECIFIC IMAGES OF AN ARBITRARILY SHAPED SCREEN

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We present a bundle of codes which realize the full cycle of simulation of black hole shadows: from massive ray tracing to depicting the shadow and its spatial Fourier transform for an arbitrarily shaped luminous screen and the radiation spectrum of the latter. Unlike available public codes, which mostly deal with ray tracing alone, our code implements the entire workflow up to providing the resulting image in a digital format. The ray tracing is parallelized on graphics processing units (GPUs) which reduces the simulation time to a few seconds. This allows for exploiting the output of the code as an input in Monte Carlo routines that fit observational data to theoretical models. It is highly relevant in view of the upcoming Event Horizon Telescope data which will make it possible to constrain the geometry and physics of accretion disks by their direct images.

E1.13-0042-18 HOW OUTFLOWS ARE COLLIMATED AND ACCELERATED? – ROLE OF TOROIDAL MAGNETIC FLUX TUBES

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Observations in the two spectral regions of the electromagnetic spectrum, in the domain of the hard X-rays on one hand, and in the domain of radio wavelengths on the other hand, revealed existence of relativistic jets known as microquasars or nano-quasars. It has been shown that the relativistic jets with significant matter content and kinematic luminosity are produced when the inner part of the disk is destroyed and evacuated. Clearly, Magnetic field has to play a major role in origin, acceleration and collimation of these relativistic jets.

Due to predominantly rotating accretion flows close to the inner edge of a disk, magnetic fields advected through the flow would be toroidal. We study the trajectories of these toroidal flux tubes inside a time dependent geometrically thick flow which undergoes a centrifugal force supported shock. These flux tubes are under the influence of drag force, tension, Coriolis force and buoyancy force. We also study effects of these flux tubes on the dynamics of the inflow and the outflow specifically focussing on the outflow properties such as its collimation and the rate. It is seen that depending upon the cross sectional radius of the flux tubes which control the drag force, these field lines may move towards the central object or oscillate vertically before eventually escaping out of the funnel wall (pressure zero surface) along the vertical direction. A comparison of results obtained with and without flux tubes clearly show the role these flux tubes play in collimation and acceleration of jets and outflows.

E1.13-0047-18 SEGREGATION OF DISC, HALO AND OUTFLOW FROM A TRANSONIC FLOW AROUND A BLACK HOLE

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Rigorous numerical simulations of rotating, axisymmetric, two dimensional viscous accretion flows in presence of cooling around black holes were performed using a grid based finite difference method. In our earlier works, we performed single quadrant (first quadrant) simulations for the same purpose. However, in this present work, we do not use reflection symmetry on the equatorial plane to inspect if the whole disc along with the centrifugal barrier oscillate vertically. The segregation of Keplerian disc, sub-Keplerian halo with oscillating shocks and bi-directional outflows are clearly seen in these simulations.

E1.13-0048-18 THE 2005 APPARENT OUTBURST OF XTE J1118+480: SPECTRAL STUDY WITH THE TCAF SOLUTION

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We have analysed RXTE/PCA data for 2005 outburst of black hole candidate (BHC) XTE J1118+480. The spectral analysis of the source has been done with two types of model: phenomenological power-law (PL) and physical two component advective flow (TCAF) fits file in XSPEC. We notice that during the entire epoch of the outburst, accretion flow is highly dominated by the sub-Keplerian halo matters. From PL model fits, it is also evident that no signature of thermal disk black body component is found while fitting spectral with only PL model. From TCAF model fits, very low contribution from Keplerian disk component is found. From nature of the variation of the spectral fitted parameters, we defined entire period of the 2005 outburst as hard/low hard state. The entire phase of the 2005 outburst, was highly dominated by jets/outflow since high radio fluxes are observed. We also estimate the mass of the black hole and contribution of the jet X-rays from our TCAF model fitted spectral analysis.

Chakrabarti, S.K., & Titarchuk, L.G., 1995, ApJ, 455, 623

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E1.13-0049-18 IMPLICATION OF SOFT LAG IN HIGH INCLINATION BLACK HOLE TRANSIENTS

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We study the time lag properties of few low and high inclination black hole sources by using the observational data of RXTE during the evolution of Quasi Periodic Oscillation (QPO). We find a positive lag for all QPO frequencies in face on sources (low inclination) while the frequency dependent time lag switches sign (positive to negative lag) at a certain crossing frequency 2-3 Hz and becomes negative for the edge on sources. We also find in both type of sources that the time lag increases when QPO frequency goes down, i.e., when the size of the Comptonizing region goes up and at around a specific QPO frequency, i.e., roughly at a specific size of the Comptonizing region, the lag changes from hard to soft (i.e., switches sign). This frequency gives rise to a characteristic length scale where the lag changes its sign. This frequency is certainly not universal as the cancellation of lags would depend on inclination angles and the mass of the black holes which determine the length scales of the Compton cloud.

E1.13-0050-18 IMPLICATIONS ON DISK DYNAMICS FROM OUTFLOWS OF TRANSIENT SOURCES

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The problem of origin and acceleration of jets in compact objects is still a long term unsolved problem. According to TCAF model, centrifugal pressure dominated region of the flow just outside the black hole horizon, with or without shocks, acts as the base of outflow. This region also up-scatters soft photons from the Keplerian disk, which is dependent on the accretion rate. These soft photons gain energy at each scattering in the Compton cloud and makes it cooler. Thus it creates a link between accretion, cooling and ejection. As the cooling increases, thermal pressure is reduced and the jet flow rate decreases. Specifically, the emerging spectrum is softened due to increase in cooling. Our main goal is to show spectral softening due to mass outflow in presence of Compton cooling. We also observe from our transonic solution that the softening is higher when both cooling and outflow are present as compared to the case with cooling alone. It is observed that during hard and intermediate states, the outflow rate is higher. Our theoretical findinggs agree with the observed results on outbursting candidates. We thus directly correlate the outflow rate with the spectral state of the disk.

Chakrabarti, S.K., & Titarchuk, L.G. 1995, ApJ, 455, 623

Mondal, S., Chakrabarti, S. K., & Debnath, D. 2014, Ap&SS, 353, 223

E1.13-0051-18 ENERGY DEPENDENT TIME LAGS OF PHOTONS: SIMULATION MEETS OBSERVATION

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Time lags of photons originated from the accretion disk provides valuable information on the geometry of the disk. Major components that contributes to the lag variations are Comptonization, disk reflection and photon bending and are articulated in the literature. Using Monte-Carlo technique, we incorporate the aforesaid physical mechanisms considering Two Component Advective Flow (TCAF) geometry. Spectral distribution of photons emitted from TCAF are obtained. Variation of time lag with the size of Compton cloud or CENBOL, accretion rate, energy and inclination angle are reported. Finally, we compare our simulated results from TCAF with the observational results reported in the literature. We show that the the main reason for increasing time lag is the increase in size of the Compton cloud, or CENBOL.

E1.14-0001-18 THE CHERENKOV TELESCOPE ARRAY: PROJECT STATUS AND SCIENTIFIC PROGRAM

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See https://www.cta-observatory.org/consortium_authors/authors_2018_01.html for full author list

The Cherenkov Telescope Array (CTA) will be the next generation gamma-ray observatory, open to the scientific community, to investigate the very high-energy emission from a large variety of celestial sources in the 20 GeV - 300 TeV energy range. The full array, distributed over two sites, one in the northern and one in the southern hemisphere, will provide wholesky coverage and will improve the sensitivity with respect to the current major arrays such as H.E.S.S., MAGIC and VERITAS by a factor of five to twenty, depending on the energy. CTA will investigate a much higher number of already known classes of sources, going to much larger distances in the Universe, performing population studies, accurate variability and spatially-resolved studies. Moreover, new light will be shed on new classes of TeV sources, such as GRBs and cluster of galaxies. Furthermore, by pushing the high-energy limit to E > 100 TeV, CTA will allow a thorough exploration of the cut-off regime of the cosmic accelerators. The search for an annihilation signature of dark matter in the Galactic halo and in prominent dwarf spheroidal galaxies is one of the most important goals of CTA. We review the current status of the CTA project, introducing the highlights from the telescope prototypes and discuss the main CTA Key Science Projects, which will focus on major scientific cases, allowing us to provide legacy data-sets of high value to a wider community.

E1.14-0002-18 THE SCHWARZSCHILD-COUDER TELESCOPE: AN INNOVATIVE TECHNOLOGY FOR SCIENCE WITH THE CHERENKOV TELESCOPE ARRAY

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A dual-mirror gamma-ray telescope design, called the Schwarzschild-Couder Telescope (SCT), has been proposed for imaging atmospheric Cherenkov telescopes, in particular as a type of Medium Sized Telescope providing excellent sensitivity in the core energy range (0.1 to 10 TeV) of the Cherenkov Telescope Array. The design features excellent optical resolution, enabling gamma-ray angular resolution and background rejection that are superior to the traditional single-mirror design. An international group is now constructing a prototype SCT alongside the VERITAS array at the Fred Lawrence Whipple Observatory in Arizona. The support tower, drive system, and optical support structure are in place, and primary mirror panel installation is now underway. The prototype camera, featuring silicon photomultipliers and waveform sampling digitizers, has achieved first light in the laboratory and will be installed on the telescope when the primary mirror installation is complete. I will describe the unique advantages of the SCT design as well as the status of the prototype telescope.

E1.14-0003-18 THE CHERENKOV TELESCOPE ARRAY AS A PROBE OF FUNDAMENTAL PHYSICS

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High-energy gamma rays can provide unique information about Particle Physics phenomena beyond the Standard Model of Particle Physics, which complements the studies performed at dedicated laboratory experiments and particle accelerators. The next generation of groundbased observatory for gamma-ray astronomy, the Cherenkov Telescope Array (CTA), will be sensitive to gamma-rays from 20 GeV to more than 300 TeV. With more than 100 telescopes located in two sites in the northern and southern hemispheres, CTA will provide full-sky coverage and will achieve an improvement by a factor of five to twenty in sensitivity with respect to the current major gamma-ray instruments. The reach of CTA encompasses considerable discovery space in the area of fundamental physics. For instance, CTA will probe the expected thermal relic cross-section for self-annihilating dark matter (DM) for a wide range of dark matter masses, including those inaccessible to the Large Hadron Collider (LHC). Besides the search for annihilation signals from dark matter, there is the exciting possibility of detecting spectral modulations in the gamma-ray emission from distant sources due to axion-like particles (ALPs), and finding evidence of Lorentz invariance violation (LIV) associated with possible quantum gravity effects on space-time at the Planck scale. In this talk, I will provide an overview of the fundamental physics topics in gamma-ray astronomy and the prospects for CTA to address them. A particular focus will be given to the CTA key science projects that relate to the studies of DM, ALPs and LIV.

E1.14-0004-18 FERMI STATUS (IN THE CONTEXT OF CTA)

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The Fermi Gamma-ray Space Telescope has revolutionized our understanding of the high-energy gamma-ray Universe. Since its launch about ten years ago, its primary instrument, the Large Area Telescope (LAT), is surveying the whole sky with unique sensitivity and location accuracy. These characteristics have made possible extraordinary scientific breakthroughs and also provided fundamental support for other facilities. Furthermore, the LAT collaboration has produced different catalogs of sources for the astronomy community allowing new discoveries, follow ups, and in general, an unprecedented characterization of the GeV sky. In this contribution, we will review the latest major results from the LAT collaboration, mainly focusing on extragalactic science. There is no doubt that Fermi-LAT will be an essential instrument in the coming multi-messenger multi-energy era in which CTA will play a crucial role in the TeV range.

E1.14-0005-18 HAWC AND WIDE ANGLE GAMMA-RAY SURVEYS IN THE CTA ERA

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HAWC Collaboration https://www.hawc-observatory.org/collaboration/

The High-Altitude Water Cherenkov (HAWC) observatory, now completing its third full year of operations, is conducting a wide-angle survey of TeV gamma rays and cosmic rays from two-thirds of the sky. With its discoveries of extended sources in the galactic plane, its highstatistics measurements of cosmic-ray backgrounds, and its continuous long-term monitoring of galactic and extragalactic objects, HAWC is carrying out a broad science program ranging from studies of galactic particle acceleration to searches for physics beyond the Standard Model. Data from HAWC are highly complementary to the sensitive pencil-beam surveys performed by imaging air Cherenkov detectors, and provide excellent opportunities for multi-wavelength and multi-messenger studies of steady and transient objects. I will present highlights from the first three years of HAWC measurements, and discuss the many synergies between current and future wide-angle surveys and the planned CTA observatory.

E1.14-0006-18 FUTURE GAMMA-RAY MISSIONS IN THE MEV REGION AND THE CONNECTION WITH CTA

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The energy range between 300 KeV and 100 MeV is an experimentally very difficult range and remained uncovered since the time of COMPTEL. Future instruments like e-ASTROGAM can address all astrophysics issues left open by the current generation of instruments. In particular, a better angular resolution in the energy range 10 MeV - 1 GeV is crucial to resolve patchy and complex features of diffuse sources in the Galaxy and in the Galactic Centre as well as increasing the point source sensitivity. This instrument addresses scientific topics of great interest to the community, as matter evolution, dark matter search, antimatter generation, very energetic phenomena in compact objects and massive black holes with particular emphasis on multifrequency correlation studies involving radio, optical, IR, X-ray, soft gamma-ray and TeV emission.

E1.14-0007-18 LATTES: DESIGN AND EXPECTED PERFORMANCE FOR A HYBRID DETECTOR FOR VHE GAMMA-RAYS COMPLEMENTARY TO CTA

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Current detectors for Very-High-Energy gamma-ray astrophysics are either pointing instruments with a small field of view (Cherenkov telescopes), or large field-of-view instruments with relatively large energy thresholds (extensive air shower detectors). The next generation of Cherenkov telescopes, the Cherenkov Telescope Array (CTA) will be installed in the Canary Islands and in Chile, and has already entered construction phase. Extensive air shower arrays are complementary to observatories such as CTA, as they are specially suited for detecting transient phenomena, working as a powerful trigger of extreme variable sources such as GW counterparts and gamma-ray bursts. In this talk we present the proposal for LATTES, a new hybrid extensive air shower detector, to be installed in South America, sensitive in an energy region starting from about 100 GeV. The detector combines a small water-Cherenkov detector, able to provide a calorimetric measurement of shower particles at ground, with resistive plate chambers which contribute significantly to the accurate shower geometry reconstruction. A full simulation of this detector concept shows that it is able to reach better sensitivity than any previous gamma-ray wide field-of-view experiment in the sub-TeV energy region. It is expected to detect with a 5-sigma significance a source fainter than the Crab Nebula in one year at 100GeV and, above 1TeV a source as faint as 10% of it.

E1.14-0008-18 COSMIC RAY STUDIES IN THE CTA ERA

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More than a century after their discovery, the origin of cosmic rays is still a matter of debate. Gamma ray observations are one of the most powerful ways to test our ideas about cosmic ray origin. In this talk, I will briefly review the status of the field, with particular attention to the role of future gamma ray facilities such as the Cherenkov Telescope Array.

E1.14-0009-18 FUTURE RADIO ASTRONOMY IN THE CONTEXT OF CHERENKOV TELESCOPE ARRAY

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In order to have a better understanding of the physics behind the non-thermal cosmic sources a multi-wavelength approach is necessary. Radio Astronomy has played a fundamental role in determining accurately the positions, structures and behaviors of many of the sources detected at gamma-rays. The synergies between radio and gamma will be strongly reinforced in the next decade thanks to the Square Kilometer Array (SKA) and the Cherenkov Telescope Array (CTA). These future new generation observatories will enable breakthrough science not possible with current facilities in radio and gamma. I will briefly report the main performances of these facilities and what kind of discoveries can we expect from the contemporaneous use of these new generation instruments.

E1.14-0010-18 X-RAY ASTRONOMY IN THE CONTEXT OF CTA

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The Cherenkov Telescope Array (CTA) promises to open a new frontier in very high energy gamma-ray astrophysics, with unprecedented sensitivity and angular resolution. Its broad science goals include the investigation of sites and mechanisms for particle acceleration, physical processes in the extreme environments of neutron stars and black holes, and the broad contributions of shocks, jets, and accretion to the high energy Universe. Previous observations and theoretical studies have made clear the intimate connection between gamma-ray emission in these environments and the observed properties of the associated X-ray emission. From constraints on magnetic fields and the properties of thermal gas to contemporaneous observations of variability and high-resolution studies of shocks and jets, X-ray observations provide unique insights into the environments that produce energetic gamma-rays. It is thus of crucial interest to consider the available X-ray resources for complementing gamma-ray studies in the era of CTA.

In this talk I will provide a brief summary of X-ray connections to key studies in the field of VHE gamma-ray astrophysics, and investigate future prospects for this synergy in the context of ongoing and upcoming X-ray facilities. With continued contributions from current observatories along with new capabilities provided by upcoming missions with survey capabilities, high spectral resolution, and polarimetry, the prospects for unique advances in high energy astrophysics are extremely promising.

E1.14-0011-18 COSMOLOGY IN THE CHERENKOV TELESCOPE ARRAY ERA

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The Cherenkov Telescope Array (CTA) will be the next generation gamma-ray observatory, open to the scientific community, and with two operational sites, one each in the northern and southern hemispheres. The observatory will thus provide full-sky coverage and an energydependent improvement by a factor of five to twenty in sensitivity with respect to the current major arrays. Thanks to CTA's low energy threshold of 20 GeV and a superb flux sensitivity in the range 50 GeV to 1 TeV CTA will detect hundreds of extragalactic sources (presumably mostly blazars) both in flaring and in quiescent states in a redshift up to z=2, and even beyond in case of extraordinary flares.The resolution of CTA will allow unique identification of spectral features induced during the propagation of gamma rays in the universe, which is sensitive to the density of the Extragalactic Background Light and to the magnetic fields in voids for reprocessed gamma rays In this talk I will give prospects for CTA to perform observational cosmology by resolving the evolution of the EBL with redshift as well as measuring the intergalactic magnetic field.

E1.14-0012-18 ASTRONOMY'S NEXT: WHAT CAN WE EXPECT FROM CTA AND GRAVITATIONAL WAVES?

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The discovery of gravitational waves and their multi-messenger fingerprint has opened tremendous opportunities for astrophysics. Instrumental breakthroughs in gravitational-wave detectors, electromagnetic and neutrino observatories shall lead to an information explosion during the coming years rapidly expanding humanity's cosmic and scientific horizon. Observations of gravitational-wave sources with the Cherenkov Telescope Array (CTA) promises opportunities that are complementary to insights with other cosmic messengers. The observation of an electromagnetic counterpart to the gravitational-wave event GW170817 by a multitude of instruments highlighted the value of multi-messenger astrophysics and indicated that short gamma-ray bursts (GRB) could arise from mergers of pairs of neutron stars, and, more generally, that binary mergers are capable of accelerating particles and producing high-energy emission. Potential GeV-scale emission from gravitational-wave events probes the environments into which the mergers are exploding, as well as the physics of particle acceleration at relativistic shocks. The Cherenkov Telescope Array, with a detection threshold of 20 GeV and rapid slewing capability, will be uniquely capable of characterizing the multi-GeV emission. The wide field of view of CTA enables it to efficiently observe the gravitational-wave localization region, allowing CTA to provide rapid source localizations for other instruments.

E1.14-0013-18 NEUTRINO ASTRONOMY AND CTA

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CTA will soon provide a greatly enhanced view of the very high energy gamma ray sky. Complementing the past decade's groundbreaking observations by gamma ray observatories such as HESS, MAGIC, VERITAS, Fermi and HAWC, discoveries of gravitational waves by LIGO and cosmic neutrinos by IceCube are opening the door to a new era of multi-messenger astronomy. We will review recent observations of cosmic neutrinos and the planned next steps in neutrino astronomy, and discuss the prospects from joint observations with CTA.

E1.14-0014-18 ESTIMATION OF GAMMA-RAY BURST DETECTION WITH CHERENKOV TELESCOPE ARRAY

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Observations by Fermi-LAT have proven that GeV emission is a relatively common feature in 12-13% of the GRBs detected at low energy by the GBM instrument. However, the number of photons detected at these energies is still limited due to the poor effective area of space-based detectors. Despite the long-lasting observational efforts of the current generation of Imaging Atmospheric Cherenkov Telescopes (IACTs), GRBs are still undetected with ground facilities.

The small number of photons detected between few tens of GeV and 100 GeV together with the lack of detections above 100 GeV have left unanswered many important questions about GRB physics. The next generation Cherenkov Telescope Array (CTA) has identified the GRBs as one of its multi-year key observational programs. The improved sensitivity of CTA will allow the study of GRB emission above few tens of GeV with a sufficiently large photon statistics to discriminate between the proposed emission models.

In this work, I report about the prospects for CTA detection rate on a physically-modeled GRB population. The analysis of the simulated events have been performed by using the latest version of Ctools, one of the CTA data analysis pipeline and instrumental response functions. As an additional outcome, this work could help us to determine the best observational setup for the north and south arrays.

E1.14-0015-18 INVESTIGATING THE ORIGIN OF THE RECOMBINING PLASMA IN W49B WITH X-IFU ONBOARD ATHENA

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The X-ray Integral Field Unit (X-IFU) on board Athena will provide spatially resolved highresolution X-ray spectroscopy in the 0.2-12 keV energy band with a spectral resolution of 2.5 eV up to 7 keV. Observations with X-IFU, will enable us to better understand the origin of the recombining plasma (RP) in W49B. In this work, we investigate the RP in the spectra of W49B with detailed simulations for X-IFU detector and we examine the spatial distribution of the RP in this remnant. Here, we present our initial results and compare them with those obtained from other X-ray observatories.

E1.14-0017-18 A STUDY OF THE PLERIONIC COMPOSITE SUPERNOVA REMNANT MSH 15-56 WITH SUZAKU

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The Galactic supernova remnant (SNR) MSH 15-56 is a member of the class of plerionic composite SNRs that consists of the remnant shell and a displaced pulsar wind nebula (PWN). The previous X-ray observations reported the comet-like morphology of the PWN, and also ejecta distribution of the SNR. In this work, we present a study of MSH 15-56 using the archival Suzaku data. We investigate the thermal and non-thermal nature of the emission and spectral parameters of the remnant. Our spectral analysis and initial results will be presented and discussed.

E1.14-0018-18 ANALYSIS OPTIMISATION FOR MORE THAN 10 TEV GROUND-BASED VERY-HIGH-ENERGY GAMMA-RAY ASTRONOMY

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The High Energy Stereoscopic System (H.E.S.S.) is a gamma-ray instrument that operates in the broad energy range between a few 10s of GeV to more than 50 TeV. Most of the very-highenergy sources visible to H.E.S.S. emit gamma rays with energies up to 10s of TeV and the nominal analysis methods are optimised to have the best sensitivity in this core energy band. The work presented in this contribution aims at optimising analysis techniques for the gammaray detection at the highest energies to improve the sensitivity above 10 TeV. Moreover, current analysis techniques in H.E.S.S. typically allow for the reconstruction of events with offsets of up to 2.5 degrees - the field-of-view of the Cherenkov cameras. Optimisation of the reconstruction and selection tools can increase the acceptance to gamma-ray events at larger offsets and can hence increase the effective field of view up to 9 degrees. As a result, this allows for an increased photon statistics and improved the sensitivity in the high-energy domain. An improved method that is capable of reconstructing events with offsets up to 4.5 degrees will be presented in this contribution.

E1.14-0019-18 DETECTION OF THE GAMMA-RAY BINARY PSR J2032+4127/MT91 213

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PSR J2032+4127 is a young gamma-ray pulsar located in the same direction as the extended TeV gamma-ray source TeV J2032+4130. The pulsar has recently been discovered to be in a 45- 50 year period, highly eccentric binary orbit with the Be star MT91 213. Periastron occurred in November 2017 and was accompanied by a significant enhancement in the X-ray and very-highenergy gamma-ray flux. I will present results of the intensive VERITAS observing campaign over the November 2017 periastron period, compare this system with other gamma-ray binaries and explore the relationship between this system and TeV J2032+4130.

E1.14-0020-18 STUDYING THE ELEMENTAL ABUNDANCES OF KEPLER SUPERNOVA REMNANT WITH ATHENA

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The lines of Cr and Mn expected in the X-ray spectra of young supernova remnants. The X-ray Integral Field Unit (X-IFU) onboard Athena, provides spatially-resolved high resolution spectroscopy. We investigate Mn, Cr as well as Fe K lines in the spectra of Kepler to study its progenitor and the explosion mechanism of supernovae, as well as mapping the distribution of these elements. To this investigation, we make detailed simulation of Kepler performed with Athena X-IFU using XSPEC 12.9.1 and ATOMDB 3.0.9. Here, we present the preliminary results of our investigation with Athena and the comparison of these results with the published results in the literature. We also give initial interpretations of these results.

E1.14-0021-18 THE POPULATION OF GAMMA-RAY BINARIES

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Gamma-ray binaries, whose spectral energy distribution peaks above 1 MeV, are rare objects thought to be composed of a pulsar in orbit around a massive star. How many gamma-ray binaries are there in the Galaxy ? What are the prospects for detecting them ? We have carried out mock gamma-ray surveys of synthetic populations of gamma-ray binaries to answer these questions.

E1.14-0022-18 PULSAR HIGH-ENERGY MAGNETOSPHERIC AND WIND EMISSION MODELS

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Most current pulsar emission models assume photon production and emission within the magnetosphere. Low frequency radiation is preferentially produced in the vicinity of the polar caps whereas the high-energy tail is shifted to regions closer but still inside the light-cylinder. We conducted a systematic study of the merit of several popular radiation sites like the polar cap, the outer gap and the slot gap. We computed light-curves emanating from each emission site according to a prescribed distribution function for the emitting particles made of an electron/positron mixture. Calculations are performed using a three dimensional integration of the plasma emissivity in the vacuum electromagnetic field of a rotating centred dipole. We compare newtonian electromagnetic fields to their general-relativistic counterpart. In the latter case, light bending is also taken into account. As a typical example, curvature radiation light-curves and sky maps are plotted for several power-law indices of the particle distribution function. The detailed pulse profiles strongly depend on the underlying assumption about the fluid motion subject to strong electromagnetic fields from which we deduced the photon propagation direction directly or from the aberration formula. Estimates of high and very high energy pulsed spectra are also shown.

E1.14-0023-18 TESTING THE ORIGIN OF EXCESS GAMMA RAYS COINCIDING WITH 3FHL J1907.0+0713

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We used the off-pulse component of 9 years of Fermi-LAT data taken from the pulsar, PSR J1906+0722, and found excess gamma rays located 0.12 deg away from the supernova remnant (SNR) 3C 397 and 0.27 deg away from the pulsar. The position of this excess emission coincides with the gamma-ray source 3FHL J1907.0+0713. The 3FHL source also overlaps with a dense molecular cloud (MC), which raises the question whether the gamma-ray emission could be due to the interaction of very high energy particles escaping from either the SNR or a possible pulsar wind nebula (PWN) associated with PSR J1906+0722. The distance of the MC is either 10.7 kpc, therefore, close to the SNR, or 2.1 kpc, in the vicinity of the pulsar. The gamma-ray spectrum is probed for the leptonic model and two hadronic models, the interacting cloud scenario and the illuminating cloud scenario, in order to understand the dominant gamma-ray emission model. The results of this analysis may reveal the existence of a PWN for PSR J1906+0722, in case leptonic model dominates. Alternatively, when the hadronic model dominates, we might be able to differentiate between the two models within the hadronic scenario.

E1.14-0024-18 XMM-NEWTON OBSERVATION OF THE WOLF-RAYET COLLIDING-WIND BINARY WR 11

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We present an analysis of the Wolf-Rayet (WR) binary system WR 11 (γ2 Velorum, WC8+O7.5III) using XMM-Newton X-ray data. We investigate the plasma state and spectral parameters of WR 11. We also search for the radiative recombination continuum in this system. Finally, we will discuss our initial results.

E1.14-0025-18 GAMMA RAY BURST OBSERVATIONS WITH H.E.S.S.

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Fermi-LAT observations have proven that GeV γ-ray emission is a relatively common feature for many GRBs. However the low effective area of space detectors implies low statistics for such high energy photons which impede any physical interpretation at such energies. The highest energy photon detected by LAT reached 95 GeV proved that γ rays coming from GRBs can reach very high energies. However, the current generation of Imaging Atmospheric Cherenkov Telescopes (IACTs) array observing above few tens of GeV has not detected any GRB yet.

The High Energy Stereoscopic System (H.E.S.S.) is an IACT belonging to the current generation of such instruments. It is the first hybrid IACT array composed of four 12 m diameter and one 28 m diameter telescopes. The large light collection area of 600 m2 of the largest telesope is perfectly suitable to observe γ rays between 50 GeV and 100 GeV with an unprecedented sensitivity. This caracteristic makes H.E.S.S. among the instruments that are most promising to constrain or probe short time scale emission of GRBs at very high energies.

This contribution will describe the H.E.S.S. GRB observation program, trigger conditions of GRB observations and analyses of several tens of GRBs. This compilation of observations represents the largest list of GRB observations with IACTs and provides numerous results for GRB modeling at very high energy.

E1.14-0026-18 NOVEL SEARCH FOR TEV-INITIATED PAIR CASCADES IN THE INTERGALACTIC MEDIUM

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The observed magnetic fields in galaxies and galaxy clusters are believed to result from the dynamo amplification of weak magnetic field seeds, whose origin remains a long-standing open question. TeV emission from blazars can be used to probe the intergalactic medium and measure the intensity, coherence length, and helicity of the intergalactic magnetic field. Intergalactic magnetic fields deflect the electron-positron pairs produced by very-high-energy gamma-rays from blazars, resulting in broadened beams of cascade gamma-rays known as pair halos. Such pair-cascades develop along the projected direction of the blazar jet, which is known from imaging radio observations. We present a joint analysis of Fermi-LAT data from 12 selected high-synchrotron-peaked (HSP) blazars with well-determined jet orientation from VLBA radio observations. Our search improves the sensitivity of previous studies by taking the asymmetry of the pair haloes into account, increasing the signal to noise. Although there is no significant detection, a hint for an offset halo with a global p-value of about 0.035 is found in the 30

300 GeV energy range, corresponding to an intergalactic magnetic field with 10−15 Gauss, consistent with the inferred field from a prior, (largely independent) study using stacked HSP

BL Lacs. Based on our findings, prospects for a detection of pair haloes using the improved sensitivity and angular resolution of the CTA observatory will be presented.

E1.14-0027-18 LARGE-SCALE DIFFUSE INTERGALACTIC MAGNETIC FIELDS CONSTRAINTS WITH THE CHERENKOV TELESCOPE ARRAY

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Magnetic fields of the order of micro-Gauss are observationally detected in galaxies and galaxy clusters, which are believed to be created by the amplification of much weaker primordial seed fields. These fields within galaxies should be carried out by strong galactic outflows over time, magnetically enriching the InterGalactic Medium (IGM) at larger cosmological distances. However direct observation of magnetic fields in the IGM is scarce. Knowing the distribution of magnetic fields within the large-scale-structures is crucial in understanding the origin of the seed fields. In this talk, I will give a review of how Intergalactic Magnetic Field (IGMF)'s strength and filling factor can be constrained using numerical simulations and gamma-ray observations.

We are performing cosmological hydrodynamical simulations containing dark matter and all relevant physical processes for the baryons: metal cooling, star-formation, supernovae (SN) feedback, Active Galactic Nuclei (AGN) accretion and feedback. We analyze the simulations following the methodology of Barai (2008, ApJ, 682, L17), and compute the magnetic field in the simulation volume IGM. Our objectives are: to explore the evolution of IGMFs through cosmic times, and to compute the contributions of galactic outflows (driven by SN versus AGN) in the advection of magnetic fields from the galaxies to the IGM.

On the observational side, high-energy TeV photons emitted by distant blazars can interact with the cosmic extragalactic infrared/optical background light, producing electron-positron pairs, and initiating electromagnetic cascades in the IGM. The charged component of these cascades is deflected and delayed by IGMFs, thereby reducing the observed point-like TeV flux, and creating an extended image in the GeV energy range. Such GeV flux extensions around TeV blazars can potentially be detected with gamma-ray telescopes (Fermi-LAT, HESS, CTA). Studies calculating the GeV flux of blazars, employing different models of the IGMF, and using Monte Carlo simulations for the cascade development [e.g., Neronov Vovk (2010, Science, 328, 73); Dolag et al. (2011, ApJ, 727, L4)] have put lower limits on the IGMF strength of the order of 10−16 10−15 G, and filling factors of 60%. I will overview such studies; and describe the constraints on the IGMF which the Cherenkov Telescope

Array sensitivity is expected to give (Acharya et al. 2017, CTA consortium science paper, submitted).

E1.14-0029-18 PROMISING CTA EXTRAGALACTIC SOURCE CANDIDATES PREVIOUSLY UNDETECTED IN FERMI-LAT CATALOGUES

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In the expectation of future CTA scientific exploitation, we have conducted a detailed study of a population of 150 bright high-synchrotron-peaked blazars recently detected with Fermi-LAT as part of the 1BIGB catalog. The 1 BIGB sources are defined by the presence of excess signal in the 0.3 - 500 GeV band and stand out as promising TeV blazar candidates, which might be in reach of the forthcoming CTA observatory. Here we present the 1-100 GeV gamma–ray spectral energy distribution for the sources in this population, considering PASS8 data, and integrating over 9 years of observations with Fermi-LAT. Most of the 1BIGB sources do not appear in any previous Fermi-LAT catalogue, having been identified through selection of their lower-energy counterparts from the WHSP catalogue. Their gamma-ray spectral properties are therefore presented here for the first time. We stack the gamma-ray SEDs, normalizing them via the Synchrotron-peak parameter to extract a gamma-ray template, representative of current undetected gamma-ray blazars, attempting to identify a family of extreme blazars (EHBLs) among them. We use our results to evaluate the importance of these sources in the context of future CTA population studies, by comparing some of the derived source spectra to the published CTA sensitivity curve to estimate detectability by CTA.

E1.14-0030-18 ELECTROMAGNETIC CASCADES INSIDE AND OUTSIDE BLAZARS: IMPLICATIONS FOR CTA

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Blazars are among the main targets for the forthcoming CTA gamma-ray observatory. Models describing intrinsic spectra of blazars and properties of the intergalactic medium have experienced an unprecedented progress during the last decade. In particular, it was found that:

some blazars may have very hard (γ<1.5) intrinsic spectra in the GeV-TeV energy region these hard-spectra ("extreme") blazars are often apparently non-variable or slowly variable sources 3) the absorption-only model of gamma-ray propagation, that accounts for only γγ pair production and adiabatic losses, is often insufficient to describe intergalactic gamma-ray propagation. These and other facts should be accommodated in a self-consistent model of gamma-ray production and intergalactic propagation. We argue that the account of electromagnetic (EM) cascades from primary gamma-rays is an important component of such a model. Namely, the account of the intergalactic cascade process allows to qualitatively explain all known deviations from the absorption-only model ("anomalies"). On the other hand, the possibility of the development of EM cascades from primary protons or nuclei does not modify the effective opacity of the Universe significantly for realistic models of the source and magnetic field between the source and the observer. These results are described in detail in our recent paper [AA, 603, A59 (2017)]. We predict the shape of the "flux modification factor", i.e. the ratio of the observable spectrum in the framework of the EM cascade model to the one assuming the absorption-only model, and show how this prediction could be tested with the full CTA array. We predict the existence of a new population of blazars with very hard (γ<1.5) intrinsic spectra in the GeVTeV energy region that may already have been observed with the Fermi LAT telescope and could be discovered in future by the CTA observatory. Finally, we discuss EM cascade process inside broad line regions (BLR) of flat-spectra radio quasars and its possible implications on the mechanism of gamma-ray escape from these objects. Our findings have important implications for axion-like particle searches, extragalactic magnetic field measurement and blazar population studies.

E1.14-0031-18 A METHOD OF SEPARATION CHERENKOV AND FLUORESCENT LIGHT OF EAS FOR GROUND-BASED AND AEROSPACE UHE CR DETECTORS

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Direct and scattered Cherenkov light (CL) is one of the relevant contributions to the uncertainty of the measured flux of fluorescent light (FL) from extensive air showers (EAS). The impact of the backscattered CL was noted in response modelling of few detectors. The problem of a reliable CL and FL separation is relevant for the better high energy EAS registration and primary particle parameters estimation. This study is first step to solving for both theoretical approaches to the problem and possible design of electronics for ground, airborne and space detectors.

E1.15-0001-18 STATUS OF THE VIRGO COLLABORATION IN EUROPE

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Last year, the European Virgo detector achieved the first detection of a gravitational wave. The Advanced Virgo detector joined LIGO in the second observation run for a period of 25 days. Several detections were made. The detected waveform of event GW170814 match the predictions of general relativity for the inspiral and merger of a pair of black holes and the ringdown of the resulting single black hole. Three days later, event GW170817 constituted the first detection of a binary neutron star merger. Our observations provide unique access to the properties of space-time at extreme curvatures: the strong-field, and high velocity regime. It allows unprecedented tests of general relativity for the nonlinear dynamics of highly disturbed compact systems such as neutron stars and black holes.

The scientific impact of the recent detections will be explained. In addition key technological aspects will be addressed.

E1.15-0002-18 SAGE: USING GEOSYNCHRONOUS CUBESATS TO DETECT GRAVITATIONAL WAVES

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The SAGE (SagnAc interferometer for Gravitational wavE detection) observatory is based on multiple 12-U CubeSats in geosynchronous orbit. The objective of this project is to create a Sagnac interferometer with 210.000 km circular arms. The geometry of the interferometer makes it especially sensitive to circularly polarised gravitational waves of frequency close to 1Hz. The nature of the Sagnac measurement makes it almost insensitive to position error, relaxing the need of drag free spacecrafts. The light source and recombination units of the interferometer are based on compact fibered technologies, including fibered Erbium doped amplifiers, and fibered switches. With a 10W laser source, and 10-centimetre diameter apertures, a sensitivity of 0.2 pm/sqrt(Hz) can be expected. This would allow detection of gravitation wave with a strain of 10e-21, enabling the two main science cases. The first one is the detection of black holes (e.g. GW150914) several weeks before they can be detected by LIGO, to finely test prediction of general relativity upstream the merge. The second science goal consists in detecting IMBH mergers, whose event probability would give an important constraint on galactic evolution. We will present a development plan in 5 years, leveraging on the low cost/ fast development/risk acceptance of CubeSat technology.

E1.15-0003-18 ON THE SENSITIVITY OF ATLAS AND PS1 FOLLOWUP OF O2 LIGO EVENTS

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The potential for the joint detection of electromagnetic and gravitational-wave emissions is one of the most challenging tasks in multi-messenger astronomy. In this analysis, we report on the sensitivity of the Pan-STARRS and ATLAS followup of gravitational-wave triggers reported by LIGO during its most recent science run. We show the sensitivity of the followup campaigns to a variety of potential lightcurve models, including those from kilonovae. We discuss lessons learned with an outlook on improvements as we enter the open alert era.

E1.15-0004-18 STUDY OF PULSAR SPINDOWN USING AN ANALYTIC APPROACH

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Direct detection of gravitational waves from pulsars will be the next landmark in the field of multi-messenger gravitational wave astronomy.In this context we develop an analytic approach to study pulsar spindown. We use the monopolar spindown model by Alvarez and Carraminana (2004), which assumes an inverse linear law of magnetic fi eld decay of the pulsar, to extract an all-order formula for the spindown parameters using the Taylor series representation of Jaranowski et al.(1998). We further extend the analytic model to incorporate the quadrupole term that accounts for the emission of gravitational radiation, and obtain expressions for the period and frequency in terms of transcendental equations. We derive the period of the pulsar evolution as an approximate fi rst order solution in the small parameter present in the full solution. We fi nd that the fi rst three spindown parameters of the Crab, PSR B1509-58, PSR B0540-69 and Vela pulsars are within their known bounds providing a consistency check on our approach.

E1.15-0005-18 WHAT CAN WE LEARN ABOUT FUNDAMENTAL PHYSICS FROM GWGRB EVENTS

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In this talk, we will present how the quasi-coincidence of the events GW170817 and GRB 170817A improved our knowledge on the fractional speed difference between gravitational and electromagnetic waves by more than 14 orders of magnitude, and what it means in various frameworks of alternative theories of gravitation.

E1.15-0006-18 MASSIVE BLACK HOLE MASSES IN THE CONTEXT OF GRAVITATIONAL WAVE OBSERVATIONS

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The recent discovery of gravitational waves from merging pairs of massive black holes [1-4] and even neutron stars [5] has marked the beginning of a new chapter in astronomy. The increasing sensitivity of the next generation of ground-based gravitational wave detectors and of the future space-borne ones will allow for the detection of high redshift merging black hole events, down to the realm of the first-generation black holes which is inaccessible to present and future electromagnetic observations. To better estimate the expected rates of black hole mergers and mass ratios [6], existing all-sky catalogues of black hole masses (e.g. BH-Cat [7]) needs to be further developed and refined based on current observations. In the context of Romanian participation to LISA collaboration, we will present an updated version of the massive and supermassive black hole mass catalog, BH-Cat, together with its mass function and its implication for the LISA space mission. This catalog can be used to predict the mass and space distribution of the first-generation black holes, test the feedback between the black holes and the hosting galaxy evolution activities, study the growth mechanism of the black holes and predict the black holes mass merger ratios. 1. J. Aasi, B. P. Abbott, R. Abbott,

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E1.15-0007-18 BOUNDS ON THE HEIGHT OF A MOUNTAIN ON A MILLISECOND PULSAR

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Spinning neutron stars with a structural ellipticity should emit continuous gravitational waves. Here, using the multiwavelength data from an accreting millisecond pulsar, I argue that its observed spin-down should be primarily due to gravitational wave emission. Consequently, the lower and upper limits of the ellipticity of this pulsar can be obtained.

E1.15-0008-18 PROBING THE ACCRETION DISK WITH THE GRAVITATIONAL WAVE.

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Gravitational wave signal characteristics from a binary black hole system in which the companion moves through the accretion disc of the primary are studied. This disk can exert non negligible hydrodynamic drag on the compact objects rotating around the central black hole. Hence, the gravitational wave signal emitted from an extreme or intermediate mass ratio binary system (EMRI/IMRI) may be modified due to the modified motion of orbiting companion by the influence of hydrodynamic drag of the disk. Thus the emitted gravitational wave signals which carries the imprint of the trajectory of the companion, contains signature of the hydrodynamic features of the accretion disk. In this work, we find that there is a significant reduction in the companions infall time due to the drag exerted by the disk. This shows that the disk indeed has non negligible effects on companions dynamics. Thus, gravitaional wave can serve as another probe for studying the hydrodynamic profiles of the accretion disk. Till now the elecromagnetic spetrum emitted by the accretion disk is routinely observed and is the only observational input to check the various properties of disk. A combination of observations in the electromagnetic wave spectrum and the gravitational wave spectrum would provide us with a large number of information about the accretion disk. Further, we plan to estimate the change of the amplitude and frequency of the GW signal due to the effect of the accretion disk on the motion of the companion and modelling the waveform accordingly

E1.15-0009-18 GRAVITATIONAL-WAVE RINGDOWN ECHOES FROM BLACK HOLES IN MASSIVE GRAVITY

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LIGO's detection of the black hole quasinormal modes has proved the existence of the photosphere outside the gravitational radius. Other sub-dominant long-lived modes depend on the existence of the event horizon, as well as the black hole hairs outside. These modes may reveal themselves in future gravitational-wave detectors as echoes. In this work, we study the ringdown of a de Sitter-Schwarzschild black hole in the dRGT theory of massive gravity. We find interesting signatures of ringdown echoes as we turn on the coupling between spacetime perturbations and the background vector field outside the black hole.

E1.15-0010-18 FERMI GBM AND THE ERA OF GRAVITATIONAL-WAVE ASTRONOMY

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On 2017 August 17 at 12:41:06 UTC the Fermi Gamma-ray Burst Monitor (GBM) detected and triggered on the short gamma-ray burst (GRB) 170817A. Approximately 2 s prior to this GRB, the LIGO gravitational-wave observatory detected a binary compact merger candidate associated with the GRB. This is the first unambiguous coincident observation of gravitational waves and electromagnetic radiation from a single astrophysical source and marks the start of gravitational-wave multi-messenger astronomy. We report the GBM observations and analysis of this short GRB and the joint science that results from this watershed joint discovery. We also detail the ongoing work to search for weak, sub-triggered counterparts to gravitational wave detection candidates

E1.15-0011-18 DEEP LEARNING TO STUDY THE NOISE IN GRAVITATIONAL WAVE INTERFEROMETERS

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The detection of gravitational waves has inaugurated the era of gravitational astronomy and opened new avenues for the multimessenger study of the cosmos. Thanks to their sensitivity, the Advanced LIGO and Advanced Virgo interferometers can probe a much larger volume of space and will expand the potential to discover new gravitational wave sources. The characterization of these detectors is very important in order to recognize the main sources of noise and optimize the sensitivity. In particular glitches are transient noise events that impact the data quality of the interferometers, and their classification is very important to characterize the detector. Deep learning techniques are a promising tool to recognize and classify glitches. We will discuss the potential of deep learning in studying noise in gravitational wave detectors and distinguishing it from real astrophysical signals. In particular we will present a method based on deep learning for the classification of glitches based on their time-frequency evolution represented as images. Using tests on simulated data, we show its capability of disentangling the noise from real gravitational signals, and its accuracy in classification coupled with short execution times, thus providing a promising tool for online, low-latency, detector characterization.

E1.15-0012-18 PLAUSIBLE DETECTION OF GRAVITATIONAL WAVE FROM HIGHLY MAGNETIZED WHITE DWARFS

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Since last 6 years or so, we have initiated exploring possible existence of highly magnetized white dwarfs (B-WDs) with a new super-Chandrasekhar mass-limit. It has many implications including observed over-luminous type Ia supernovae, white dwarf pulsars, soft gamma-ray repeaters and anomalous X-ray pulsars. In the talk, we however show that these spinning B-WDs are attractive sites for gravitational radiation. The amplitude of gravitational wave produced by a B-WD with mass of the order of 2 solar mass, polar radius 700 km, rotational period about 1 sec with oblateness parameter 1/10000 and at 100 pc away from us is within the sensitivity of the Einstein@Home search for early LIGO. If the B-WD's polar radius is 2000 km, rotational period 10 sec and other parameters intact as above, a firm confirmation of gravitational wave emission can be provided by DECIGO/BBO. Nevertheless, high magnetic field rotating white dwarfs approaching a B-WD would be common and it is possible that such white dwarfs of radius about 7000 km, period 20 sec, at a distance 10 pc will is detectable by LISA.

E1.15-0013-18 SEARCHING FOR SHORT GRBS IN SOFT GAMMA-RAYS WITH INTEGRAL/PICSIT

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The first electromagnetic detections associated with a gravitational wave trigger on 17 August 2017 produced a flurry of results across the EM spectrum. A notable example at hard X-ray/soft gamma-ray energies is how extremely under luminous the short gamma-ray burst (SGRB) was compared to others with known redshifts, which suggests a population of low luminosity events. The most popular interpretation has been that the GRB was viewed off-axis, rather than that the event had an intrinsically low luminosity. Regardless, this result has spurred searches for SGRBs below instrument trigger thresholds in hopes of finding similar bursts. Here we have analyzed data from the INTEGRAL soft gamma-ray detector IBIS/PICsIT (200 keV - 10 MeV) to try to corroborate the untriggered SGRB candidates reported by Fermi/GBM. In addition, we present initial results of our real-time burst analysis with PICsIT.

E1.15-0014-18 A PECULIAR LOW-LUMINOSITY SHORT GAMMA-RAY BURST FROM A DOUBLE NEUTRON STAR MERGER PROGENITOR

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Double neutron star (DNS) merger events are promising candidates of short Gamma-ray Burst (sGRB) progenitors as well as high-frequecy gravitational wave (GW) emitters. On August 17, 2017, such a coinciding event was detected by both the LIGO-Virgo gravitational wave detector network as GW170817 and Gamma-Ray Monitor on board NASA's Fermi Space Telescope as GRB 170817A. Here we show that the fluence and spectral peak energy of this sGRB fall into the lower portion of the distributions of known sGRBs. Its peak isotropic luminosity is abnormally low. The estimated event rate density above this luminosity is at least 190 per cubic Gpc per yr, which is close to but still below the DNS merger event rate density. This event likely originates from a structured jet viewed from a large viewing angle. There are similar faint soft GRBs in the Fermi archival data, a small fraction of which might belong to this new population of nearby, low-luminosity sGRBs.

E1.15-0015-18 THE SVOM MISSION.

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On behalf of the Svom collaboration

The Chinese-French space mission SVOM (Space-based multiband astronomical Variable Objects Monitor) is mainly designed to detect and localize gamma-ray burst (GRB) events. The satellite, to be launched in late 2021, will carry a set of gamma-ray, X-ray, and optical imagers. Thanks to its pointing strategy, quick slew capability, and fast data connection to Earth, ground-based observations with large telescopes will allow us to measure redshifts for an unprecedented number of GRBs. While the association of long GRBs with core-collapse supernovae (SNe) is well established, short GRBs are most likely due to neutron star (NS)-NS or NS-BH (black hole) mergers and are thus expected to occur simultaneously with bursts of gravitational waves. After briefly reminding the overall science goals of the SVOM mission in the framework of the multi-wavelength and multi-messenger panorama of the next decade, we focus on the organization of the scientific ground segment, in charge of rapidly disseminating the alerts of GRB detected on board, but also organizing the ground monitoring of multi-messenger alerts from other instruments.

E1.15-0016-18 THE GRAVITATIONAL CAPTURE OF COMPACT OBJECTS BY MASSIVE BLACK HOLES

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One of the most interesting sources of gravitational waves is the inspiral of compact objects on to a massive black hole (MBH), commonly referred to as an extreme-mass ratio inspiral. The small object, typically a stellar black hole, emits significant amounts of GW along each orbit in the detector bandwidth. In this talk I will summarise the science that we can do with these gravitational waves. In particular, I will review the gravitational capture of compact objects by supermassive black holes, and by intermediate-mass black holes, in globular clusters.

E1.15-0017-18 MERGER OF COMPACT BINARIES IN THE CONTEXT OF GRAVITATIONAL WAVES AND SHORT-LIVED GAMMA-RAY BURSTS

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The discovery of gravitational waves resulting from the merger of two massive black holes (GW150914) has revolutionized our view of merging compact binaries. More recently, the Swope Supernova Survey of the optical counterpart of a gravitational wave event in the NGC 4993 galaxy, GW170817, emanating from the merger of two neutron stars, has triggered a lot of research work. Emphasis has been on comparing the existing theoretical models with the observational data, allowing for the prospect of an even more stringent test of general relativity. The afterglow of this event was observed in a wide range of wavelengths extending from radio waves to gamma rays. In this work, we first explore the evolutionary pathways of compact binary systems following the in-spiral, merger, and ring down sequence. We then proceed to discuss the processes leading to the production of gravitational waves and electromagnetic emission resulting from the merger of compact objects, particularly neutron star binaries and neutron starblack hole systems. We construct a basic inventory of the energy released during the merger of compact binaries in all bands of the electromagnetic spectrum with emphasis on gamma-ray burst emission. The constraints on certain wavelength emissions, such as gammaray bursts, are discussed in terms of orbital dynamical instabilities, energy transfer processes, and possible jet orientations with respect to the observer.

E1.15-0018-18 THE GRAVITATIONAL-WAVE OPTICAL TRANSIENT OBSERVER (GOTO)

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Many GW sources, such as merging neutron stars, should be accompanied by an electromagnetic signal. We are currently building a new, powerful facility designed to find the first optical counterparts to GW sources - The Gravitational-wave Optical Transient Observer (GOTO).

http://goto-observatory.org/

Located on the island of La Palma, GOTO first came on-line in summer 2017 with four telescopes and will be expanded to eight telescopes within 2018 in preparation for the LIGO/VIRGO O3 run. Plans are also underway to double the facility on La Palma and add another node in Australia.

GOTO will immediately respond to GW triggers and hunt for a new optical transient source. The gravitational wave skymaps are large and the challenge is how to search such large areas of sky efficiently. GOTO is specifically designed for this task, providing an instantaneous field of view (with eight telescopes) of 36 square degrees. To provide a view of the night sky for comparison, GOTO will monitor the sky every night providing a unique, temporally-resolved view of the optical transient universe down to 21 magnitude. At these depths, GOTO data will enable a unique study of many classes of extragalactic source, including Gamma-Ray Bursts, Supernovae, Tidal Disruption Events and Active Galactic Nuclei, as well as many sources within our own galaxy.

E1.15-0019-18 THE X-RAY COUNTERPART TO THE GRAVITATIONAL WAVE EVENT GW170817

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The second run of advanced LIGO led to the breakthrough discovery of the first gravitational wave (GW) signal from a neutron star merger, GW170817, coincident with a short duration gamma-ray burst, at a distance of 40 Mpc. The discovery of GW170817 and its electromagnetic counterparts marked the beginning of a new era of multi-messenger astrophysics, in which photons and gravitational waves provide complementary views of the same source.

I will present the discovery and long-term monitoring of the X-ray counterpart associated with GW170817. While the electromagnetic counterpart at optical and infrared frequencies was dominated by the radioactive glow from freshly synthesized r-process material in the merger ejecta, known as kilonova, observations at X-ray and, later, radio frequencies revealed the emergence of a relativistic, structured outflow interacting with the surrounding low-density environment. I will discuss the key results of our multi-wavelength campaign, the open questions raised by this event, and the critical role of X-ray observations in the new era of multi-messenger astrophysics.

E1.15-0020-18 NEUTRON STAR MERGERS, KILONOVAE, AND THE COSMIC ORIGIN OF THE HEAVY ELEMENTS

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The recent detection of the binary neutron star merger GW170817 by LIGO and Virgo was followed by a firework of electromagnetic counterparts across the entire electromagnetic spectrum. In particular, the ultraviolet, optical, and near-infrared emission is consistent with a kilonova that provided strong evidence for the formation of heavy elements in the merger ejecta by the rapid neutron capture process (r-process). In this talk, I will discuss our current understanding of how kilonovae are produced in neutron star mergers, specifically in light of GW170817, but also with regard to future events. I will discuss possible scenarios and mass ejection mechanisms that can give rise to the observed kilonova features and demonstrate how r-process nucleosynthesis in these outflows can explain the cosmic origin of the heavy elements in the universe, which has been an enduring mystery for more than 70 years.

E1.15-0021-18 WIDE-FIELD UV SURVEY FOR THE EARLY PHASE EMISSION FROM GW SOURCES

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A wide-field ultraviolet survey mission with 6U cubesat for investiging gravitational wave sources and the other intriguing transients is presented. GW170817 showed kilonova-like IR emission which arose about 3 days after the GW detection. While in the earlier phase, the observed optical counterpart was much bluer than that of the expected kilonova models and its emission process is still unclear. To reveal the mysterious early phase blue emission just after the merging and constrain the geometrical distribution and velocity of the neutron-rich ejecta, we are developing an UV wide field telescope. To cover the large error circle of GW detectors the UV telescope was designed to have a FoV of 20 deg2. The detection limit is 20 mag for 1000 s exposure in NUV band, which is rather shallow but is sufficient to detect UV emission from NS-NS merger within 200 Mpc from the earth, assuming the intensity of GW170817. In this presentation we show the mission overview and progress report.

E1.15-0022-18 DEVELOPING AN EARLY-WARNING SEARCH FOR GRAVITATIONAL WAVE TRANSIENTS USING RANDOM MATRIX FACTORIZATION

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Increased bandwidth and improved sensitivity at low frequencies in the advanced LIGO/Virgo detectors have led to a vast increase in the number of templates against which data is cross correlated. It has also resulted in longer template waveforms. Both of these effects have amplified the computational cost of the gravitational wave (GW) searches from compact binary systems by several orders of magnitude. In a seminal work, Hanna, Canon et al. have validated the use of the singular value decomposition (SVD) method to deal with a large number of templates. However, performing SVD on large matrices in situ has severe memory and logistical challenges. Random matrix factorization is an efficient technique for low-rank approximation of such large template matrices, where the templates are randomly projected into a much lower dimensional space. The basis vectors in the projected space are obtained by QR decomposition. We investigate the application of this technique to optimize the total computational and memory requirements of typical GW searches. Our approach is easily scalable and can be deployed over a distributed memory computer architecture. We further develop the idea into a early-warning hierarchical search pipeline for transient GW signals from compact binaries. Observing such transients in Earth and space based electromagnetic telescopes holds enormous potential for new discoveries. Our numerical experiments indicate that the proposed new algorithm is as accurate as the standard SVD within a fixed probabilistic error bound.

E1.15-0023-18 RADIO FOLLOW-UP OF GRAVITATIONAL WAVES IN THE ADVANCED LIGO/ VIRGO ERA

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During their second observing run (O2), the advanced LIGO and Virgo detectors scored their first direct observation of gravitational waves from a binary neutron star (NS) merger, GW170817. This event also gifted the astronomical community with an electromagnetic (EM) counterpart spanning all bands of the spectrum. The delayed radio afterglow of GW170817 uniquely probed the mass, velocity, and geometry of the fastest ejecta, as well as the density of the ambient ISM. The radio has also unveiled key features of the interaction between relativistic ejecta and neutron rich matter, fundamentally advancing our knowledge of jet physics, and critically informing expectations for future EM-GW searches. In this talk, I will discuss these future expectations in the context of both the upcoming run O3, and the longer-term future of advanced GW detectors and next generation radio arrays.

E1.15-0024-18 IDENTIFYING EM COUNTERPARTS TO NS-NS MERGERS: AN OPTIMIZED RADIO FOLLOW-UP STRATEGY

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Recently the first merger of two neutron stars was observed both through electromagnetic and gravitational waves. It was detected in all the electromagnetic bands, from gamma rays to radio. In the near future many more of these events will be discovered, therefore, we need to have an efficient radio follow-up plan to detect and identify them, and to be able to determine their physical parameters. In this talk, I will present a new statistical method that allows us to optimize the follow-up strategy, maximizing the accuracy in identifying binary neutron star mergers, and recovering their physical parameters.

E1.15-0025-18 INVESTIGATING SUPERMASSIVE BLACK HOLE BINARY MASS-RATIOS IN ROTATING GALAXIES

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There is strong observational evidence that supermassive black holes (SMBHs)–weighing in the range between 106 and 109 times the mass of the sun–are present in the center of most of the galaxies. After two galaxies merge, their SMBHs advance towards each other, form a binary system and ultimately coalesce into each other emitting a burst of gravitational waves. SMBH binary coalescence is believed to be one of the loudest sources of gravitational waves. To understand the physics of SMBH binary coalescence, various observational, theoretical and computational efforts are being made. These studies showed that binaries with equal mass SMBHs are strongly affected by the rotation of galactic merger remnant. However, it is unclear if the mass-ratio between primary and secondary SMBHs residing in rotating galaxies affects the binary's evolution. In order to extract this dependence of binary evolution on mass-ratios, direct N-body simulations were carried out on a Graphics Processing Units (GPUs accelerated supercomputer. We employed ϕ-GPU code for performing the simulations which is based on fourth order Hermite integrator and is massively parallel to run on the GPUs based machines. SMBH binaries of several mass-ratios were investigated by placing them in both co and counter galaxy models. The results indicate a decreasing trend of binary eccentricity values from equal to small mass-ratio binaries for counter-rotating models while small and roughly equal eccentricities for co-rotating models. The time of formation of binary was also observed to follow a pattern with binary massratios. These results are vital to estimate SMBH merger events having an impact on future gravitational waves antennas such as eLISA—enhanced Laser Interferometer Space Antenna.

E1.15-0026-18 DETECTING UV GRAVITATIONAL WAVE SOURCES WITH GLUV

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GLUV is a 30cm ultraviolet survey telescope under development at ANU (Sharp et al. 2016) for a high altitude balloon platform. It will feature a 7deg2 field of view and a limiting magnitude in near-UV of 22. Ridden-Harper et al. (2017) explores the application of GLUV to gravitational wave source characterisation, showing that early UV observations could provide a powerful diagnostic to identify merger pathways. The system is expected to fly in 2019 and build towards a constellation of telescopes flying in observation campaigns.

E1.15-0027-18 KILOHERTZ RADIO SIGNAL BY GW OF NS-NS COLLAPSE CONVERTED BY PLANETARY,GALACTIC FIELDS: A DETECTABLE NOVEL DISCOVERY?

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The very recent Gravitational Wave detection at several hundreds Hertz by LIGO due to a few tens solar masses binary black hole collapse at 400 Mpc distance imply also a much abundant population of a few solar masses BH-NS or NS NS merging event, bounded in a more rapid collapse system. Indeed the very recent and very near GW170817 and its correlated GRB170817A did exibith such a GW kilohertz peak signatures occurring at a much nearer volumed (40 Mpc distance) and at a consequent much higher rate. The (NS-NS) merging frequency should be much higher than heavier tens Solar masses BH events, and they will be detectable within 20-80 Mpc by future LIGO-VIRGO GW advanced array detector, possibly leading to several NS-NS event each year. However their low energy graviton (tens Kilohetz) conversion into long radio ones along their flight from the source, by galactic (or even by solar or planetary) magnetic fields, may lead to sudden radio burst correlated with the same GW and or GRB burst. These very low radio bangs (and their polarization), foreseen more than twenty years ago, might be observable today at best from a screened radio array antenna located for instance on the Moon hidden and silent side. If such radio array might be sent also at solar system edges (Voyager distances) their far diluted plasma space will allow a better radio detection even at the low KHz radio waves, comparable to the recent GW-GRB 170817A event and even to the lightest BH-BH collapse. Triangulations, time correlation also with LIGO-VIRGO signals, may filter and disentangle the event from most interstellar radio noises. References: 1) D.Fargion, Prompt And Delayed Radio Bangs At Kilohertz By SN 1987A: A Test For Graviton-Photon Conversion; Grav.Cosmol. 1, 301-310, (1995).

E1.15-0028-18 GRAVITATIONAL WAVE ASTROPHYSICS IN THE MID-BAND: PROGENITORS AND PRE-MERGER LOCALIZATIONS OF ADVANCED LIGO/VIRGO BINARY-MERGER EVENTS

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We consider the scientific potential of gravitational wave (GW) observations in the 30 mHz to 3 Hz frequency range with the Mid-band Atomic Gravitational-wave Interferometric Sensor (MAGIS). MAGIS is a probe-class space-mission concept, using an atom-based gravitational wave detector, that will provide allsky strain sensitivities of 1E-21 sqrt(Hz) and better (1- year) in the GW-frequency mid-band between the LISA/L3 detector (planned 2034 launch) and ground-based Advanced LIGO/Virgo interferometers. Primary gravitational wave astrophysics science in the mid-band include GW observations of the binary black hole population discovered by Advanced LIGO/Virgo at higher-frequencies, prior to their merger stage. For such systems, MAGIS will observe the binaries in their inspiral phase, where system parameters such

as eccentricities are most easily constrained, and will provide pre-merger, degree-scale localizations that would enable electromagnetic observations of possible precursor emission 1-week to 1- month prior to their mergers as well as prompt post-merger transient emission. Joint GWobservations with MAGIS and Advanced LIGO/Virgo covering all stages of binary coalescence will further reduce uncertainties in the GWlocalizations and distances, and will be powerful paired with galaxy catalogs, to enable unique galaxy counterpart identifications in the case black hole binary mergers are completely absent of detectable electromagnetic precursor or transient signals. These possibilities for MAGIS extend to neutron star binary systems (black hole - neutron star, neutron star - neutron star), and mid-band prospects for such systems will also be considered. Importantly, the full sequence of binary evolution of Advanced LIGO/Virgo merger events through the GW mid-band and post-merger electromagnetic follow-up, will unfold within PhD-timescales.

The MAGIS team is a collaboration between institutes in the U.S. including Stanford, AOSense, Harvard, NASA/GSFC, NASA/JPL, NIST, NRL, and UC Berkeley, and international partners at Birmingham, Bordeaux, CNRS, Dusseldorf, Ecole Normale Superieure, Florence, Hannover, and Ulm University.

E1.15-0029-18 SCALAR AND ELECTROMAGNETIC PERTURBATIONS OF NONSINGULAR NONROTATING BLACK HOLES IN CONFORMAL GRAVITY

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We study scalar and electromagnetic perturbations of a family of nonsingular nonrotating black hole spacetimes that are solutions in a large class of conformally invariant theories of gravity. The effective potential for scalar perturbations depends on the exact form of the scaling factor. Electromagnetic perturbations do not feel the scaling factor, and the corresponding quasinormal mode spectrum is the same as in the Schwarzschild metric. We find that these black hole metrics are stable under scalar and electromagnetic perturbations. Assuming that the quasinormal mode spectrum for scalar perturbations is not too different from that for gravitational perturbations, we can expect that the calculation of the quasinormal mode spectrum and the observation with gravitational wave detectors of quasinormal modes from astrophysical black holes can constrain the scaling factor and test these solutions.

E1.15-0030-18 RESULTS FROM THE NASA SPACE TECHNOLOGY 7 DISTURBANCE REDUCTION SYSTEM MISSION ON LISA PATHFINDER

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Space Technology 7 Disturbance Reduction System (ST7-DRS) is a NASA technology demonstration payload that was hosted on ESA's LISA Pathfinder mission to provide drag-free control of the spacecraft. The DRS used the inertial sensor on board ESA's LISA Technology Package (LTP) to provide feedback and keep the spacecraft following one of two free-floating test masses at noise level acceptable for a future gravitational wave (GW) observatory. The DRS includes four subsystems: (1) The Integrated Avionics Unit (IAU), a computer; (2) Colloid Micro Newton Thrusters (CMNT), two clusters of four thrusters, each; (3) Dynamic Control Software (DCS), a software subsystem which implements drag-free control algorithms and

(4) Flight Software (FSW), a software subsystem which processes commands and telemetry and hosts the DCS. LISA Pathfinder was launched on December 3, 2015, and the DRS went through IAU, FSW, and thruster commissioning in January 2016, full instrument commissioning in July to August 2016, prime mission and experiment from August to December 2016, and an extended mission and experiment from March to April 2017. Experiments included controlling the spacecraft through various drag-free control modes, observing test mass position and acceleration noise, thruster calibration and performance model validation. The DRS met all mission-level requirements for a successful demonstration of the colloid microthruster and 18 degree-of-freedom drag-free control technologies and showed good performance. Here we summarize the performance of the NASA thrusters and control laws throughout the mission.

E1.15-0031-18 AUSTRALIAN FOLLOW-UP OF GRAVITATIONAL WAVE COUTERPARTS

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We will present on behalf of a large collaboration observational results on the electromagnetic follow-up of GW170817. We will in particular focus on the Australian led efforts in the optical and radio domains and discuss the implications of these observations on the nature of this event. Finally will outline our plans for the next LIGO-Virgo observational run planned for late 2018.

E1.15-0032-18 ACCURATELY RECALIBRATED WAVEFORMS FOR EXTREME-MASS-RATIO INSPIRALS IN EFFECTIVE-ONE-BODY FRAME

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How to calculate the gravitational waves (GWs) of Extreme-mass-ratio-inspirals (EMRIs) in a highly accurate and efficient way still keeps a challenge. In this paper, we present a so-called fully recalibrated waveforms for EMRIs with high accuracy. Based on the numerical data by solving the Teukolsky equations, we recalibrate all mass-ratio independent coefficients of the factorized waveforms which are used in the effective-one-body (EOB) models. Due to these new coefficients, the precision of waveforms is improved enormously, and is much higher than the original forms and at the same time higher than other existing calibration models. We believe our model will play an important role in the waveform-template construction of the space-based GW detectors.

E1.15-0033-18 OBSERVING GRAVITATIONAL WAVE SOURCE ERROR BOXES WITH THE TAROT NETWORK OF AUTOMATED TELESCOPES

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During the previous runs (O1 and O2) of Virgo and LIGO, the TAROT network has followed the localizations that were communicated. This set of small instruments (25cm) is distributed in three locations around the globe in France, Chile and La Réunion island (F). We present the observations that were made, and the methods we have developped to process the data.

E1.15-0034-18 G-CUBE: A NOVEL NANO-SATELLITE FOR GRAVITATIONAL WAVE ELECTROMAGNETIC COUNTERPART (GW EM) DETECTION

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Beneficial from the nano-satellite technology exploration in the past decades and the innovative development of Silicon photomultipliers technology, in the present paper, a nano-satellite mission to detect X/gamma-ray EM counterpart of compact binary star merger GW observed by LIGO and Virgo will be proposed (G-cube project). Aiming to guarantee the reliability, the matured cubesat technology is adopted, and most platform components of nano-satellite are inherited from STU-2 cubesat mission, which was successfully launched into orbit in Sept. 2015. The payload consists of three novel and compact gamma-ray detectors sensitive from 10 keV to 1 MeV, each of which is made with a LaBr3 scintillator read out by an array of SiPM. G-cube project will verify the space application of this novel gamma-ray detector which will be used in the future space-based gamma-ray detection, and shall become the first effort internationally to demonstrate inexpensive gravitational wave EM detection technology based on the nano-satellite.

E1.15-0035-18 TIME DELAY BETWEEN SN NEUTRINO PROMPT SIGNALS BY NEARBY GALAXIES AT HYPERKAMIOKANDE: A DETECTABLE (AND GUARANTEED) ATMOSPHERIC NEUTRINO MASS.

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Ther recent LIGO-VIRGO detection of GW did show succesfully the possibility to observe nearby (40 Mpc) NS-NS collapse even with correlated GRB burst. The eventual NS-NS collapse and spherical thermal neutrino flash will be hardly detectable by ICECUBE GigaTon or Super Kamiokande SK tens KiloTons underground neutrino detectors. However the near future HyperKamiokande (HK) Megaton twin detector in Japan and possibly Corea might be able to reveal ten MeV thermal neutrino in wider distances and at more frequent and abundant Super Novae event rate. A non negligible fraction of such SN might be triggered by a NS merging with white dwarf stars leading to observable GWs and neutrino burst. Also assymmetric SN explosion may be source of GW and huge thermal neutrino burst. Their SN occurence might be hundred time more abundant than NS NS collapse. Therefore such SN triggered binary collapse and their GW might be take place within a few Mpc (at less intense metric perturbation respect NS NS event) each year and their correlated neutrino burst might be reachable by HK opening a fundamental thermal neutrino versus GW multifrequency signal. Moreover nearer (but a little more rare) SN-GW within one or two Mpc distances sites, the eventual correlated GW (by Ligo-Virgo) and its (millisecond sharp) first prompt neutrino signal (obervable in HK), its time delay (a few milliseconds later) than its GW, it might be observable (for instance from Andromeda). Such a time delay measure might disentangle even the minimal (tiny but guaranteed) atmospheric (0.05 eV) neutrino mass. That result might be therefore the first and most sophisticated astrophysical mass neutrino measure never achieved or even foreseen, by any terrestrial laboratory. References: 1) D.Fargion, Time Delay Between Gravitational Waves and Neutrino Burst From a Supernova Explosion: a Test for the Neutrino Mass Lett.Nuovo Cim. 31 (1981) 499-500. 2)D. Fargion, D. D'Armiento, Inconsistence of super-luminal Cern-Opera neutrino speed with observed SN1987A burst and neutrino mixing for any imaginary neutrino mass; J. Phys. G: Nucl. Part. Phys. 39. 085002,(2012)

E1.15-0036-18 GEOMETRIC-STOCHASTIC TEMPLATE BANKS FOR GRAVITATIONAL WAVE SEARCHES FROM COMPACT BINARIES IN ADVANCED-LIGO DATA

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Gravitational waves from compact binary coalescence are the most promising candidate for terrestrial broadband interferometric observatories like the Advanced LIGO/Virgo detectors. Searches for compact binary sources involve matched-filtering the data with a set of possible template waveforms spanning a range of waveform parameters. Development of efficient gridding strategies for covering the search parameter space leads to computationally efficiency. This is particularly important in the era of advanced detectors, where the increased bandwidth and low-frequency sensitivity have resulted in a vast increase in template bank sizes as seen in the recently concluded O1 and O2 searches. To this end, we present a new template placement algorithm that combines the robustness of the stochastic placement method along with the efficiency afforded by the use of (A∗n) lattice to cover the volume. We show that the template placement is resilient to variations in the curvature of the parameter space and can deal with so-called “boundary effects” with no explicit fine tuning in the design. We also develop a numerical method to evaluate the metric in the space of waveform parameters, used to place these hybrid templates. We compare these hybrid banks against existing stochastic template banks to establish that while both are equally effective in capturing sources modeled by IMRPhenomD and SEOBNRv4 waveform families, the new hybrid banks are significantly smaller in size and take an order of magnitude less time for generation.

E1.16-0001-18 WFIRST: SURVEY OVERVIEW AND MISSION STATUS

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The Wide-Field InfraRed Survey Telescope (WFIRST) will be the next NASA Astrophysics flagship mission to follow JWST. The observatory payload consists of a Hubble-size telescope with a wide-field NIR instrument, and a coronagraph operating at visible wavelengths and employing state-of-the-art wavefront sensing and control. The Wide-field instrument is optimized for large area NIR imaging and spectroscopic surveys, with performance requirements driven by programs to study cosmology and exoplanet detection via gravitational microlensing. All data will be public immediately, and a substantial guest observer program will be supported.

The WFIRST Project is presently in Phase A, with a transition to Phase B expected in early to mid 2018. Candidate observing programs are under detailed study in order to inform the mission design, but the actual science investigations will not be selected until much closer to launch. We will present an overview of the present mission design, expected performance of representative surveys, and a summary of Project status.

E1.16-0002-18 UNVEILING THE DARK UNIVERSE WITH THE EUCLID SPACE MISSION

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The Euclid Consortium and the ESA Euclid Team

The ESA Euclid mission aims to understand why the expansion of the Universe is accelerating and pin down the source responsible for the acceleration. It will uncover the very nature of dark energy and gravitation by measuring with exquisite accuracy the expansion rate of and the growth rate of structure formation in the Universe. To achieve its objectives Euclid will observe the distribution of dark matter in the Universe and its evolution over the last ten billion years by measuring the shapes of weakly distorted distant galaxies lensed by foreground cosmic structures. The shapes of lensed galaxies will be measured using the Euclid wide field imaging instrument VIS. In parallel, Euclid will analyse the properties of baryon acoustic oscillations and redshift space distortion and the distribution of clusters of galaxies by measuring the redshifts of galaxies with the NISP photometer and spectrometer instrument. The Euclid mission will observe one third of the sky (15,000 deg2) to collect data on several billion galaxies spread over the last ten billion years. In parallel to the space mission, the Euclid survey also comprises ground-based photometric and spectroscopic observations that will be used jointly with the Euclid satellite data to get photometric redshifts of billions of sources. Altogether the Euclid data set will be an exceptional gold mine for cosmology and fundamental physics but also for all fields in astrophysics. The presentation will describe the main scientific objectives and expected performances of the Euclid mission. The most recent forecasts and constraints on dark energy, gravity and dark matter will be presented as well as the expectations for the physics of inflation or neutrinos and the other domains of astronomy that will benefit from the Euclid mission data base.

E1.16-0003-18 THE EUCLID MISSION AT THE CRITICAL DESIGN REVIEW

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Euclid is a space-based optical/near-infrared high precision and high accuracy survey mission of the European Space Agency (ESA) to investigate the nature of dark energy, dark matter and gravity by observing the geometry of the Universe and on the formation of structures over cosmological timescales. Euclid will mainly use two probes of the signature of dark matter and energy: Weak gravitational Lensing, which requires the measurement of the shape and photometric redshifts of distant galaxies, and Galaxy Clustering, based on the measurement of the 3-dimensional distribution of galaxies through their spectroscopic redshifts. The mission is scheduled for launch in 2022 and is designed for 6 years of nominal survey operations. The Euclid Spacecraft is composed of a Service Module and a Payload Module. The Service Module comprises all the conventional spacecraft subsystems, the instruments warm electronics units, the sun shield and the solar arrays. In particular the Service Module provides the extremely challenging pointing accuracy required by the scientific objectives. The Payload Module consists of a 1.2 m three-mirror Korsch type telescope and of two instruments, the visible imager "VIS" and the near-infrared spectro-photometer "NISP" both covering a large common fieldof-view enabling to survey 15,000 sqd, more than 35% of the entire sky. All sensor data are downlinked using K-band transmission and processed by a dedicated ground segment for science data processing. The Euclid data and catalogues will be made available to the public at the ESA Science Data Centre. Euclid is currently undergoing to a Critical Design Review, a major milestone to prove the soundness of the mission design in all its aspects before manufacturing of flight hardware is fully deployed. We will also report on the expected mission performance following the latest simulations. This is based on the calculated and measured image qual- ity parameters of the optical system which shows exceptional capability of the Euclid space observatory.

E1.16-0004-18 AN OVERVIEW OF THE CHINESE SPACE STATION OPTICAL SURVEY

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The Chinese Space Station Optical Survey is a major science project under the Space Application System of China Manned Space Program. It will be carried out by a 2m off-axis telescope in the same orbit as the Chinese space station, starting from early 2020s. The telescope is designed for a minimum lifetime of 10 years and can dock with the space station for service when needed. The survey plans to cover roughly 17,500 square degrees of the sky at a resolution of 0.15” in at least 6 broadband filters from 250nm to 1000nm, reaching an average depth of AB 25.5 mag (point source, 5-sigma). Low resolution slitless spectra will be taken at the same time over the same area reaching broadband depths of AB 22-23 mag. Deeper exposures will be made over selected areas across the sky. I will give a brief introduction to the project in this talk and discuss the expected performance from simulations.

E1.16-0005-18 THE LARGE SYNOPTIC SURVEY TELESCOPE (LSST)

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LSST is a large-aperture, wide-field, ground-based telescope designed to provide a time domain imaging survey of the entire southern hemisphere in six optical colors. Over ten years of operations, LSST will acquire roughly one thousand visits of every part of the southern sky, reaching 24th magnitude in a single visit, and 27th magnitude for the co-added images. The resulting database will enable a diverse array of scientific investigations, ranging from studies of small moving bodies in the solar system, to the structure and evolution of the universe as a whole. The design of LSST incorporates an 8.4 m monolithic primary/tertiary mirror, a 3.5 m secondary, and 3.2 gigapixel camera, mounted up near the secondary. The construction is well underway, with most of the key subcomponents in the final stages of fabrication, leading to “first light” in 2020 and the onset of the survey in 2022. I will provide a brief overview of this project, and highlight some of the exciting science that is likely to emerge from LSST when it comes on line.

E1.16-0007-18 DARK ENERGY WITH EUCLID

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Euclid is an ESA medium-class mission expected to launch in 2020 that will map the geometry of the Universe by imaging 109 galaxies and measuring 107 galaxy redshifts in 15000 square degrees of the sky. This will provide us detailed information about the accelerated expansion, the evolution of large-scale structure and the matter-energy content of the Universe up to a redshift of about z 2. In this talk, I will review how the main probes of Euclid, namely galaxy clustering and weak lensing, will be able to constrain theories beyond the standard cosmological ΛCDM model and how we will be able to pin down the equation of state of dark energy with about 1% precision. Galaxy clustering measures mainly the movement of tracers along geodesics, while weak lensing is an almost direct mapping of the gravitational potentials at large scales. Using both of these observables, we can obtain valuable information about the growth of perturbations and the geometrical quantities of the Universe and therefore constrain the properties of General Relativity. Since the measurements of Euclid will also give insights on the properties of dark matter and neutrinos at cosmological scales, I will also show how we can measure non-standard couplings between matter species and dark energy and how we can give tight constraints on many alternative theories of gravity.

E1.16-0008-18 DARK ENERGY WITH WFIRST

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The cause of the now observationally well established cosmic acceleration over the last five billion years remains one of the most fundamental questions in physics. Either Einstein's theory of gravity break down on cosmological scales or the universe is dominated by some form of Dark Energy which we still know very little of. The Wide Field Infrared Survey Telescope (WFIRST)'s primary Dark Energy science objective is to determine the expansion history of the universe and the growth history of its large-scale structure in order to test possible explanations of its accelerating expansion. This goal will be achieved through a combination of the dedicated High Latitude Survey (HLS), which will provide four bands (Y, J, H, F184) imaging and spectroscopy (1.35 - 1.95um) over 2000 square degrees, along with a three-tiered survey aimed at detecting supernova Ia. In this talk, I will discuss how WFIRST observations enable higher precision measurements of cosmological parameters using three complementary techniques (i.e. supernova Ia, weak gravitational lensing, and baryon acoustic oscillations) using forecast simulations and comparisons to other ground and space based missions.

E1.16-0009-18 SCIENCE OF THE CHINESE SPACE STATION OPTICAL SURVEY

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The Chinese Space Station Optical Survey (CSS-OS) is a space-borne mission designed to have a 2m aperture and about 1.1 square degrees field of view. It will carry out both imaging and spectroscopic surveys with the wavelength coverage from 255nm to 1000nm. The primary science goal of CSS-OS is to understand the dark Universe by probing the large-scale structures via weak lensing effects and galaxy clustering. Meanwhile, its wide wavelength coverage and high imaging quality can enable a broad range of studies from the solar system to galaxy formation and evolution. In this presentation, I will discuss the scientific potential and challenges of CSS-OS with an emphasis on cosmology.

E1.16-0010-18 NEUTRINOS, MODIFIED GRAVITY AND NON-GAUSSIANITY WITH EUCLID

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Upcoming spectroscopic and photometric surveys such as the Euclid mission will measure the large scale structure (LSS) of our Universe to an unprecedented level. LSS data not only contains information about dark energy but allows us to constrain the sum of neutrino masses and primordial non-Gaussianity as well as to test gravity. I will present an overview of the observational effects of these extensions to the vanilla ΛCDM model on the LSS, discuss expected constraints and provide an outlook of potential theoretical and observational challenges.

E1.16-0011-18 ASTROMETRY WITH WFIRST

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Robyn E. Sanderson, Andrea Bellini, Stefano Casertano, Jessica R. Lu, Peter Melchior, David Bennett, Michael Shao, Jason Rhodes, Sangeeta Malhotra, Scott Gaudi, R. Michael Fall, Ed Nelan, Puragra Guhathakurta, Jay Anderson, Shirley Ho, Mattia Libralato

The Wide-Field InfraRed Space Telescope (WFIRST) will be capable of delivering precise astrometry for faint sources over the enormous field of view of its main camera, the Wide-Field Imager (WFI). This unprecedented combination will be transformative for the many scientific questions that require precise positions, distances, and velocities of stars. I will describe the expectations for the astrometric precision of the WFIRST WFI in different scenarios, illustrate how a broad range of science cases will see significant advances with such data, and outline synergies with current and future projects such as Gaia and LSST.

E1.16-0012-18 THE STARSHADE PROBE MISSION CONCEPT

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The Starshade Rendezvous Mission Concept Probe is a Starshade that works with the WFIRST Mission, but is built and launched separately, with a rendezvous on orbit. A 2015 Exo-S report first detailed the mission concept. In the current study we develop a new scientific vision for WFIRST exoplanet discovery and characterization, using the complementary coronagraph and starshade to execute the most sensitive and thorough direct imaging campaign ever attempted. The overarching goal is to carry out the first “deep dive” direct imaging exploration of planetary systems orbiting the nearest sun-like stars in a search for Earth-like planets using only a fraction of the WFIRST telescope time. The study aims to improve on the Exo-S 2015 report with updated study of the key spacecraft and starshade technology development issues, as related to WFIRST design changes since 2015 that make the timely implementation of such a mission possible. Starshade mission options beyond the Rendezvous Mission Concept with WFIRST are also described.

E1.16-0013-18 MICROLENSING WITH WFIRST

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Roughly a quarter of WFIRST's primary mission will be spent conducting an exoplanet microlensing survey. The survey will provide a statistical assay of the cold exoplanet population with masses greater than that of Mars and orbits beyond 1 AU, with a total planet yield comparable to Kepler's. It will also measure the mass function of free-floating planets potentially down into the mass regime of large Kuiper Belt Objects. The WFIRST microlensing survey parameter space spans critical mass and distance scales in planet formation theories, including the ice line, the isolation mass, and the critical mass for runaway gas accretion. I will give an overview of the WFIRST microlensing survey, and the highlights of its expected results. I will also describe the legacy value of the WFIRST microlensing data set of high-cadence near-infrared lightcurves of 200 million stars, which are potentially useful for asteroseismology, astrometry, transiting hot and warm Jupiters, and isolated black holes, to name but a few.

E1.16-0014-18 CASTOR: A WIDE-FIELD UV-OPTICAL IMAGING TELESCOPE

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Since 2012, the Canadian Space Agency has been developing a mission concept for a widefield, nearly diffraction limited UV/optical space telecope: the Cosmological Advanced Survey Telescope for Optical and uv Research (CASTOR). CASTOR is a 1m telescope that uses a three mirror anastigmat design to provide deep, panoramic imaging in three filters covering the 150-550nm wavelength range. In this talk, I describe the current design of the facility and highlight its extraordinary scientific potential by focusing on specific programs in cosmology and dark energy, galaxy evolution and star formation, AGNs and QSOs, near-field cosmology, Galactic structure, stellar astrophysics, exoplanets and the outer solar system.

E1.16-0015-18 SPHEREX: AN ALL-SKY SPECTRAL SURVEY

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SPHEREx, a mission in NASA's Medium Explorer (MIDEX) program that was selected for Phase A in August 2017, is an all-sky survey satellite designed to address all three science goals in NASA's astrophysics division, with a single instrument, a wide-field spectral imager. We will probe the physics of inflation by measuring non-Gaussianity by studying large-scale structure, surveying a large cosmological volume at low redshifts, complementing high-z surveys optimized to constrain dark energy. The origin of water and biogenic molecules will be investigated in all phases of planetary system formation - from molecular clouds to young stellar systems with protoplanetary disks - by measuring ice absorption spectra. We will chart the origin and history of galaxy formation through a deep survey mapping large-scale spatial power in two deep fields located near the ecliptic poles. Following in the tradition of all-sky missions such as IRAS, COBE and WISE, SPHEREx will be the first all-sky near-infrared spectral survey. SPHEREx will create spectra (0.75 - 5 um at R = 40 and 135) with high sensitivity using a cooled telescope with a wide field-of-view for large mapping speed. During its two-year mission, SPHEREx will produce four complete all-sky maps that will serve as a rich archive for the astronomy community. With over a billion detected galaxies, hundreds of millions of highquality stellar and galactic spectra the archive will enable diverse scientific investigations and enable many synergistic analysis with other large scale structure surveys of the next decade.

E1.16-0016-18 THE HABITABLE EXOPLANET OBSERVATORY (HABEX)

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The Habitable Exoplanet Observatory (HabEx) is one of four flagship mission studies currently underway in preparation for the 2020 Astrophysics Decadal Survey. HabEx is a large UV to near-IR space telescope that is being designed to optimize high contrast direct imaging and characterization of Earth-sized and larger exoplanets using starlight suppression with a coronagraph and starshade. The large aperture, ultra-stable telescope will also enable a broad range of observatory science from two dedicated instruments: a UV to near-IR camera and spectrograph and a multi-object UV spectrograph. The optical and infrared surveys of the 2020's will reveal an enormous range of exciting new discoveries and HabEx is poised to enhance on these efforts in the 2030's with its next-generation instruments and capabilities.

E1.16-0017-18 INFRARED SURVEYS WITH THE ORIGINS SPACE TELESCOPE

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The Origins Space Telescope (OST) is the mission concept for a midand far-IR surveyor, one of NASA's flagship-class studies for the 2020 Decadal Survey. Operating between 5 microns and 660 microns, OST's cold (4K) telescope (5.9m) will provide a sensitivity that is orders of magnitude better than what can be currently achieved. This capability opens up a wide range of science goals, within the themes of "Are we alone?", "How did we get here?" and "How does the Universe work?" A suite of four instruments is being studied, which include broad-band imaging, spectroscopic, polarimetric, and coronagraphic capabilities. Moreover, OST will be capable of fast mapping speeds to support large-area surveys in the infrared. The satellite will used for projects such as targeted exoplanet investigations, tracking water through astrophysical environments, charting the rise of metals, and large-scale mapping of the Universe in IR continuum and lines. It will build upon the wide-area surveys of WFIRST and Euclid. Its complementarity with other facilities also offers OST the possibility of probing the end of the dark ages, as well as following up obscured gravitational wave sources and other transient phenomena, in ways that are not possible at optical wavelengths.

E1.16-0018-18 PIXEL FUSION: MODELING THE SKY WITH ALL AVAILABLE DATA

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The image modeling framework "scarlet" (Melchior et al. 2018) enables the joint use of multiple data sets of the same celestial scene. It can be used to improve source modeling and source separation by working on multi-band images and/or by combining low-resolution with highresolution images. It is specifically developed for joint pixel-level processing of data from LSST, WFIRST, and Euclid. I will introduce the method, discuss the statistical challenges in interpreting scenes consistently across multiple data sets, and demonstrate the improvement for precision photometry and shape measurements that are achievable with scarlet.

E1.16-0019-18 WIDE FIELD SPACE BASED SURVEYS IN THE 2020S: A PANEL DISCUSSION

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We will have a panel of scientists involved with WFIRST, Euclid, and the Chinese Space Station Optical Survey discuss planes for these ambitious surveys and take questions from the audience.

E1.16-0020-18 PANEL DISCUSSION II

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Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, United States panel discussion ii

E1.16-0021-18 ASTRONOMICAL DATA RELEASES, ARCHIVING AND USER SUPPORT - THE EUCLID PERSPECTIVE

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Releasing large volumes of survey data such that the scientific return can be maximized is a major challenge. This requires long term preparation, development of dedicated data processing and handling facilities, and a high degree of organization with the participation of scientific data experts. The Euclid Space Mission is no exception, and Euclid has the additional commitment to meet an agreed data release schedule. Many aspects have to be taken into account, not all of these aspects are visible to the end user, but can raise major (design) problems to make a data release happen on time. In addition, the end user must have access to supplementary information before starting the scientific exploitation. This extra information has to be transferred from the instrument development via the operational experience to the scientist. Even though Euclid's data rate will not be the most extreme (approximately 200 Gbyte per day of raw science data), Euclid is expected to generate a 24/7 data flow for 6 years to cover eventually an area of 15,000 deg2 in optical imaging, near-infrared imaging photometry and near-infrared spectroscopy, with space-based spatial resolution. These data will be combined with g, r, i and z-band ground-based optical photometry, covering the same sky as Euclid. In total the final Euclid survey will release about 100 Pbyte of images and catalogues. Key elements are the accessible archive with its data products, the scientific validations, and user support providing knowledge and, possibly, advanced remote processing facilities. We will review these key elements from a Euclid perspective - also considering experiences from and synergies with other missions - and discuss the possible choices enabling a successful science exploitation after data release.

E1.16-0022-18 MULTI-TRACER, HIGH-RESOLUTION MASS MAPPING OF WIDE FIELDS

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To this point, the fields of cosmic shear and the lensing analysis of individual objects such as lensing clusters of galaxies or single galaxies have been largely distinct, for good reasons. On the one hand, only pencil-beam optical/NIR observations with e.g. HST or ground-based telescopes such as Subaru fulfilled the requirements on the density of background objects and image quality/resolution to allow detailed mass reconstruction of deflectors in the field of interest. On the other hand, earlier wide-field optical surveys such as SDSS and on-going surveys such DES, KiDS or HSC deliver weak lensing observations over large portions of the sky but have to compromise in terms of weak lensing background galaxy density or the identification of additional tracers such as strong lensing features. This picture will change dramatically with the advent of ground -and space-based lensing surveys such as LSST, Euclid or WFIRST. Detailed mass reconstructions of large fractions of the sky will become possible, given the development of methods that can produce mass maps on such scales. Two qualities are key for the success of such methods: a) an adaptive resolution of the resulting mass map which is based on multiple lensing and other tracers at varying spatial scales and b) numerical efficiency and parallelism which enables almost all-sky reconstructions at potentially sub-arcminute resolution at acceptable runtimes. We have recently developed a framework which fufills these requirements. The method derives from combined weak -and strong-lenging reconstructions of galaxy clusters and it recovers the lensing potential in the so-called mesh-free domain. This means that the spatial distribution of output nodes does not have to follow any regular pattern and can hence optimally follow the distribution of input constraints. Such constrains can be either weak lensing measurements in the field, different kinds of strong lensing tracers at halo centres, baryonic tracers such as tSZ or X-ray measurements or local kinematic information as derived from galaxy spectroscopy. Secondly, the method was fully encapsulated into a three-stage parallelisation hierarchy, meaning a model that employs MPI for inter-node communication and OpenMP within individual nodes spawning threads to call multiple GPUs on each node, depending on the specific configuration of the production machine. Currently, using a single node with two NVIDIA GeForce Titan Xp GPUs we achieve runtimes of less than one second per square degree at sub-arcminute resolution. This renders future reconstructions of thousands of square degrees possible even on moderate hardware, including a full error analysis via resampling of the input catalogues.

E1.16-0023-18 A FIRST TRANSIENTS SURVEY WITH JWST: FLARE

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JWST will answer empirically how the Universe made its first stars. Instead of classical stare mode and still photography of objects of unknown spectra we quest the epoch of reionization in the time domain and target what happened to these first stars. We will observe the most luminous events: supernovae and accretion on to black holes from primordial gas. These transients provide direct constraints on star formation rates and the truly initial mass function. This will explore the physics of these events at ultra-low metallicity. These very rare events at the dawn of cosmic structure formation can be reached by JWST at 27 mag AB in 2 micron and 4.4 micron over a field of 0.1 square degree visited multiple times each year. This survey may detect massive Pop III SNe at redshifts up to 10, pinpointing the redshift of first stars, also large scale structure as the trademark of reionization; all key scientific goals of JWST.

E1.16-0024-18 THE INTEGRATED CRYOGENIC SYSTEM FOR THE SURVEY CAMERA OF THE CHINESE SPACE STATION TELESCOPE

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The integrated cryogenic system for the Survey Camera of the Chinese Space Station Telescope includes three parallel arrangement 40W/170K low-vibration cryocoolers for the UV-Optical Focal Plane, a 6W/70K low-vibration cryocooler for the NIR Focal Plane, and flexible heat transfer device based on the low temperature heat pipe technology as well. These cryogenic elements were integrated together in order to meet the Temperature requirements of Focal Plane. This paper summarizes the cryogenic integration design, technical challenges, and the results of performance testing.

E1.16-0025-18 THE NEAR INFRARED SPECTROPHOTOMETER ON-BOARD THE EUCLID SATELLITE: STATUS AFTER CRITICAL DESIGN REVIEW AND DEVELOPMENT PLAN

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The NISP (Near Infrared Spectrometer and Photometer) is one of the two instrument onboard the ESA Euclid satellite. It operates as a slitless spectrograph in the 900-2000 nm wavelength range and as Y, J, H photometer. The instrument is composed of: - a cold (135K) optomechanical subsystem consisting of a Silicon carbide structure, an optical assembly, a filter wheel mechanism, a grism wheel mechanism, a calibration unit and a thermal control system; - a detection system based on a mosaic of 16 Teledyne H2RG sensors, with their front-end readout electronic; - a warm electronic system (280K) composed of a powerful data processing / detector control unit and of an instrument control unit; this last is connected to the spacecraft via a 1553 bus for command and control and via dedicated Spacewire links for science data transfer. NISP will provide photometric redshifts for sources imaged by the other Euclid instrument, the VISible imager, and more than 30 million accurate redshifts from slitless spectroscopy using H-alpha emission lines. This paper, presented on behalf of the NISP Team of the Euclid Consortium, describes: - the final architecture of the instrument following the Critical Design Review, - the subsystems hardware and software qualification or flight models, - the expected performances, - the development and the test plan.

E1.16-0026-18 EVALUATING AGE OF UNIVERSE BY PHOTO-METRIC ANALYSIS OF GLOBULAR CLUSTERS.

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The atoms of mankind exist from the "début de l'Univers" (beginning of Universe) encapsulated with its several other life forms. The keen drive for knowing more has always been the igniter of every thumping discovery ever made. The biggest pig in a poke where Genesis is concerned is that of the whole universe which can be unveiled by two broad methods, either by the study of the expansion of Universe or performing the same on Globular clusters containing numerous Stars because all the evidence seems to indicate that the Universe has not existed forever but that it had a beginning. Several studies have been conducted on various missions to NGC 2420 and other clusters such as NGC 4472 and NGC 2419. Futurology of this paper lies in the study of globular cluster NGC5466, which is approximately 51,800 light years away from us. As the entire information of genome is known by the DNA, likewise the age of the universe will be evaluated by the photo-metric analysis of different globular clusters in different colour bands by various methods commanded by DAOFIND, TVMARK, PHOT, PSTSELECT, etcetera. The ages of these old clusters will be compared by contrasting the estimated ages of the universe from Hubble constant and other cosmological models. Globular clusters like M2, M15, M68, M92 and NGC5466 which consists of Population III stars (extremely metal-poor stars that are theorised to have been the 'first-born' stars created in the universe) will be analysed together for evaluation of the approximate age of the universe. In addition, colour magnitude diagram(CMD) and Hertzsprung-Russel(HR) diagram evaluated from obtained data will be compared by the classical model like Benchmark, Einstein and de Sitter model for a better age estimation. Additionally, if we extrapolate back infinitely lingering around these stars, we will be able to understand if the classical age13.772 Billion years accepted so far based on the nomology is correct or not. Also, the demeanour of Universe will assist in manifesting the veracious spaciotemporal phenomenon that happened then.

E1.16-0027-18 GALAXY ELLIPTICITY MEASUREMENTS FOR WEAK LENSING USING NIR IMAGES

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One of the primary science goals of Euclid is to constrain cosmological parameters through weak gravitational lensing. For the weak lensing shape measurement, the Euclid survey will detect galaxies in a broad optical R+i+z band (VIS), which reaches a 10 sigma depth of 24.5 AB magnitude. In this study, we demonstrate that co-added J+H-band near-infrared (NIR) images at Euclid's resolution and depth can yield better ellipticities of galaxies at redshifts $0.5<z<3$ than such optical images. There are several reasons for this better performance: Due to the morphological k-correction, galaxies have an intrinsically smoother shape distribution in the NIR bands than in the VIS, the latter mostly tracing the rest-frame UV light which follows the clumpy distribution of star-forming regions. Also, near-IR (J+H) images of galaxies have a higher surface brightness with more than three times the number of source photons per pixel and are less affected by dust extinction. Another benefit of using the near-IR bands is that they are sensitive to more than a factor of 2 more galaxies at $z>1.5$. We select galaxies at $0.5<z<3$ satisfying the Euclid sensitivity limit from CANDELS GOODS-S and GOODS-N fields and use F606w(V), F814w(I), F125w(J) and F160w(H) HST images of them. We then simulate Euclid VIS and near-IR images by degrading the co-added CANDELS/HST V+I and J+H images to the Euclid resolution, respectively, and compare the ellipticities estimated from CANDELS (I or and Euclid (V+I or J+H) images. By doing so, we find 20% better ellipticity measurement in J+H than in VIS. Despite the worse spatial sampling of the Euclid imaging data in the NIR compared to VIS (0.3" vs. 0.1"), we can extract a robust ellipticity measurement from the NIR bands. Our study motivates the careful assessment of NIR shape systematics for future weak gravitational lensing surveys, such as with Euclid and WFIRST.

E1.16-0028-18 LARGE-SCALE STRUCTURE STUDIES WITH THE OPTICAL AND INFRARED SURVEYS BY EUCLID AND WFIRST

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We will discuss how the Euclid and WFIRST space surveys will revoluzionize our understanding of large-scale structure during the epoch when the knots of the cosmic web first start forming. Our predictions are based on recent results from current optical and infrared surveys with the Hubble Space Telescope (HST). Imaging and grism spectroscopy obtained by the HST CANDELS (Grogin et al. 2011; Koekemoer et al. 2011) and CARLA (Wylezalek et al. 2013) surveys are giving us our first glimpse of large-scale structure formation at $z>1.5$ from these small samples. We are able to study the formation of clusters and proto-clusters and of the progenitors of the most massive galaxies in the Universe. These new observations enable us to optimize the study of large-scale structure at these high redshifts with Euclid and WFIRST.

E1.16-0029-18 ORIGINS SPACE TELESCOPE CONCEPT-2 SCIENCE TRACEABILITY MATRIX

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Presented on behalf of the Origins Space Telescope (OST) study team, with engineering support at Goddard Space Flight Center. OST is one of four potential flagship studies supported by NASA Headquarters to prepare for the 2020 Decadal Survey. As a large cold mid-to-far infrared telescope OST will provide a sensitivity that is orders of magnitude more powerful than Spitzer and Webb. OST's key scientific goals are to (1) To characterize exoplanet atmospheres looking for bio-signatures in transiting planets and directly imaging thermal emission in Jupiterand Saturnexoplanet analogs; (2) To measure water across cosmic time from the first galaxies to proto-planetary disks to hundreds of comets in the solar system to solve the mystery of the origin of water on Earth; (3) To study proto-galaxies before the epoch of reionization in the cosmic dark ages and map the evolution of metals and chemistry over all cosmic time. In the evolution of the mission study, Concept 2 has been designed to have minimal deployments to mitigate risk and reduce integration costs and fit within a 7m fairing. Concept 2 is a cold (4K) telescope with 25 sq-meter collecting area, diffraction limited at 30 microns, with four instruments providing imaging and spectroscopy covering 5 to 660 microns. This paper will address the Science Traceability Matrix for the OST Concept 2.

E1.16-0030-18 EUCLID QUICK LOOK ANALYSIS SOFTWARE

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Euclid is an ESA mission due to launch in 2021 and aim at mapping the geometry of the dark Universe in the optical/near-infrared domain, investigating the distance-redshift relationship and the evolution of cosmic structure out to redshifts 2. It will use mainly two cosmological probes: the Weak Gravitational Lensing and the Baryon Acoustic Oscillations. Euclid will map the entire extragalactic sky with two instruments, VIS (VISible imager) and NISP (NearInfrared Spectro-Photometer), providing a huge amount of data: 850 Gbit per day of raw data, 1 Pbit per year of higher processed data.

The Science Operations Centre (SOC), located at the European Space Astronomy Centre (ESAC), Villanueva de la Cañada, Spain, is responsible for implementing the survey strategy, its operation and monitoring its performance. It is also responsible to develop and run the Quick Look Analysis (QLA) software, the system in charge of pre-assessing - within 48 hours of data reception - the quality of the data in order to react as soon as possible in case of instrumental problems (mis-configurations, abnormal data, etc.). The system is based on a pass/fail structure given a set of quality flags and raising alerts accordingly.

It consists of two main parts:

the QLA Processing Framework (QPF), developed in Qtk/C++, provides the processing framework to execute system functionalities, a human-machine interface (HMI) to control all its tasks, access to a local and Euclid archives, interaction with VO-Space and an alerting system via email the QLA Diagnostic Tools (QDT), developed in Python, implements different algorithms and diagnostic functions to check the quality of all the data: VIS, NISP but also housekeeping and Attitude and Orbit Control System (AOCS) product.

QLA will analyse all level 1 data: this is uncompressed, reordered raw data with tagged metadata associated. All the checks will be executed automatically due to the large amount of data. QLA shall be capable to:

Check the correctness of instrument commanding sequence

Assess the science data content against e.g. anomalies, mainly at pixel and instrumental level. However, QLA will not asses data quality from the scientific point of view

Implement quick feed-back on survey execution and image quality

Version 2.0 was released in the first quarter of 2018: it includes most of the envisaged checks for VIS and AOCS; the code for

NISP is under development in collaboration with NASA/IPAC and currently includes the backbone architecture and a couple of diagnostics.

E1.17-0001-18 MULTI-MESSENGER OBSERVATIONS OF BLACK HOLES - AN OVERVIEW

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A steady growth in observational capability, throughout the electromagnetic spectrum and beyond, has led to a corresponding steady growth in our understanding of the underlying physical processes at work around black holes. This is especially true of those holes observed in the nuclei of galaxies, in X-ray binaries and being formed in Gamma Ray Bursts and gravitational radiation sources. Powerful accretion disks, jets and winds show a rich variety of behaviors. The case will be made that much of the transient activity is mediated by strong magnetic field. The strong prospect of future discovery from recently commissioned and soon to be operational facilities will be emphasized.

E1.17-0002-18 FERMI TRANSIENT J1544-0649: A FLARING RADIO-WEAK BL LAC

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On May 15th, 2017, the FERMI/LAT γ-ray telescope observed a transient source not present in any previous high-energy catalogue: J1544-0649. It was visible for two consecutive weeks, with a flux peak on May 21st. Subsequently observed by a Swift/XRT follow-up starting on May 26, the X-ray counterpart position was coincident with the optical transient ASASSN17gs = AT2017egv, detected on May 25, with a potential host galaxy at z=0.171. We conducted a 4-months follow-up in radio (Effelsberg-100m) and optical (San Pedro Martir, 2.1m) bands, in order to build the overall Spectral Energy Distribution (SED) of this object. The radio data from 5 to 15 GHz confirmed the flat spectrum of the source, favoring a line of sight close to jet axis, not showing significant variability in the explored post-burst time-window. The Rx ratio, common indicator of radio loudness, gives a value at the border between the radio-loud and radio-quiet AGN populations. The CaII H&K break value (0.29±0.05) is compatible with the range expected for the long-sought intermediate population between BL Lacs and FRI radio galaxies. An overall SED fitting from Radio to γ-ray band shows properties typical of a low-power BL Lac. As a whole, these results suggest that this transient could well be a new example of the recently discovered class of radio-weak BL Lac, showing for the first time a flare in the γ/X-ray bands.

E1.17-0003-18 A UNIFIED MODEL FOR GRB PROMPT EMISSION FROM OPTICAL TO GAMMA-RAYS: EXPLORING GRBS AS STANDARD CANDLES

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The Band function traditionally used for Gamma Ray Bursts (GRB) often fails to fit their prompt emission spectra. Our new model composed of three separate components provides an excellent description of the time-resolved prompt emission: a thermal-like and two non-thermal components. For the first time, analysis of GRBs with correlated optical and gamma-ray prompt emission show that our new model describes very accurately the whole broadband spectrum from the optical regime to higher energy gamma rays. In addition, this new model enables a new luminosity/hardness relation intrinsic to one of the non-thermal components showing that GRBs may be standard candles. If statistically confirmed, this relation will be used to (i) constrain the mechanisms powering GRB jets, (ii) estimate GRB distances, (iii) probe the early Universe, and (iv) constrain the cosmological parameters. I will present this new unified model using analysis of GRBs detected with various observatories and instruments such as Fermi, CGRO/BATSE and the combination of the three instruments on board Swift and Suzaku/WAM. I will discuss here the striking similarities of GRB spectral shapes, whose components inform on the nature of the prompt emission, as well as the possible universality of the proposed luminosity/hardness relation in the context of our new model.

E1.17-0004-18 SYNTHETIC SPECTRA FOR AN OFF-AXIS AFTERGLOW FROM A SHORT GAMMA-RAY BURST

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The simultaneous detection of gravitational waves by the LIGO and Virgo detectors from a binary neutron star (BNS) merge, GW 170817, is the first gravitational wave event that has electromagnetic (EM) follow-up observations, from gamma-rays to millimeter wavelengths. The data from these EM counterparts lead to the idea that the GW 170817 might be the first offaxis afterglow observed from a short gamma-ray burst (sGRB), and they would provide the first direct observational evidence for the launching of relativistic jets in BNS mergers. The properties of the jets, as well as their interaction with the environment, can be studied at the microscopic level by using particle-in-cell (PIC) numerical simulations. We study the evolution of relativistic plasma jets containing helical magnetic fields and examine how these helical magnetic fields affect (i) kinetic instabilities (such as the Weibel instability, the kinetic KelvinHelmholtz instability, and the Mushroom instability) and (ii) magnetic reconnection in the jets. We also calculate synthetic spectra and spectral evolution for the off-axis radiation emitted by the particles accelerated in such sGRB jets and compare them with observations. Nevertheless, simulations using very large systems are required in order to thoroughly follow the evolution of global jets containing helical magnetic fields.

E1.17-0005-18 ANALYSIS OF RECENT SHORT GRB AFTERGLOW LIGHT CURVES

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Since the historic Aug. 17, 2017 simultaneous detection of gravitational and electromagnetic waves produced by the merger of two neutron stars, the GW-GRB 170817 event, interest in short gamma-ray bursts (SGRBs) has increased exponentially. SGRBs (bursts with durations less than 2.0 seconds) represent only about 10 % of all bursts, and unlike long GRBs, there was until this recent event no complete consensus on the (merger) physical mechanism responsible for SGRBs. This combined fact had kept interest toward short bursts relatively low. But in the few years before the GW-GRB connection, which fully cemented the merger model as the physical process behind SGRBs, the detection of kilonovae/ macronovae associated with three SGRBs had already started to raise the interest in this class of bursts.

Fong et al. (2015) collected and analyzed afterglow observations of SGRBs from 2005 to 2014, covering their broadband emission from X-rays to radio. Using the widely adopted theoretical prescription of Panaitescu Kumar (2000) for calculating afterglow fluxes, Fong et al. (2015) extracted individual and statistical values for the bursts' and afterglows' physical parameters: kinetic energy, medium density, electron and magnetic energy fractions, and jet opening angles.

We have extended that work to the last 3 years (Jan. 2015 to Dec. 2017), using Swift events (29 short bursts recorded during that period) and Fermi events (116 events). We have searched the literature (GCN reports and published papers) to collect afterglow observations, whether positive or negative (upper limits), limiting ourselves to optical and near-infrared data, the bands where kilonova detections can be successful.

Our aim is to fit or constrain the afterglow light curves with physical parameters, to the extent possible, and to try to identify cases that most resemble those that have had a kilonova detection. We present the most interesting cases that we have uncovered, along with the physical results from the sample.

E1.17-0006-18 GRB JET IN NS-NS COLLAPSE FEEDING NARROW JET AND WIDER ORTHOGONAL GAMMA DISK.

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The short GRB 170817A observed by Fermi and Integral correlated with LIGO-VIRGO GW 170817 posed several key questions. The associated Optical transient OT source in NGC4993 implied a very rare nearest source, a consequent averaged large rate for such events (almost) compatible with the expected NS NS merging rate, if the GRB signal was nearly spherical. However the expected GRB (or Short GRB) must be beamed, mostly aligned at a different direction than our one. Therefore even soft GRB photons, more spread than hard ones, might be hardly be able to shine and shower to us in the very first GW by NS-NS collapse. We therefore suggested that in GRB jet there is a new Ultra-relativistic spiraling electron "skin" (surrounding the jet itself) ruled by synchrotron radiation electron rings contained by external magnetic fields, born at the birth of the NS-NS collapse. Such a new synchrotron equatorial radiation might shine by its tangential gamma photons in a much spread way into a 360 degree gamma disk, orthogonal to the much collimated (advancing forward) narrow jet. The consequent solid angle of view for such a prompt, soft, wide disk gamma radiation may be wider than within any common (cosmic) thinner gamma jet, offering a solid angle large enough to be more probably observed (at a much weaker apparent luminosity), as it has been indeed observed. References: 1) D. Fargion, M. Khlopov, and P. Oliva, Could GRB170817A be really correlated to an NS-NS merging?, Int. J. Mod. Phys. D (2017). 2) D.Fargion, On the nature of GRB-SGRs blazing jets, Astron. Astrophys. Suppl. Ser. 138, 507-508 (1999)

E1.17-0007-18 MULTI-WAVELENGTH POLARIMETRY OF FAST TRANSIENTS

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In the context of pulsar studies we have developed a tool for pulsar gating at radio and gammaray energies, in order to disentangle the pulsar signal from that of its pulsar wind nebula (PWN), using the technique of the subtraction of the pulsed component. In the case of the future Imaging X-ray Polarimetry Explorer (IXPE), which will be launched in 2021 and will be able to perform spectral-polarimetry together with spectral timing, the same approach can be applied to obtain phase-resolved polarimetry for the pulsar-PWN systems (one of its key science objectives) where the instrument resolution does not easily allow the separation of the two sources.

In parallel, we are developing a tool to search for pulsars and fast radio bursts (FRBs), with a technique alternative to the Fourier transform (FT), which uses the Karhunen-Loève transform (KLT). The KLT is a mathematical algorithm which has not been fully explored yet, due to its high computational demand, but which is potentially more powerful than the FT when applied to a generic signal buried in noise. The same approach can be applied to the search of fast transients of yet unknown nature, or for the search of the same transients, at other wavelengths than radio, if enough statistics is available.

The combination of these tools provides the starting point for a pipeline for the detection of new fast transients and their time-resolved and polarimetric studies. We present the application of the tools to the multi-wavelength analysis of real and simulated data of a sample of pulsars and their PWNe, for which we determine the

spectral timing and polarimetry properties from radio to gamma-rays and discuss how the new generation of telescopes can help constrain the geometrical structure and emission mechanisms of fast transients.

E1.17-0008-18 DISK-JET COUPLING OF BLACK HOLE SOURCES WITH THE TCAF SOLUTION

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Jets/outflows are important feature in black holes. The ejection mechanism depends on the accretion flow and spectral states. Compact jets are generally observed in low/hard states. Blobby jets or discrete ejection generally observed in the intermediate states. Jets are quenched in the soft states. Jets are observed in multiwave bands, form radio to high energy X-rays and gamma-rays. In case of compact jet, radio and X-ray fluxes are correlated. However, for blobby jets, the correlation is not trivial. We have developed a new method to calculate jet X-ray flux from spectral analysis with two component advective flow (TCAF) model fits file in XSPEC. We use the fact that normalization must remain constant throughout the outburst since it is a function of intrinsic source parameters such as, mass, distance and inclination angle of the system. If jet is present, constancy of the model normalization breaks, and higher values of normalization may require to fit the spectra. This allowed us to assume on the minimum normalization day, jet contribution is also minimum. On the basis of this assumption, we developed a new method to separate X-ray contribution from inflowing / accretion disk matter and from jets / outflowing matter. Using this newly developed method, we have calculated X-ray contributions of jets/ outflow for Swift J1753.5-0127 during its 2005 outburst and MAXI J1836-194 during its 2011 outburst. We find jet contributes in the X-ray is upto 44% and 86% for Swift J1753.5-0127 and MAXI J1836-194 respectively. We also find correlation between radio (FR) and jet (Fout) X-ray fluxes, as FR F 0.6, which is similar to the standard correlation. From the correlation plot, we conclude that in the intermediate state Swift J1753.5-0127 showed blobby jet while MAXI J1836-194 showed compact jet throughout the outburst.

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E1.17-0009-18 ESTIMATION OF MASSES OF BLACK HOLE SOURCES FROM SPECTRAL ANALYSIS WITH THE TCAF SOLUTION

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Recently after the inclusion of two component advective flow (TCAF) model into HEASARC's spectral analysis software package XSPEC as an additive table model, accretion flow dynamics around black holes are more clearly understandable from physical point of views. The TCAF model fitted spectral parameters i.e., two component (Keplerian disk and sub-Keplerian halo) accretion rates, shock (location, i.e., the size of the Compton cloud, and the compression ratio) parameters are quite capable of describing evolutions of various spectral and temporal properties/ phenomena during active phases of black hole sources. Spectral analysis with the TCAF model is also allowed us to estimate masses of black hole objects, since in the current version of the TCAF model fits file mass is an important input parameter. So, one can obtain one best-fitted mass value from each best-fitted spectrum. Unlike other phenomenological or theoretical models, TCAF model normalization should not change for one object on daily basis, since it depends on intrinsic source parameters such as, distance and disk inclination angle and mass of the black hole. So, using the method of constant normalization until now, we have been able to estimate probable mass ranges for more than half a dozen of black hole objects quite successfully. We have also verified our estimated masses with that of other methods, and found that our estimated masses are consistent with sometimes even better accuracy.

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E1.17-0010-18 NON-EQUILIBRIUM IONISATION IN MHD SIMULATIONS

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Although with a Magnetohydrodynamic (MHD) simulation we can reproduce many astrophysical scenarios, the plasmas in the simulations are often assumed to be CIE. If radiative cooling from heavy elements is significant in the MHD simulation or a detected spectrum is one of the results of the simulation, the CIE assumption should be removed and an NEI calculation should be done along with the simulation.

An eigenvalue method NEI calculation is added into FLASH code MHD simulation with an updated atomic database. The updated database and the eigenvalue method are compared with the original ones separately. With the eigenvalue method the calculation efficiency is improved on a large scale, and the radiative cooling can be calculated simultaneously. Some common ways to measure ionization states are investigated with an example simulation. The ion average charge difference from the equilibrium is shown to be a better method.

E1.17-0011-18 FINDING MULTI-MESSENGER TRANSIENTS WITH SWIFT: LESSONS LEARNED FROM SEARCHING FOR MAXI, ICECUBE AND LIGO/VIRGO TRANSIENTS

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We present results and lessons learned from multi-messenger and multi-telescope searches for X-ray and UV counterparts of transients, utilizing the Neil Gehrels Swift Observatory. Swift is unique in many ways, firstly it is a multi-wavelength observatory, observing in 0.5-150 keV in X-rays, and visible to UV in optical, utilizing the it's three instruments, the Burst Alert Telescope (BAT), X-ray telescope (XRT) and UV/Optical Telescope (UVOT). Secondly, Swift is a robotic telescope, capable of responding rapidly (minutes to hours) to transient triggers from a variety of sources. Thirdly it's rapid slewing capability allows it to perform unique tasks, such as very low-overhead tiling of large error regions to search for transients. Here we discuss lessons learned and recent results from Swift's search for transients discovered by the Japanese "Monitor of the All Sky X-ray Image" (MAXI) near-all-sky X-ray survey instrument. We show how we applied lessons learned from 8 years of collaborating with MAXI, and show results from recent searches for optical/UV and X-ray counterparts of possible astrophysical neutrino sources, as triggered by the IceCube Neutrino Observatory. Finally we discuss searches for EM counterparts of LIGO sources with Swift, as we prepare for O3.

E1.17-0012-18 GRAVITATIONAL-WAVE ASTRONOMY WITH ADVANCED LIGO

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On 2017 August 17, the field of gravitational-wave (GW) astronomy made the big leagues with a dazzling discovery. After several GW detections of black hole (BH)-BH mergers with no convincing EM counterparts, advanced LIGO and Virgo scored their first direct detection of GWs from a binary neutron star (NS) merger, an event dubbed GW170817. Soon after the GW discovery, GW170817 started gifting the astronomical community with an electromagnetic (EM) counterpart spanning all bands of the spectrum. In this talk, I will review what we have learned from GW170817, what questions remain open, and what are the prospects for future EM-GW studies of the transient sky.

E1.17-0013-18 FERMI OBSERVATIONS FOR GRAVITATIONAL WAVE COUNTERPARTS

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The Fermi Gamma-ray Space Telescope monitors the sky for gamma-ray transients, making it an ideal facility for detecting counterparts to gravitational wave sources. As demonstrated with the detection of GRB 170817A, 1.7 seconds after the LIGO-Virgo detection of the binary neutron star merger, GW170817, the Fermi Gamma-ray Burst Monitor (GBM) began the expansive multi-wavelength campaign. These observations led to important insights into the physics of compact object mergers and their emission components. I will describe both the GBM and Large Area Telescope (LAT) capabilities and pipelines for gravitational wave counterpart searches. The observations of gravitational wave counterparts provide unique insights into the physics of neutron stars and gamma-ray bursts, and implications for fundamental physics.

E1.17-0014-18 INTEGRAL OBSERVATIONS OF THE GRAVITATIONAL-WAVE GAMMA-RAY COUNTERPARTS

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The INTErnational Gamma RAy Laboratory (INTEGRAL) has carried out a search for gammaray signals temporally and/or spatially coincident with gravitational-wave (GW) triggers distributed by the LIGO and Virgo collaboration (LVC). Its high duty cycle (90%) ensures an ideal coverage; the omni-directional and high sensitivity of the SPI Anti Coincidence shield yield the most stringent constraints on any impulsive gamma-ray signal between 75 keV and 2 MeV, for almost the full sky. The other INTEGRAL instruments, in particular the imager IBIS and its Veto system, provide complementary coverage in the regions with reduced sensitivity for the SPI-ACS.

The relative large field of view of the INTEGRAL coded-mask instruments allows us to place stringent limits from 3 keV to 2 MeV for a large part of a GW localization region of a blackhole binary merger, when it is serendipitously covered by planned observations. Moreover, we performed follow-up observations for the most favorable GW triggers, in order to investigate any after-glow-like associated emission.

We will report on INTEGRAL gamma-ray observations related to the detection of the neutronstar binary merger GW170817, as well as the non-detections related to the various GW signals from the binary black-hole mergers, and discuss the implications of our findings.

E1.17-0015-18 THE X-RAY COUNTERPART TO THE GRAVITATIONAL WAVE EVENT GW170817

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The second run of advanced LIGO led to the breakthrough discovery of the first gravitational wave (GW) signal from a neutron star merger, GW170817, coincident with a short duration gamma-ray burst, at a distance of 40 Mpc. The discovery of GW170817 and its electromagnetic counterparts marked the beginning of a new era of multi-messenger astrophysics, in which photons and gravitational waves provide complementary views of the same source.

I will present the discovery and long-term monitoring of the X-ray counterpart associated with GW170817. While the electromagnetic counterpart at optical and infrared frequencies was dominated by the radioactive glow from freshly synthesized r-process material in the merger ejecta, known as kilonova, observations at X-ray and, later, radio frequencies revealed the emergence of a relativistic, structured outflow interacting with the surrounding low-density environment. I will discuss the key results of our multi-wavelength campaign, the open questions raised by this event, and future prospects for observations with the Athena X-ray Observatory.

E1.17-0016-18 X-RAY OBSERVATIONS OF GW170817

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I present the current status of the X-ray observations of GW170817 in the context of collimated ultra-relativistic outflows and spherical outflows.

E1.17-0017-18 HUNTING GRAVITATIONAL WAVE COUNTERPARTS WITH SWIFT.

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GW 170817/GRB 170817 was the first event definitively detected both by gravitational wave observatories and via their EM emission. In this talk I will present the results of observations of X-ray and UV observations of GW 170817 with the Neil Gehrels Swift Observatory, discuss their scientific interpretation, and consider the lessons we can learn from this object to inform follow-up of events detected by future LIGO-Virgo observing runs.

E1.17-0018-18 OBSERVATION OF X-RAY COUTERPARTS OF GW SOURCES WITH MAXI

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We present the results and prospects of the search for X-ray counterparts of gravitational wave sources by the Monitor of All-sky X-ray Image (MAXI), an all-sky X-ray monitor onboard the International Space Station (ISS). With the orbital revolution of the ISS, MAXI scans most of the sky in the 2-25 keV band every 92 minutes with a typical transit duration of 60 seconds. Thus MAXI has chance to obtain the early X-ray observation of gravitational wave events without planned pointing based on GW localization alerts. At the epoch of GW170817, MAXI was not operational due to its orbital position with high charged particle background. Even worse, with an unfortunate coincidence of the orbital geometry and phase with respect to the source location in the sky, the source was not observed for the subsequent few orbits. Still MAXI provided the earliest X-ray upper limit for GW180817 albeit not sufficiently constraining. With the more opportunities of GW events in the coming LIGO/Virgo O3, MAXI should be able to provide early X-ray observations, with which we can test various hypothesis on the X-ray emission from the neutron star merger events, and compare the known X-ray signatures of short GRBs such as extended emission and afterglows.

E1.17-0019-18 THE HUNT FOR FAINT SHORT GRBS WITH INTEGRAL/PICSIT

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The short gamma-ray burst (SGRB) associated with the gravitational wave trigger GW170817 showed timing and spectral characteristics consistent with previously observed SGRBs. Yet its isotropic luminosity was found to be several orders of magnitude lower than other SGRBs with known red-shift. This result has motivated searches for similar events below on-board instrument trigger thresholds. Here we have analyzed data from the INTEGRAL soft gamma-ray detector IBIS/PICsIT (200 keV - 10 MeV) to look for the untriggered SGRB candidates reported by Fermi/GBM. Also, we present initial results from real-time analysis to independently search for similar events.

E1.17-0020-18 SEARCHING FOR GAMMA-RAY COUNTERPARTS TO GRAVITATIONAL WAVES FROM MERGING BINARY NEUTRON STARS WITH THE CHERENKOV TELESCOPE ARRAY

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The recent detection of gravitational waves (GWs) from a binary neutron star (BNS) merger by Advanced LIGO and Advanced Virgo (GW 170817), in coincidence with a weak short GRB observed by Fermi-GBM and INTEGRAL (GRB 170817A), opened the era of multi-messenger astronomy and provided the first direct evidence that at least a fraction of BNSs are progenitors of short GRBs. One of the challenges for future multi-messenger observations will be the detection of short GRBs at very-high energies (VHE, > 20 GeV) in association with GW signals, that will allow us to better understand the physics of the GRB outflow and the radiation mechanisms.

The Cherenkov Telescope Array (CTA), an advanced, next generation ground-based facility, will be fundamental for the EM follow-up of transient GW events at VHE, owing to its unprecedented sensitivity, rapid response (few tens of seconds) and capability to monitor large sky areas via survey-mode operation; furthermore, it will have a coincident observational schedule with GW detectors at design sensitivity, when many GW triggers are expected to be shared with the astronomical community.

We present a comprehensive study on the prospects for joint GW and VHE EM observations of merging BNSs with Advanced LIGO, Advanced Virgo and CTA, based on detailed simulations of the multi-messenger emission and detection. We propose a new observational strategy optimized on the prior assumptions about the EM emission and we show how this novel method can improve the coverage of the GW skymaps and then the probability of detecting the EM counterparts with repect to the commonly used strategies. We explore different assumptions about the EM emission and we estimate the expected joint GW and VHE EM detection rates.

E1.17-0021-18 CALET GAMMA-RAY BURST MONITOR OBSERVATIONS

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The CALET Gamma-ray Burst Monitor (CGBM) is the secondary scientific instrument of the CALET mission, continuously operating on board of the International Space Station (ISS) since October 2015.

The CGBM consists of 2 Hard X-ray Monitors (HXMs) and one Soft Gamma-ray Monitor (SGM), utilizing different scintillators, LaBr3(Ce) and BGO respectively. The primary goal of CGBM is to observe a wide variety of gamma-ray bursts and other X/gamma-ray transients with fine temporal resolution (up to 62.5 us around triggers), broad spectral range (7 keV

20 MeV) and wide field of view. By combining the data of CGBM and CALET primary instrument, Calorimeter (CAL), the energy coverage is extended to the GeV - TeV range.

The CGBM has been detecting GRBs with an average rate of 3 per month, as expected from pre-launch estimation. CALET also takes

part in the electromagnetic follow-up of gravitational wave (GW) observations made by LVC collaboration, by investigating the existence of possible X-ray and gamma-ray counterparts.

We will report on CGBM in-orbit operation, performances, observations of GRBs and search for GW counterparts.

E1.17-0022-18 SEARCH FOR GAMMA-RAY COUNTERPARTS OF GRAVITATIONAL WAVE EVENTS BY CALET

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We present results of searches for gamma-ray counterparts of the LIGO/VIRGO gravitationalwave events from the CALorimetric Electron Telescope (CALET). The main instrument of CALET, the CALorimeter (CAL), observes gamma-rays from 1 GeV up to 10 TeV with a field of view of 2 sr. The CALET Gamma-ray Burst Monitor (CGBM) views 3 sr in the 7 keV - 1 MeV and the 40 keV - 20 MeV bands using a lanthanum bromide and a bismuth germanate scintillator, respectively. CALET observation on the International Space Station started in October 2015, and here we report analysis of events associated with the gravitational wave event GW151226 and successive events reported by LIGO/VIRGO. We also discuss the CALET sensitivity for detecting high-energy gamma-ray emission associated with future gravitational wave observations.

E1.17-0023-18 THE UNITED NATIONS OPEN UNIVERSE INITIATIVE FOR DATA IN SPACE SCIENCE

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"Open Universe" is an initiative under the auspices of the Committee on the Peaceful Uses of Outer Space (COPUOS) that aims at stimulating a dramatic increase in the availability and usability of space science data, extending the potential of scientific discovery to new participants in all parts of the world, especially for developing and underdeveloped Countries. The initiative is carried out under the coordination of the United Nations Office of Outer Space affairs (UNOOSA) as part of the activities in preparation for UNISPACE+50 and the United Nations Space2030 agenda. Open Universe seeks to trigger a major evolution of current space science data availability fostering the publication of all existing open space science data in a way that is easily discoverable and immediately usable, thus responding to the global demand for transparency. A number of technical activities are currently in development towards the launch of the initiative, which include a prototype, multi-discipline (astrophysics, planetary sciences, cosmicray and atmospheric physics) and multi-messenger Open Universe Portal at the Italian Space Agency (ASI), available at openuniverse.asi.it. The purpose of the Open Universe actions is to integrate and render as interoperable as possible a large number of space science data sets, analysis tools, and general information services, provided by many online space science data archives, based on VO-technology. The Open Universe is designed to answer the needs of professional scientists and common citizens alike, offering services and data products,which can be used to learn about space science or perform scientific analyses. This presentation will briefly illustrate the principles behind the Open Universe initiative and provide a description of the main features currently under development, specially for science in the multi-messenger era.

E1.17-0024-18 RESULTS FROM MULTI-MESSENGER SEARCHES FOR THE SOURCES OF HIGH-ENERGY ASTROPHYSICAL NEUTRINOS

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The IceCube observatory announced in 2013 the detection of a cosmic flux of high-energy neutrinos in the TeV to PeV range. This breakthrough discovery has prompted a wide-ranging observational effort aimed at identifying the sources of the neutrino flux by combining IceCube measurements with observations spanning the entire electromagnetic spectrum. The detection of these sources would represent a major step forward for high-energy astrophysics, which could reveal the acceleration sites of cosmic rays and provide a unique probe into the extreme environments in which these particles are produced. This talk will summarize recent IceCube observations, present an update on results from the multi-messenger search for neutrino sources concentrating on gamma-ray counterparts, and outline how future instruments may help pinpoint and characterize these objects.

E1.17-0025-18 OVERVIEW OF ANTARES NEUTRINO TELESCOPE RESULTS

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The ANTARES underwater neutrino telescope has been taking data continuously since 2007. Its primary goal is the search for astrophysical neutrinos in the TeV-PeV range. The transparency of the water allows for a very good angular resolution in the reconstruction of interactions from neutrinos of all flavors. This results in unprecedented sensitivity for searches for neutrino sources located in the Southern Sky. Thus, valuable complementary observations have been performed and constraints have been set on the origin of the cosmic neutrino flux discovered by the IceCube detector. ANTARES is actively developing a manifold multi-messenger program: latest experimental results from searches for neutrinos correlated with the recently discovered gravitational wave signals and FRB events will be reported. Other physics topics are addressed as well, that include e.g. setting constraints on dark matter from a search of neutrinos from potential dark matter annihilation in massive objects like the Sun and the Galactic Center. The high quality of the data provided by ANTARES and the competitiveness of the results achieved demonstrate the tremendous potential of the new, much larger array, KM3NeT, now under construction in the Mediterranean Sea.

E1.17-0026-18 NEUTRINOS AND OTHER HIGH ENERGY TRANSIENTS

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Seven years after the last optical sensor was lowered into the deep ice at the South Pole, IceCube remains the only kilometer-scale neutrino telescope in the world. The observatory was constructed with the principal goal of identifying sources of high-energy neutrinos in the Universe: natural gravity-powered particle accelerators that give rise to cosmic rays spanning an enormous range of energies. The charged cosmic rays are deflected by galactic and extragalactic magnetic fields and diffuse in propagating over vast distances, the neutrinos that must accompany them at the production sites travel without interaction and are the only known particles capable of mapping the ultrahigh-energy sky at cosmological distances. In 2013, IceCube reported the observation of a flux of high energy astrophysical neutrinos consistent with isotropic sources: a breakthrough discovery. Four years later the identities of sources of these high energy neutrinos and the consequent cosmic rays remain a mystery. However, the Observatory has expanded its public, real-time alerting capabilities as interest in multimessenger astrophysics grows with the hopes of correlating neutrinos, high energy gammas, and potentially even gravitational waves with sources identified by optical observatories. Even a singular such occurrence would constitute again a scientific breakthrough. This talk will discuss IceCube in the new age of multimessenger astronomy and will briefly highlight other science results from this unique telescope in the ice.

E1.17-0027-18 FALLBACK AND CIRCULARIZATION OF TIDAL DISRUPTION EVENTS DEBRIS

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While early investigations of the hydrodynamics of tidal disruption events has mostly focussed on the proper disruption phase, it has been progressively realized that an equally important process is that of the subsequent circularization of the stellar debris. Currently, it is not clear whether circularization is efficient or not, not whether the discs or torii formed in this way remain in stable circular configurations. From the observational point of view, while the accretion process is expected to provide the soft X-ray emission from TDE, the optical/UV emission appears to be produced by a relatively cold component, with an almost constant temperature throughout the flare. Such emission is most naturally explained in terms of the energy released during the circulariztion process. In this talk, I will discuss recent theoretical efforts to model the circularization and early evolution of the debris in tidal disruption events.

E1.17-0028-18 X-RAY OBSERVATIONS OF TIDAL DISRUPTION EVENTS

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The disruption of a star from the strong tidal forces of a supermassive black hole can cause the stellar debris to fall back towards the black hole at super Eddington rates. Efficient circularization of the debris can lead to the formation of an accretion disc with luminosities close to or potentially exceeding Eddington limit. Most super-Eddington accretion flow models (including recent magnetohydrodynamic simulations) predict large scale height, optically thick equatorial winds at relativistic velocities. In this talk, I will give an overview of X-ray observations of tidal disruption events. In particular, I will present observational results from two of the most well-observed X-ray emitting TDEs, Swift J1644+57 and ASASSN-14li. Both of these objects show evidence for massive outflows at tens of percent of the speed of light. The outflow in Swift J1644+57 was detected via blue shifted emission and reverberation of the iron K alpha line, and ASASSN-14li shows a potential P Cygni profile of the OVIII line. I will discuss how these and other X-ray observations are putting constraints on super-Eddington accretion flows of TDEs.

E1.17-0029-18 FAST RADIO BURSTS - AN OVERVIEW

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I will review the main characteristics of Fast Radio Burst, describe how they could be used as cosmological probes, and present some of the recent efforts to localize them through multiwavelength studies.

E1.17-0030-18 COUNTERPART EMISSION OF FAST RADIO BURSTS

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Fast radio bursts are intense radio transients with a millisecond duration, which are widely thought to come from extragalactic objects. Their sources and radiation mechanisms have been unknown since the discovery, and many attempts to search for the counterpart emissions have been made. Many theoretical models including ones involving magnetars and double neutron star mergers have been suggested, and we discuss their multi-wavelength signatures at radio waves, X rays, and gamma rays. In particular, in certain types of pulsar and magnetar models, one can expect bright quasi-steady emission from their wind nebulae as well as possible radio afterglows. We also discuss implications of the persistent radio emission associated with FRB 121102.

E1.17-0031-18 COORDINATED X-RAY AND RADIO OBSERVATIONS OF THE REPEATING FAST RADIO BURST

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FRB 121102, discovered with the Arecibo radio telescope, is the only known repeating fast radio burst source. Its extragalactic nature was unambiguously established via sub-arcsecond localization using the VLA along with Gemini and Hubble optical observations, which identified the host as a faint, low-metallicity, star-forming dwarf galaxy at redshift z=0.193. Recent radio polarimetry revealed that the FRB source resides in an extreme magneto-ionic environment. In an attempt to constrain the nature of the underlying source, we have undertaken X-ray observing campaigns with Chandra, XMM-Newton, and NuSTAR in coordination with radio observations of FRB 121102 to search for X-ray burst as well as persistent counterparts. I will present the results of these observations and discuss them in the context of the host environment of this FRB and of possible sources of fast radio bursts in general. I will conclude with a review of future prospects for high energy studies of FRBs using existing and future facilities.

E1.17-0032-18 SPECTRAL PROPERTIES OF BURSTS FROM FRB 121102: FIRST DETECTION AT 5-8 GHZ FROM BREAKTHROUGH LISTEN

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We report the first detections of the repeating Fast Radio Burst FRB 121102 above 5 GHz. Observations were performed using the 4-8 GHz receiver of the Robert C. Byrd Green Bank Telescope with the Breakthrough Listen digital backend. We detail spectral, temporal and polarization properties of 21 bursts detected over a period of 60 minutes. These observations comprise the highest burst density yet reported in the literature, with 18 bursts being detected in 30 minutes. A few bursts also clearly show temporal sub-structures with distinct spectral properties. Broad features occur in 1 - GHz wide subbands that typically differ between bursts within the total 4 to 8 GHz observation. Finer scale structure within these bursts are consistent with Galactic interstellar scintillation. The bursts exhibit nearly 100% linear polarization with a large average rotation measure of 93559pm101 rad m−2. We measure a constant polarization position angle in 14 of the brightest bursts. The average flux density for all bursts, 0.2pm0.1 Jy, is consistent with lower frequency (<3 GHz) measurements, suggesting a spectrally flat intrinsic emission or extrinsic transmission process.

E1.17-0033-18 WHERE NEXT FOR FRB SCIENCE?

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After the first decade of fast radio burst (FRB) science much has been achieved. Many astrophysical and cosmological applications of FRBs have been identified, progress is being made into identifying their progenitors, and discovery rates are accelerating. But where next for FRB science? A huge number of unknowns remain and the field is full of open questions. Here I will summarise the science questions that can be addressed by instruments such as ASKAP (imminently joined by CHIME) which has a large and growing haul of bright and/or nearby FRB detections. Separately I will consider the complementary work that can be done with a smaller crop of much higher redshift FRBs as can be detected by instruments such as Parkes (imminently joined by MeerKAT). I will finish by proposing several strategies for maximising the scientific output of FRB science in the next decade.

E1.17-0034-18 THE HERMES PROJECT (HIGH ENERGY RAPID MODULAR ENSEMBLE OF SATELLITES): PROBING SPACE-TIME QUANTUM FOAM AND HUNTING FOR GRAVITATIONAL WAVE ELECTROMAGNETIC COUNTERPART

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I discuss how several of the proposed models for space-time quantization predict an energy dependent speed for photons. Although the predicted discrepancies with the general speed of light are minuscule, I discuss how it is possible to detect this intriguing signature of space-time granularity with a new concept of modular observatory for photons in the energy band 10 keV

30 MeV. This observatory may consist of a swarm of micro/nano-satellites on low orbits. Sub-microsecond time resolution and wide energy band allows to probe tiny energy dependent delays, expected to be the signature of the granular structure of space-time in several of the proposed theories of Quantum Gravity. Moreover this kind of experiment allows to perform temporal triangulation of high signal to noise impulsive events with positional accuracies of few arcseconds, making an observatory like that a promising hunter for the elusive electromagnetic counterparts of Gravitational Waves.

E1.17-0035-18 HIGH RESOLUTION IMAGING X-RAY SPECTROSCOPY: THE X-IFU INSTRUMENT ON ATHENA

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The X-ray Integral Field Unit (X-IFU) on board the Advanced Telescope for High ENergy Astrophysics (Athena) is the second large mission of the ESA Cosmic Vision science program. X-IFU will provide spatially resolved high resolution spectroscopy from 0.2 to 12 keV with 5 arc second pixels over a field of view of 5 arc minute equivalent diameter and a spectral resolution of 2.5 eV up to 7 keV. We will present how the core scientific objectives of Athena drive the instrument performance requirements, the key system issues, and the instrument baseline design in view of the Instrument Preliminary Requirement Review planned end of 2018. A special emphasis will be put on the X-IFU spectroscopic capabilities in the context of the fast reaction time of the Target of Opportunity observation mode of Athena. The X-IFU will be provided by an international consortium led by France, The Netherlands and Italy, with ESA member state contributions from Belgium, Finland, Germany, Poland, Spain, Switzerland, with additional contributions from the United States and Japan.

E1.17-0036-18 SCIENTIFIC AND SYSTEM PERFORMANCE ANALYSIS OF THE ECLAIRS INSTRUMENT WITHIN THE SVOM MISSION

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SVOM is a French-Chinese space mission to be launched in 2021, which goal is to perform multi-wavelength analysis of transient events in the sky, among which Gamma-Ray Bursts, the most powerful stellar explosions in the Universe. SVOM aims to be the next Gamma-Ray Bursts multi wavelength space observatory.

The ECLAIRs space telescope is part of the French contribution on the SVOM mission. By detecting the very first lights (prompt emission) of the Gamma Ray Bursts in the [4 keV

150 keV] energy range, ECLAIRs will be the initiator of the follow-up (multivawelength observations) based on a complementary network of space and ground instruments.

The scientific performance of the ECLAIRs instrument and its design are deduced from the scientific objectives allocated to ECLAIRs within the SVOM mission. The architecture is based on a combination of 3 key solutions: the coded mask imaging associated with advanced imaging software, a compact ASIC-CdTe hybrid detector with low noise/low energy level threshold (4 keV) as well as high sensitivity and an onboard powerful processor along with its associated trigger algorithms for gamma ray bursts detection.

Each of ECLAIRs subsystems have therefore needed specific system performance analysis and simulators developments in order to reach optimized solutions allowing the ECLAIRs system to meet the expected scientific performances.

We present the performance system analysis at mission and instrument levels. We also detail the main scientific performance (sensitivity, localization accuracy, energy resolution .) of the ECLAIRs instrument together with the tools developed to validate these performances at system and subsystem levels.

E1.17-0037-18 THE GAMMA-RAY BURST TRIGGER ECLAIRS ON-BOARD SVOM

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The Space-based multi-band astronomical Variable Objects Monitor (SVOM) is a FrenchChinese satellite mission dedicated to Gamma-Ray Burst (GRB) studies. The project was adopted in 2017 and started its detailed definition (phase C), before construction and launch foreseen in late 2021. With its set of 4 on-board instruments observing the sky in the X-ray, gamma-ray and visible-band, as well as a set of dedicated prompt-observation and follow-up ground-based visible-band telescopes, SVOM will study GBRs in great details, including their temporal and spectral properties of the prompt and afterglow emission from visible to gammarays. The start of every GRB observation sequence is given by the coded-mask telescope ECLAIRs on-board SVOM. Its on-board electronics system equipped with a real-time GRBtriggering software, continuously analyzes the 2 sr-wide field-of-view of the telescope in the 4-120 keV energy range, repeatedly performing coded-mask deconvolutions in order to detect and localize the GRBs for SVOM. Thanks to its low-energy threshold, ECLAIRs is particularly sensitive to X-ray rich and redshifted GRBs, but care has to be taken to handle known sources and variable background on-board. After detection, ECLAIRs requests the spacecraft to slew autonomously, to perform GRB follow-up observations with the on-board narrow field-of-view telescopes MXT in X-rays and VT in the visible-band. SVOM also alerts the worldwide community of follow-up observers via a dedicated VHF network placed under the satellite track. This paper presents the status of the ECLAIRs on-board GRB-trigger system.

E1.17-0038-18 HXMT MISSION, HIGHLIGHTS AND RECENT RESULTS

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At 3:00 AM(GMT) on Jun 15, 2017 the China Space Agency launched space observation HXMT(Hard X ray Modulation Telescope,also nanme “Insight”),which is a first X ray space explorer of China. Telescope operated in a circular orbit of 550Km altitude and 43°inclination. HXMT will detect X ray from universe which possible erupted from black hole or pulsar(neutron star) between 1-250KeV with high sensitivity and angular resolution(batter than 1 arcmin.) ,besides this, HXMT is also with a powerful capability for receiving the gamma-ray burst, which its energy coverage of 200 keV - 3 MeV and the largest detection area. During the first three month in orbit, 26 GBR and X93 solar flare event were detected by HXMT. Several signals of neutron star were also received. This paper present an overview of HXMT project, including mission and highlights of technical design ,flight results from first 6 months of this mission.

E1.17-0039-18 POSTER PRESENTATIONS

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Short talks of poster presenters for the whole E1.17 event (max. 1 slide, 2minutes allowed for each poster)

E1.17-0040-18 THE EINSTEIN PROBE MISSION: A LOBSTER-EYE X-RAY MONITOR FOR EXPLORING THE TRANSIENT X-RAY SKY

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As an approved mission in the space science programme of the Chinese Academy of Sciences, the Einstein Probe (EP) is a small astronomical satellite to monitor the soft X-ray sky. EP will carry out systematic surveys of high-energy transients with unprecedented sensitivity, Grasp and monitoring cadence. Its wide-field (3600 sq. deg.) imaging capability is enabled by using lobster-eye MPO X-ray focusing optics. It also carries a Wolter-I X-ray telescope for deep follow-up observations of newly discovered transients. Transient alerts will be issued in nearly real time to trigger quick follow-up observations at multi-wavelengths. The scientific goals of EP are to discover and characterise the X-ray sources of new transient phenomena to be explored in the upcoming era of multi-wavelength and multi-messenger time-domain astrophysics. The mission is scheduled for launch by the end of 2022.

E1.17-0041-18 GRID FOR STUDENTS: A NETWORK TO MONITOR THE GAMMA-RAY SKY FOR MULTI-MESSENGER ASTRONOMY

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In the near future, ground based gravitational wave (GW) detectors will routinely detect neutron star mergers in the local universe. An all-sky monitor in the gamma-ray band is important to understand the gamma-ray bursts (GRBs) associated with the mergers and may help obtain a better localization accuracy needed for follow-ups at longer wavelengths. We propose to deploy at least 10 identical scintillation detectors, named the gamma-ray integrated detectors or GRID, distributed in low earth orbits using CubeSats to monitor the whole gamma-ray sky from 10 keV to 10 MeV. In combination with different techniques (interplanetary network and flux modulation), GRID is capable of localizing a GRB within 200 Mpc in synergy with GW detections (with a horizon of 200 Mpc around 2020) with an accuracy of around 1 degree for an on-axis event or about 10-15 degrees for a GRB170817A like event. GRID is a student project. As a platform to train students how to organize a large science project, it was proposed and developed mainly by undergraduate students, and will be operated by students in the future. The current GRID collaboration involves 12 institutes and keeps growing. New members from all over the world are welcome. Here we will introduce the science with GRID, the detectors, current progresses, and future perspectives.

E1.17-0042-18 PERFORMANCE OF THE CALET CALORIMETER FOR GEV ENERGY GAMMARAY OBSERVATIONS

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The CALorimetric Electron Telescope (CALET) has been successfully taking scientific data on the ISS since October 2015. We present the instrument performance for GeV gammaray observations based on high statistics EPICS/Cosmos simulations with the reconstruction algorithms used in the flight data analysis. A comparison of the Monte Carlo results with the first two years of flight data is made and the sensitivity of the CALET calorimeter to GeV energy gamma-ray sources is discussed.

E1.17-0043-18 GAMERA: A GAMMA-RAY TELESCOPE FOR THE GRAVITATIONAL WAVE ASTROPHYSICS ERA

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We describe GAMERA, a SmallSat concept for a single, large, broad-band (20 keV - 2 MeV), wide field-of-view (>2π sr) instrument that would serve as the prime γ-ray telescope for gravitational wave (GW) astrophysics in the Advanced/LIGO-Virgo era. GAMERA can be built today using components currently at TRL 6 or higher, thus can be quickly developed for an existing SmallSat-class spacecraft bus, assembled, tested, and launched by the time Advanced/ LIGOVirgo reach their design sensitivities in the ~2023+ timeframe.

The instrument consists of an array of scintillator detectors with effective area 5 times greater than Fermi GBM and more than half that of Compton BATSE. It will detect short GRBs (SGRBs) like the low-luminosity GRB170817A, coincident with the binary neutron star merger event GW170817, at 3x greater distances (120 Mpc). Moreover, with its excellent time resolution and large area, it will perform detailed spectral analyses of such bursts to characterize the prompt γ-ray emission component in detail. To enable joint GRB and sub-threshold GW signal searches seeded on the γ-ray detection, GAMERA will provide typical degree-scale localizations. This could potentially uncover GW emission signals beyond the nominal horizon distances achievable by the ground-based interferometers alone.

GAMERA will provide the most detailed GRB physics measurements achievable within the lowcost SmallSat envelope (<$35M). This includes detections, localizations, and spectral characterizations that will be markedly improved over currently deployed γ-ray monitors. In addition to forefront GRB physics, GAMERA will provide continuous monitoring of other types of γ-ray transients, addressing the physics of accreting pulsars, magnetars, and Galactic binary systems.

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E1.17-0044-18 HARD GAMMA GEV PHOTON SHOWERING ALONG TANGENTIAL AIR ATMOSPHERE SPACE TRACED BY THEIR SKIMMING SECONDARIES LOW ENERGY GAMMA X RAYS SHINING ON ORBIT SATELLITE

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Hard tens-GeV up to TeV gamma sources, as AGN active flare or SGR blazars, may airshower in high altitude terrestrial atmosphere leading to beamed and skimming secondaries photons at XMeV lower energy band. The terrestrial cilindrical envelope of such secondaries X-gamma flares may shine at Earth atmosphere horizons. Their terrestrial X-gamma flash of such skimming airshower may be revealed in GRB detector in orbit while crossing the correlated cilindrical blazing X-gamma cone. These relevant signatures, often tagged by the satellite Keplerian period, might, and possibly already had, been already observed.

E1.17-0045-18 A LOW ENERGY COMPTON IMAGER FOR GRB POLARIZATION STUDIES

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The Gamma Ray Polarimeter Experiment (GRAPE) is designed to investigate one of the most exotic phenomena in the universe - gamma-ray bursts (GRB). There has been intense observational and theoretical research in recent years, but research in this area has been largely focused on studies of time histories, spectra, and spatial distributions. Theoretical models show that a more complete understanding of the inner structure of GRBs, including the geometry and physical processes close to the central engine, requires the exploitation of gamma-ray polarimetry. Over the past several years, we have developed the GRAPE instrument to measure the polarization of gamma-rays from GRBs over the energy range of 50 to 500 keV. GRAPE is a large FoV instrument with a sensitive energy range covering the peak energy distribution of GRBs. The design is based on an array of independent modules, each of which consists of an array of (high-Z and low-Z) scintillator elements read out by a multi-anode PMT (MAPMT). Our eventual goal is to fly GRAPE on a long duration balloon (LDB) platform to collect data on a significant sample of GRBs. Our experience with two balloon flights (in 2011 and 2014), coupled with further design efforts focused on orbital payloads, has led to an improved polarimeter concept that represents a natural evolution of the current design. The new concept employs a large number of small (1 cm), optically-isolated scintillator cubes, each of which is read out by its own silicon photomultiplier (SiPM). These cubes are stacked in a three-dimensional arrangement that allows the determination of event interaction locations in three dimensions within the sensitive volume. The resulting three-dimensional location data provides a moderate level of Compton imaging capability (1 sigma angular resolution of 10-15°). Even this level of imaging can be used to significantly reduce the instrumental background by limiting the influence of the cosmic diffuse flux, resulting in an improved polarization sensitivity. Here we shall describe this concept and the expected performance for GRB polarization measurements. We will also describe our efforts to develop a working prototype, which is initially focused on the testing of various scintillators (both organic and inorganic) with SiPM readouts.

E1.17-0046-18 DETECTION CAPABILITY OF ULTRA-LONG GAMMA-RAY BURSTS WITH THE ECLAIRS TELESCOPE ABOARD THE SVOM MISSION UNDER DEVELOPMENT

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It has recently been pointed out that ultra-long gamma-ray bursts (ULGRBs), with very atypical durations of more than 1000 seconds, could form a new class of GRBs (Levan+13). ULGRBs could have a different progenitor than standard GRBs and be produced by the core collapse of a low metallicity supergiant blue star (Gendre+13) or the birth of a magnetar following the collapse of a massive star (Greiner+14). However ULGRBs could also just represent the tail of the standard long GRB distribution (Virgili+13). In any case, it is clear that the dura- tion of these bursts make them peculiar. To progress, the sample the few ULGRBs detected so far by the Swift Burst Alert Telescope and some other instruments has to be increased. SVOM (Space-based multi-band astronomical Variable Objects Monitor, Wei, Cordier+16) is a French-Chinese mission dedicated to GRBs and transient events, currently under development and scheduled for launch after 2020. SVOM will help understanding ULGRBs, since its orbit and pointing strategy will permit to image the same portion of the sky continuously during nearly one day with the onboard coded-mask telescope ECLAIRs. Thanks to the image trigger foreseen onboard (Schanne+15), we expect to increase the sample of ULGRBs with SVOM. In this paper we present methods developed to clean detector images from X-ray background and known X-ray source contributions in the onboard imaging process, and we show the capability of the image trigger to detect the currently available ULGRBs sample as well as a synthetic population of fainter and more distant ones.

E1.17-0047-18 ANALYSIS OF GRS 1915+105 IN THE 'HARD' PHASE: ACCRETION AND OUTFLOW IN THE TCAF PARADIGM

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The class variable source GRS 1915+105 is at variance with the transient sources in the sense that it exhibits peculiar time variabilities in the range of a few seconds to days. Depending on cts/s in different energy bands and the color-color diagram, the variability was first grouped into twelve classes and later, the χ class (where the variability is minimum) was classified into four sub-classes χ1, χ2, χ3, χ4. These classes were sequenced in ascending order based on the quantity Comptonization Efficiency (ratio of power-law photon and blackbody photon), and it shows that χ class is relatively harder with respect to other classes. The χ1,3 classes are associated with outflow. However, since all such exotic features ultimately should be associated with the variation of accretion rates with which TCAF solution is concerned of, it should treat all such apparently different classes in the same framework. This motivated us to study this object in the TCAF paradigm. The χ2,4 states are different only in the peak count, and could be fitted with different normalizations for the TCAF solution. It was shown by Rao et al. (2000) that the χ3 class data could be fitted using diskbb+CompST+Power-law model in the 3-190 keV energy range. Since the Compton cloud is self consistently addressed in the TCAF solution, here in the χ1,3 state, the spectra could be fitted using Cutoff power-law model associated with TCAF solution to take care of the outflow. The exponential roll-off factor agrees with the respective slopes in the spectra, and also TCAF+Cutoff power-law model upto high energy domain.

E1.17-0048-18 ANALYSIS OF FERMI GRB DURATIONS IN THE OBSERVED AND INTRINSIC REFERENCE FRAMES

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Gamma-ray bursts (GRBs) are usually classified into two populations, according to their durations, denoted by T90: long bursts (T90 > 2.0 s) and short bursts (T90 < 2.0 s). Recent work has suggested the existence of an intermediate population in the bursts observed by the Swift satellite (Bromberg et al. 2013, Zitouni et al. 2015, Horváth & Tóth 2016). Moreover, a number of researchers have questioned the universality of the 2.0-second dividing line between short and long bursts: some bursts may be short but actually result from collapsars, the physical mechanism behind normally long bursts.

In this work, we focus on GRBs detected by the Fermi satellite and study the distribution of their durations measured in the observer's reference frame and, to the extent possible, in the bursts' reference frames. However, bursts with measured redshifts are limited, and this makes a statistical study difficult. We thus proceed in two ways. First, following Zhang & Wang (2017), we determine pseudo-redshifts from the correlation relation between the luminosity Lp and the energy Ep both calculated at the peak of the flux. Interestingly, we find that the uncertainties over the quantities used in the determination of pseudo-redshifts affect the precision of the results significantly, although they remain within acceptable limits. We thus present the advantages and disadvantages of using these correlation relations as cosmological candles. Secondly, we compare the results obtained with the pseudo-redshifts with those obtained from a sample of 43 GRBs with actual redshifts given by Heussaff (2013).

A chi-square statistical test shows that the distribution of the durations of Fermi bursts, both observed and intrinsic, are composed of two peaks, not three, as we had found for the BATSE bursts. We propose an explanation for the presence of an intermediate class of bursts in the Swift data, based on a selection effect related to the Swift/BAT energy band.

E1.17-0049-18 TIDAL EFFECT ON ACCRETION FLOWS IN COMPACT BINARY SYSTEMS

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Black hole binary orbits are expected to have some eccentricity, albeit small. Stellar companion of a black hole orbiting in an eccentric orbit will experience modulating tidal force with a periodicity same as that of the orbital period which will result in a modulation of accretion rates, seed photon flux, and flux of inverse Comptonized harder photons as well. Timing analysis of long-term X-ray data (1.5 to 12 keV) of RXTE/ASM and all sky survey data (15 to 50 keV) of Swift/BAT satellites reveal aforesaid periodicity in several black hole candidates. If this modulation is assumed to be solely due to tidal effects (without taking other effects, such as eclipses, reflection from winds, super-hump phenomena etc. into account), the RMS-value of the peak in Fourier spectrum gives us a notion of eccentricities of these orbits as well as the sizes of the Keplerian disk in two important classes of black hole binary systems. We present these very interesting results. We show that our results generally agree with independent studies of these parameters. Unknown orbital period of a binary system may also be obtained by our simple method.

E1.17-0050-18 IMPLICATION OF ACCRETION GEOMETRY ON VARIABILITY PROPERTIES IN GALACTIC BLACK HOLE SOURCES

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The evolution of the low frequency quasi-periodic oscillations (LFQPOs) in outbursting black hole sources can be explained by the systematic variation of the Compton cloud size in propagatory oscillating shock (POS) solution. In this solution, each of observed QPO frequency implies the location of shock i.e., the size of the Comptonizing region and the frequency drifting implies the Geometrical variation of Comptonizing region, i.e., the steady radial movement of the shock front, which is triggered by the cooling of the post-shock region. As the shock moves in with increase in disk accretion rate, the density and optical depth also generally increases. We study the X-ray variability properties of a set of low and high inclination black hole source. We find the dependence of variability properties, such as time lag, and rms power with the inclination of the source and time lag becomes negative for high inclination source after a certain QPO frequency (i.e., particular size of Comptonizing region). We discuss the effects of accretion geometry on the variability properties.

E1.17-0051-18 FROM METEORS TO GRBS - DETECTION OF OPTICAL TRANSIENTS WITH MINI-MEGATORTORA

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We present the summary of some results obtained by a novel 9-channel wide-field optical monitoring system with sub-second temporal resolution named Mini-MegaTORTORA (MMT-9). This multi-element telescope can observe the sky in wide (900 square degrees) or narrow (100 square degrees) field of view with exposure time ranging from 0.1 to hundreds of seconds. Observations can be performed in white light or using arbitrary combination of the filters (Johnson-Cousins B, V and R). Observations in polarized light are also possible. The data analysis pipeline operates in real time and detects automatically rapid moving or motionless transient events. Faint meteors, satellites, variable stars, optical counterparts of X-ray sources and GRBs are routinely detected and investigated by MMT. We present statistical and physical parameters for some of them.

E1.17-0052-18 OBSERVATION OF COSMIC GAMMA RAY BURSTS IN LOMONOSOV SPACE MISSION

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GRB study is one of the main goals of the Lomonosov space mission launched on 28-04-2016 from Vostochny cosmodrome to solar synchronous orbit with 490 km altitude and 98o inclination. The mission payload includes the BDRG gamma-ray spectrometer designed for spectral measurements and timing in 10-3000 keV energy range as well as for GRB triggering. Two wide-field optical cameras SHOK are placed within fields of view of the gamma-monitor. This allows the simultaneous GRB observations in gammas and optics in all-time scale of event evolution including obtaining optical light curves of prompt emission as well as of precursors. About 20 GRBs were detected by BDRG/Lomonosov during observational period from 05.2016 to 01.2017, as well as several bursts from SGR and a number of solar flares. No triggered GRB sources appeared in the FOV of on-board optical cameras but the joint observations of BDRG/Lomonosov with MASTER net of robotic telescopes allowed one to compare optical and gamma-ray light curve of some of detected GRBs at different phases of their activity. A new space project of M.V. Lomonosov Moscow State University named Universat-SOCRAT will include advanced gamma-ray instrument for GRB triggering, wide-field optical cameras and a fast-pointing optical telescope with moving mirror. The set of instruments for monitoring of space radiation and for studying of atmospheric phenomena in the optical range will also be included. The proposed gamma-ray spectrometer will be based on the considerably simple wide field-of-view coded mask telescope with 300 pixel PSD allowing to check the presence of a point gamma-ray source on the sky and to obtain its coordinates with accuracy of 1-2 degrees so one can identify GRBs on the background of various reading increases mostly caused by the electron precipitation. Immediate transfer of the GRB notice to the ground global net will be realized.

E1.17-0053-18 OBSERVATIONS OF GAMMA-RAY BURSTS (GRB) AND GRAVITATIONAL WAVE ELECTROMAGNETIC COUNTERPARTS (GW EM) BY INSIGHT-HXMT

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The High Energy X-ray telescope (HE) onboard Insight-HXMT (Hard X-ray Modulation Telescope), which is the first Chinese X-ray space telescope launched on June 15, 2017, is primarily designed to observe the hard X-ray sky with a Field of View of 1x6 deg. An advanced capability was developed for HE is to use its anticoincidence detector CsI to monitor GRBs and observe the GW EM counterparts. Hence in the so-called GRB mode, HE turns out to be a unique all-sky monitor, characterized by an effective area over than 1000 cm^2, a moderate angular resolution of 10 deg, an excellent time resolution of microseconds, and a broad energy coverage of 0.2-5 MeV. So far, Insight-HXMT has observed dozens of GRBs, including a few that were firstly detected by HE with a short duration and a hard spectrum. During the observation of the first binary neutron star merger (GW170817), Insight-HXMT/HE monitored the entire GW localization area throughout the trigger time. Although Insight-HXMT did not detect any significant high energy (0.2-5 MeV) radiation from GW170817, its observation helped to confirm the unexpected weak and soft nature of GRB 170817A. Meanwhile, Insight-HXMT/HE provides one of the most stringent constraints (10-7 to 10-6 erg/cm^2/s) for both GRB170817A and any other possible precursor or extended emissions in 0.2-5 MeV, which help us to better understand the properties of EM radiation from this BNS merger.

RESEARCH IN ASTROPHYSICS FROM SPACE (E)

INFRARED ASTRONOMY: STAR FORMATION AND INTERSTELLAR PROCESSES OVER MANY SCALES (E1.18)

E1.18-0001-18 INTERSTELLAR FILAMENTS AND STAR FORMATION

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I will review recent progress in our observational understanding of the link between the structure of molecular clouds and the formation of solar-type stars. In particular, I will describe the filamentary paradigm favored by Herschel studies of the nearest molecular clouds of the Galaxy which point to the key role of the quasi-universal filamentary structure pervading the cold ISM. I will also discuss observational constraints on the formation and evolution of molecular filaments, coming from Planck polarization data and ground-based mm line studies. Overall, the available observations support a picture in which interstellar filaments and prestellar cores represent two fundamental steps in the star formation process: First, large-scale compression of interstellar material in supersonic MHD flows generates a cobweb of filaments in the ISM; second, the densest filaments fragment into prestellar cores (and subsequently protostars) by gravitational instability, while simultaneously growing in mass and complexity through accretion of background cloud material. I will end by emphasizing the need for high-resolution polarimetric imaging at far-infrared wavelengths to clarify the role of magnetic fields in the formation and evolution of star-forming filaments.

E1.18-0002-18 SOFIA OBSERVATIONS OF INTERMEDIATE LUMINOSITY PROTOSTARS IN ORION AND THEIR OUTFLOWS

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Observations of protostars probe the transition of interstellar matter into stars and shape our understanding of how infall, accretion and outflow determine the masses of stars, the properties of nascent planetary systems, and the rate and efficiency of star formation. While the protostellar luminosity function peaks around 1 solar luminosity, 10% of protostars have luminosities from 20-1000 solar luminosities. These intermediate luminosity protostars include precursors of intermediate mass stars as well lower mass protostars undergoing large accretion driven outbursts. Their study is important for understanding the origin of the IMF, the role of episodic accretion in low mass star formation, and the impact of feedback from protostars on the surrounding cloud. We present SOFIA observations made with FORCAST and GREAT of five intermediate mass protostars. These were identified in the Herschel Orion Protostar Survey (HOPS) using 2-870 micron SEDs from 2MASS, Spitzer, Hershel and APEX photometry. SOFIA/FORCAST 9-14 micron spectra are combined with the HOPS photometry of these sources to refine our measurements of their luminosities and envelope properties. SOFIA/GREAT observations trace the outflow from the most luminous of the protostars, HOPS 370 or OMC2 FIR3, in far-IR lines of CO and [OI]. By combining the line profiles from GREAT with line maps from PACS/Herschel, we find both far-IR emission from the jet launched by the protostar and from the gas swept up by the jet. By comparing the far-IR maps and line profiles with ground-based sub-mm data from the APEX telescope and centimeter wave continuum from the VLA, we build a detailed portrait of the mass flow in the outflow and its impact on the surrounding dense gas.

E1.18-0003-18 THE SERPENS SOUTH PROTOCLUSTER: THE POWER OF SOFIA/FORCAST IN STUDIES OF PROTOSTARS

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The Serpens South protocluster is among the youngest known cluster of protostars. Using SOFIA, we observed the core of this cluster with FORCAST, detecting more than two dozen protostars within a single field of view. Including observations from the Spitzer Space Telescope and the Herschel Space Observatory, infrared spectral energy distributions are constructed for cluster members and the content of the cluster illuminated. We demonstrate a technique to estimate, using only FORCAST observations, the internal luminosities of protostars reliable to within 30–40% for 67% of protostars and to within a factor of 2.3–2.6 for 99% of protostars, comparable to the reliability achieved with Spitzer and Herschel observations that probe a greater fraction of the emission. FORCAST is a powerful instrument for luminosity studies of protostars. Its dynamic range and greater angular resolution enable FORCAST to discover and characterize protostars that were either saturated or merged with other sources in previous surveys.

E1.18-0004-18 SOFIA/FORCAST OBSERVATIONS OF THE GALACTIC CENTER

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In this talk I will summarize and discuss the results from our SOFIA/FORCAST GTO program on mid-infrared (19 - 37 µm) imaging of our Galactic Center. Our observations revealed the detailed "clumpy" morphology of the circumnuclear ring, the warm dusty torus around Sgr A*, and implicate its transient nature. We also imaged the most recent confirmed event of massive star formation in the inner 10 parsecs of the Galactic center as well as the HII region around the young massive Quintuplet cluster. Lastly, I will discuss the synergies between SOFIA and JWST for investigating massive star formation and the interstellar medium.

E1.18-0005-18 THE FORMATION OF MASSIVE CLUSTERS FROM HIGH REDSHIFT TO THE PRESENT DAY UNIVERSE

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Massive stars lie at the center of the web of physical processes that has shaped the universe as we know it, governing the evolution of the interstellar medium of galaxies, producing a majority of the heavy elements, and thereby determining the evolution of galaxies. A significant fraction of all stars form in massive clusters, which will be observable throughout the visible universe with JWST. In this talk, I shall present first results of the formation of clusters of stars across cosmic time, both of moderate mass, such as the Orion Nebula Cluster (ONC), and of high mass, such as the super star clusters (SSC) seen in starburst galaxies, starting with high mass cluster formation in our present day universe. These simulations are carried out using newly developed advanced techniques in our radiation-magneto-hydrodynamic AMR code ORION, for radiative transfer with both ionizing and non-ionizing radiation that accurately handles both the direct radiation from stars and the diffuse infrared radiation field that builds up when direct radiation is reprocessed by dust grains. Our simulations include relevant feedback effects such as radiative heating, radiation pressure, photodissociation and photoionization, protostellar outflows, magnetic fields and turbulence. The challenge in simulating the formation of massive stars and massive clusters is to include all these feedback effects self-consistently as they occur collectively. I will first present our recent results on cluster formation on moderate scales over the dynamic range of 5pc down to 28 au for a period of 3.5x105 yr, including magnetic fields, turbulence and both radiative and outflow feedback from the protostars. At the end of the simulation, the star formation efficiency in the cluster is 4.3% and the star formation rate per free-fall time is εff =0.04, within the range of observed values. The total stellar mass increases as t2, whereas the number of protostars in the cluster increases as t1.5. We find that the density profile around most of the simulated protostars is ρ r–1.5. At the end of the simulation, the protostellar mass function approaches the Chabrier stellar initial mass function. We infer that the time to form a star of median mass 0.2 Msun in the cluster is about 1.4 × 105 yr from the median mass accretion rate. We find excellent agreement in our simulations with the protostellar luminosities observed in recent large cluster samples and a theoretical estimate, and we conclude that the classical protostellar luminosity problem is resolved. The multiplicity of the stellar systems in the cluster simulation agrees, to within a factor of 2, with observations of Class I young stellar objects; most of the simulated multiple systems are unbound. Bipolar protostellar outflows are launched using a subgrid model, and extend up to 1 pc from their host star. The mass-velocity relation of the simulated cluster outflows is consistent with both observation and theory. I shall then present our first results on massive cluster formation starting at scales 100 pc. and forming massive SSC clusters of 106 Msun using multiple zoom-in refinements with AMR and including all of the

above mentioned coupled physics. I shall discuss preliminary results of the properties of the massive SSC clusters and ONC type clusters that form. Key questions we are addressing include how effectively is radiation trapped within the cluster and how does stellar feedback affect the formation of Orion-scale clusters and SSC.

E1.18-0006-18 STAR FORMATION RATE CALIBRATIONS WITH INFRARED DATA OF YOUNG STAR-FORMING REGIONS IN NGC6946 AND M100: THE EFFECT OF METALLICITY AND IMF UPPER MASS CUTOFF

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By means of the state-of-the-art radiative transfer code GRASIL (GRAphites and SILicates) in which the recently updated database of PARSEC's (PAdova TRieste Stellar Evolutionary Code) evolutionary tracks of massive stars has been implemented, we predict the panchromatic spectral energy distribution (including halpha emission lines) of star forming regions in the nearby and well studied starburst galaxy NGC6946 and that of the normal star-forming galaxy M100.

We carry out a critical investigation of the effect of metallicity, IMF upper mass limit and star formation regime (star bursting versus normal star forming) on star formation rate (SFR) and dust attenuation properties of star forming galaxies. This allowed for the provision, from our best fit models, of a consistent set of SFR calibrations, that are explicitly dependent on metallicity and IMF upper mass limit and also on the age of the starburst, at wavelengths ranging from 3um to 1000um. We complement these with similar calibrations at radio wavelengths which do not suffer dust attenuation.

We show that the upper mass limit can be well constrained by combining information from the observed far infrared, 24um, 33 GHz and Halpha luminosities. Another interesting property derived from the fits is that, while in normal galaxies the attenuation in the lines is significantly higher than that in the nearby continuum, in individual star bursting regions they are similar, supporting the notion that this effect is due to an age selective extinction. Since in these conditions the Balmer decrement method may not be accurate, we provide relations to estimate the attenuation from the observed 24um or 33GHz fluxes. These relations can be useful for the analysis of young high redshift galaxies.

E1.18-0007-18 [CII] EMISSION FROM NGC 4258 WITH SOFIA/FIFI-LS

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NGC 4258 is a Seyfert 1.9 galaxy known to contain a warped inner (0.3 pc) rotating disk of water-vapor masers which allowed for the first high accuracy measurements of the mass of a supermassive black hole in any galaxy. A relativistic jet is thought to be responsible for anomalous radio-continuum spiral arms, which appear several kpc from the center, and extend outwards through the outer disk. These arms do not correlate with the galaxy's underlying stellar spiral structure, and their presence suggest that in the past, the jet has strongly interacted with the galaxy's outer disk, exciting synchrotron radiation. Since that time, a new burst of activity seems to have occurred, creating a compact (VLBI) jet at the core of the galaxy, and two radio hotspots further out associated with optical "bow-shocks". The position angle of this new "active" jet is different from that needed to excited the outer radio arms, presumably because the jet has precessed, perhaps as a result of precession of the axis of the inner warped accretion disk.

We used the FIFI-LS integral-field spectrometer onboard the Stratospheric Observatory for Infrared Astronomy (SOFIA) to explore, for the first time, the distribution and large-scale kinematics of diffuse gas emitting in the [CII]157.7μm fine-structure line along the length of the "active" jet. Our observations reveal three main condensations of [CII] emission: two associated with large regions of gas at the ends of the active jet, and a third minor axis filament associated with linear clumps of star formation and dust seen in HST images offset from the nucleus. We combine the SOFIA observations with previous Spitzer mid-IR, Chandra X-ray and VLA radio observations to explore the nature of the detected [CII] emission. In regions along the northern active jet, we see a significant deficiency in the [CII]/FIR ratio, and higher ratios near the ends of the jet. this implies that the jet has changed the conditions of the gas along its length. In several places near the jet, the [CII] emission shows very broad lines, suggestive of enhanced turbulence. Additionally, the minor-axis filament we discovered may represent gas in-falling towards the nucleus perpendicular to the jet. The results provide clues about how radio jets in active galaxies can influence the star formation properties of their host galaxies.

E1.18-0008-18 UNRAVELING THE EVOLUTION OF THE INTERSTELLAR MEDIUM AND STAR FORMATION IN THE M51 GRAND-DESING SPIRAL GALAXY WITH SOFIA.

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We present results on a joint impact project to map the entire extent of the M51 grand-design spiral galaxy in the [CII] 158um line with the upGREAT and FIFI-LS instruments on SOFIA. Spiral density waves play a fundamental role in the conversion of atomic gas to molecular gas, which is followed by gravitational contraction leading to star formation. Understanding the impact of spiral density waves on the life cycle of the interstellar medium (ISM) and on star formation is a critical step for understanding galaxy evolution, and requires having a complete picture of all constituents of the ISM in galaxies. The [CII] 158m line is an important tool to diagnose the physical state of the ISM as it can reveal the distribution of the gas that is in the transition between atomic and molecular phases, including the CO–dark H2 gas (hydrogen is molecular, but carbon is not, resulting in this gas being traced neither by CO nor by HI. In this talk we present preliminary results on the distribution of [CII] across M51 and on the relationship between the different constituents of the ISM traced by FUV, Halpha, CO, HI, and [CII] emission both spatially and spectrally in the arms and interarm regions of M51.

E1.18-0009-18 HERSCHEL AND SOFIA SYNERGIES

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The very successful Herschel space mission observed in the important wavelength range between about 60 and 600 microns, most of which is completely inaccessible from the ground. After its conclusion and with no similar major space observatory becoming available in the near future, the Stratospheric Observatory for Infrared Astronomy, SOFIA, is the one facility that can still provide the astronomical community on a regular basis with new observations in the large spectral gap left betweeen JWST and ALMA. In addition, SOFIA allows for instrument augmentations, as new state-of-the-art photometric, spectrometric, and polarimetric capabilities have been added and are being further improved. The fact that SOFIA provides ample mass, power, computing capabilities as well as 4K cooling, eases the constraints on future instrument design, technical readiness, and the instrument build to an extent not possible for space-borne missions. We will review and compare the existing legacy data from Herschel with the growing instrumental capabilities of SOFIA and highlight specific science areas where the stratospheric observatory will be able to significantly advance Origins science topics.

E1.18-0010-18 THE C+ UNIVERSE

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The interstellar medium (ISM) is central to galaxy evolution over cosmic time. Interstellar gas is known to exist as atomic (HI) clouds and star forming molecular clouds. Recent observations have revealed that half of interstellar gas is in so-called CO-dark molecular gas (hydrogen is H2 but carbon is C+). Atomic and CO-dark gas have so-far eluded detailed characterization because of lack of suitable tracer and the physical conditions of these components and their relationship to the molecular reservoir are largely unknown and their role in galactic ecology is wide open.

The combination of sensitive THz heterodyne receiver arrays with a nimble telescope on SOFIA enables large scale, [CII] 158m surveys of regions of massive star formation. This line is the main cooling line of the diffuse ISM and therefore a key diagnostic of interstellar gas energy balance. In addition, the high spectral resolution inherent to heterodyne techniques allows us to study in detail the kinematics of photodissociation regions, which separate ionized from molecular gas. I will present the first results of the [CII] 158m square degree Orion Survey, its analysis and implications for large scale [CII] 158m emission from galaxies.

E1.18-0011-18 SOFIA FAR-INFRARED FIFI-LS OBSERVATIONS OF CO-RICH KNOTS IN THE SUPERNOVA REMNANT CAS A

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Supernovae are key drivers of the evolution of the interstellar medium of galaxies as they are main sources of heavy elements and kinetic energy. Dense, fast-moving ejecta knots in supernova remnants (SNRs) are prime sites for molecule and dust formation. Whether dust is survived from the reverse shock is one of the unsolved fundamental problems in understanding dust evolution and a large amount of dust detected in high-redshift galaxies.

We present SOFIA far-IR spectrometer FIFI-LS observations of CO-rich knots in Cas A in the [OIII] 52 and 88 microns and [OI] 63 micron lines. The observations covered 1 arcmin area. The FIFI-LS spectra show the line widths of [OIII] and [OI] similar to those of the Herschel PACS [OIII] and CO lines. We find that [OIII] maps show very different structure from the [OI] map. The [OIII] maps show diffuse, large-scale structures and the ratio of the two [OIII] lines implies a range of density 100 - 10,000 per cm3. In contrast, the [OI] map shows bright emission from dense CO-rich knots. We will discuss characteristics and evolution of the dense knots, the implication of [OI] cooling, reformation of CO molecules, and to the dust in the early

Universe.

E1.18-0012-18 SHOCKED AND SCORCHED: A GREAT INVESTIGATION OF [CII] AND [OI] EMISSION FROMFREE-FLOATING EVAPORATING GAS GLOBULES IN MASSIVE STAR FORMATION REGIONS

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We present first results from a GREAT program to study the atomic component of select members of a new class of tadpole-shaped free-floating evaporating gas globules (frEGGs) in massive star-formation regions. Since discovering the most prominent member of this class in an HST imaging survey, we have now identified substantial populations of such objects in several massive star-forming regions using Spitzer IRAC 8 micron images. By virtue of their distinct, isolated morphologies, frEGGs are ideal astrophysical laboratories for probing star formation in irradiated environments. Our molecular-line observations (e.g., CO, 13CO J=2-1 HCO+ J=3-2) reveal the presence of dense molecular cores associated with these objects, with total masses of cool (50 K) molecular gas exceeding 0.5-5 Msun, and our radio continuum imaging of a few reveals bright photo-ionized peripheries in these objects. Our GREAT study of 3 frEGGs has allowed us to detect the warm (few x 100 K) atomic gas that is expected to exist in a photon-dominated region surrounding the molecular gas and determine its mass, and probe the photoevaporative flow that is expected to drive the evolution of these objects. Our SOFIA data (together with existing multiwavelength data), when compared with results from sophisticated 3-D numerical simulations, will provide a unique window into the dynamical and chemical evolution of these irradiated dense gaseous globules, and the star-formation process within them.

E1.18-0013-18 MID-INFRARED MAPPING OF THE GALACTIC CENTER REGION

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The center of the Milky Way is the closet laboratory for studying nuclear stellar clusters, star formation under extreme conditions, and the immediate surroundings of a supermassive black hole. This Galactic Centre (GC) harbors three massive clusters that allow studying cluster-based star formation history over the past 8 Myr. I will present our recent mid-infrared observations of the GC region obtained in 2010 and 2016 with the ground-based instrument VISIR on the ESO Very Large Telescope. The high-resolution multi-epoch N -band data cover a large field of view of selected regions within the central tens of parsecs of the Galaxy. Photometric and astrometric analysis of mosaics of the nuclear star cluster, the Quintuplet cluster, and regions in the Arched Filaments and the Sickle provide a census of faint compact (disk candidates, YSO's, and bow shocks) and diffuse emission sources in the mid-infrared. Their spatial distribution and concentration is studied and combined with existing multi-wavelength surveys in the infrared and the X-rays. The Galactic Center is one of the targets planned to be observed with the MIRI instrument GTO time aboard the James Webb Space Telescope (JWST). This data is hence of importance in the preparation and interpretation of the upcoming MIRI observations.

E1.18-0014-18 POSTER HIGHLIGHTS SESSION

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Poster contributors will have an opportunity to present their posters as a short talk in one or two minutes. Please prepare for one slide of the summary of your poster and provide to the event organizer and your session chair.

E1.18-0015-18 SOFIA/HAWC+ FAR-INFRARED STUDIES OF MAGNETIC FIELDS AND PROSPECTS FOR SPACE

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The HAWC+ instrument, designed for far-infrared (Λ = 50-220 μm) imaging and linear polarimetry with SOFIA, was commissioned in 2016 and has begun science observations. Many of the ongoing and upcoming observations, in support of the community through the SOFIA Guest Observer process and also by the HAWC+ Guaranteed Time science team, are utilizing the alignment of interstellar dust grains to make maps of magnetic fields in nearby molecular clouds, the Galactic center, and infrared-bright galaxies. We show a sample of the first maps obtained with HAWC+, review the physical effects that are being studied, and discuss the capabilities and limitations for HAWC+ as an airborne instrument. We use the results from HAWC+ to predict potential outcomes from far-IR polarimetry from space with mission concepts such as the Origins Space Telescope.

E1.18-0016-18 FIR OBSERVATION OF THE POLARIZED DUST EMISSION IN GALAXIES WITH PILOT

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Understanding the role played by the magnetic Field in shaping ISM structures and ultimately forming new stars in galaxies is one of the next observational challenges of modern astronomy. In particular, sounding regions where stars actually form requires using dust polarization measurements, which are difficult to obtain. I will discuss this in the context of the recent Planck all-sky map of the polarized dust emission. I will also present preliminary results of the PILOT balloon-borne instrument regarding the magnetic field structure and dust properties in regions of the galactic plane and possibly the nearby Large Magellanic Cloud. These regions were observed recently in polarization of the Far-IR emission of dust grains, during the second flight of the PILOT instrument that took place from Alice Springs, Australia, in April 2017.

E1.18-0017-18 FUTURE STUDIES IN STAR AND PLANET FORMATION WITH HAWC+, GREAT AND HIRMES

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Star formation, the most fundamental process in the universe, is linked to planet formation and thus to the origin and evolution of life. We have a general outline of how planets and stars form, yet unraveling the details of the physics and chemistry continues to challenge us. The infrared and submillimeter part of the spectrum hold the most promise for studying the beginnings of star formation. The observational landscape recently shaped by Spitzer, Herschel and ALMA, continues to challenge our current theories. SOFIA, the Stratospheric Observatory for Infrared Astronomy, equipped with state-of-the-art infrared instrumentation to a vantage point up to 45,000 feet (13.7 km) flight altitude that is above 99.9% of the Earth's water vapor, enables observations in the infrared through Terahertz frequencies not possible from the ground. Examples of future SOFIA science frontiers include: (1) Establishing the role of magnetic fields on sub-parsec scales in giant molecular clouds, and in filamentary star formation regions within, with 50-200 micron polarimetry, when combined with VLT/GTC, Planck, ALMA, and Herschel data, will provide a huge leap in our understanding of the role of magnetic fields on various size scales in our Galaxy. (2) Velocity resolved imaging spectroscopic surveys of massive star formation cloud complexes in the Milky Way in ionized carbon at 158 micron and other FIR emission lines to revolutionize our understanding of the role of environment and feedback in star formation and its link to galaxy evolution. (3) Studies of the fundamental ground-state transition of 112 micron

HD and water (vapor and ice) in a survey of several protoplanetary disks to measure the mass of planet-forming matter in the Galaxy and push the planet-formation field forward.

E1.18-0018-18 CHEMISTRY IN PROTOSTELLAR REGIONS: NEW IMPLICATIONS FOR JWST MIRI/ NIRSPEC

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Observation of CO2 in exoplanet atmospheres is one of the major science themes for James Webb Space Telescope (JWST). CO2 cannot be observed in the gas phase through rotational transitions in the far-infrared or submillimeter range due to its lack of permanent dipole moment. It has to be observed through its vibrational transitions at nearand mid-infrared wavelengths. We will show how observation of protonated form of CO2 in a solar-type protostar help us to better understand the overall temperature structure, ionization structure, H2O and CO2 snow lines, and overall C/O ratio. Implications of our study to the chemistry of CO2 ices using JWST-MIRI and NIRSpec will be discussed as well.

E1.18-0019-18 THE ORIGINS SPACE TELESCOPE (OST)

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Presented on behalf of the OST study team, with engineering support at Goddard Space Flight Center.

The Origins Space Telescope (OST) one of the four science and technology definition stud- ies supported by NASA Headquarters to prepare for the 2020 Astronomy and Astrophysics Decadal Survey. OST will operate in the midand far-infrared where galaxies emit most of their energy; it offers massive sensitivity gains in this relatively unexplored regime with a large, actively-cooled telescope and background-limited far-IR detector arrays. OST will provide a complete picture of star formation, black hole growth, and interstellar processes across the arc of cosmic history; from the first proto-galaxies and emergence of heavy elements in the dark ages, through the peak of star-formation activity, to the present-day conditions in deeply-obscured regions of the Milky Way and nearby galaxies. The formation of habitable worlds is a key OST theme, and the observatory is designed to chart the trail of water from the interstellar medium through protoplanetary disks to planetary systems, including water transport in our own solar system. A particularly unique OST capability is the identification of life-bearing worlds through a dedicated mid-IR exoplanet transit spectroscopy channel targeting co-existence of methane and ozone: a combination indicating life. We will present the science drivers and broad capabilities of OST, and describe our Concept 2, a 5.9 m telescope cooled to 4 K with an integrated passive (sunshade) and active (cryocooler) systems. Concept 2 is designed to have minimal deployments to mitigate risk and reduce integration costs, while still fitting into a 7m fairing. OST instruments include the Origins Survey Spectrometer (OSS) a backgroundlimited wideband R=300 spectrometer covering 28 to 600 microns with high-resolution modes providing R up to 105, a Mid-Infrared Imager, Spectrometer and Coronagraph (MISC) offering imaging and spectroscopy from 5 to 28 microns and the dedicated exoplanet spectrograph, a Far-Infrared Imaging Polarimeter (FIP) providing broad-band imaging polarimetry from 40 to 240 microns, and possibly a HEterodyne Receiver for OST (HERO), providing R 106–107 for kinematic studies of water and other key species in disks and the interstellar medium.

E1.18-0020-18 STAR FORMATION IN THE GALACTIC CENTER: FORCAST OBSERVATIONS OF SGR B1

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The proximity of the center of our Galaxy enables us to study star formation under conditions commonly found in other galaxies, but at spatial resolutions unachievable elsewhere. The Galactic Center (GC) provides unparalleled opportunities to test theories of the interrelationship of massive stars, warm and hot gas and dust, turbulent giant molecular clouds, large-scale magnetic fields, and a black hole. The region known as Sagittarius B is one of the most complex star-forming regions in the galaxy, containing a massive molecular cloud, dozen of HII regions, and numerous young stellar objects (YSOs). It is composed of two distinct regions (Sgr B1 and Sgr B2). Although much of Sgr B is unobservable at IR wavelengths due to extinction, Sgr B1 has lower extinction. We will present data of Sgr B1 taken with the Faint Object InfraRed Camera for the SOFIA Telescope (FORCAST) at 19, 31, and 37 microns. We will present colortemperature maps of the region, which enable us to explore variations in the dust temperatures throughout the region and any relations to the known massive stars and massive YSOs in the region. We will also combine the newly obtained data with archival data to create spectral energy distributions (SEDs) for compact sources throughout the region, to better understand the type, temperature and extinction for these sources. These results will enable us to address the complex issue of the relationship of Sgr B1, Sgr B2, and proposed sequential star formation occurring as the giant molecular clouds in the Central Molecular Zone (CMZ) orbit the black hole Sgr A*.

E1.18-0021-18 STRIATIONS IN MOLECULAR CLOUDS: “HEARING” THE 3D SHAPE OF MUSCA

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Dust continuum and molecular observations of the low column density parts of molecular clouds have revealed the presence of elongated structures which appear to be well aligned with the magnetic field. These so-called striations are remarkably ordered structures in otherwise chaotic-looking clouds, so understanding their physical origin and the information they encode is expected to be revealing of the properties of their parent clouds. We probe possible mechanisms of striation formation through a series of ideal magnetohydrodynamic simulations. We demonstrate that magnetosonic waves, ubiquitous in molecuar clouds, are the most probable cause of striations, since they are the only mechanism that can reproduce quantitatively their observed properties. If indeed striations are the interstellar ripples caused by the passage of magnetosonic waves, then profound consequences are implied for their ability to reveal hidden, important information about molecular clouds. I will present a specific example: striations in the Musca molecular cloud are found to encode normal modes of the cloud’s global magnetosonic vibrations, allowing the reconstruction of it’s 3D shape.

E1.18-0022-18 NISS: NEAR-INFRARED IMAGING SPECTROMETRIC SURVEY MISSION

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The NISS (Near-infrared Imaging Spectrometer for Star formation history) have been developed by KASI as one of the scientific payloads onboard the first small satellite of NEXTSat program (NEXTSat-1) in Korea. The both imaging (spatial resolution of 15”) and low spectral resolution spectroscopy (R 20) in the wide near-infrared range from 0.95 to 2.5μm is a unique capability of the NISS for the study of star formation in local and distant Universe. It will perform the near-infrared imaging spectroscopic survey for scientific targets such as nearby galaxies, galaxy clusters, star-forming regions and low background regions. The NISS will be launched in 2018 and operated to make the spectrophotometric survey covering up to an area of 200 square degrees during around 2 years.

E1.18-0023-18 THE BALLOON EXPERIMENTAL TWIN TELESCOPE FOR INFRARED INTERFEROMETRY (BETTII): A BALLOON-BORNE INTERFEROMETER FOR EXPLORING THE FORMATION OF STARS

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The Balloon Experimental Twin Telescope for Infrared Interferometry (BETTII) is an 8-meter far-infrared interferometer designed to provide spatially-resolved spectroscopy in the 30-100 micron regime. The high angular resolution provided by BETTII, as well as the spectral coverage, complements both ground-based and space-based observations with unique FIR data that is critical for understanding the intrinsic luminosity of individual protostellar cores. BETTII had a successful engineering flight in 2017, but at the end of the flight an anomaly resulted in the loss of the payload. The team is currently working to rebuild the payload for a 2020 recommissioning flight, to be followed by science flights in 2021 and 2022 focused on nearby star formation regions.

E1.18-0024-18 THE MID-INFRARED IMAGER/ SPECTROMETER/CORONAGRAPH INSTRUMENT (MISC) FOR THE CONCEPT 2 ORIGINS SPACE TELESCOPE

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The Origins Space Telescope (OST) is one of four potential future flagship missions that have been funded by NASA for study for consideration in the upcoming Astrophysics Decadal Review to be conducted in 2020. The OST Concept 2 telescope will be 5.9 meters in diameter, cooled to 4K, and the mission will be optimized for efficient mid and far-infrared astronomical observations. An initial suite of four focal plane instruments are being baselined for the Concept 2 observatory. The MISC instrument will observe at the shortest wavelengths of any of these instruments, ranging from 5 to 28 microns, and consists of two separate optical modules providing imaging, spectroscopy, and (potentially) coronagraph capabilities. The first module covers a 4.5' x 4.5' field with filters and grisms from 5-28 microns. We are also studying the feasibility of adding a coronagraph optical path in this module that would cover 6-28 microns in five broad bands. In addition to the imager module there is a separate densified pupil spectrometer module that would be used for R 100-300 exoplanet transit and emission spectroscopy from 6-26 microns with very high spectro-photometric stability. As the shortest wavelength focal plane imager the MISC instrument will also be used for focal plane guiding as needed for the other OST science instruments.

E1.18-0025-18 MEASURING STAR FORMATION, BLACK HOLE GROWTH AND GALACTIC FEEDBACK WITH THE ORIGINS SPACE TELESCOPE

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Since a significant fraction of star formation and black hole growth occurs behind dust, our understanding of how and why galaxies evolve will remain incomplete until deep, wide area spectroscopic surveys in the Far-Infrared can be carried out from space. The Origins Space Telescope (OST), a mission concept being studied for presentation to the 2020 Decadal Survey, represents an enormous leap over any existing infrared mission, and will uniquely measure black hole growth and star formation in dusty galaxies over more than 95% of cosmic history, generating a 3D map of the extragalactic, infrared sky. With wide wavelength coverage (5-600 microns), a large primary mirror actively cooled to 4K, and a capable suite of imagers and spectrometers, OST will be an extremely sensitive probe of the power sources in galaxies, and the effects of feedback on the multi-phase ISM, through measurement of key tracers such as OH and H2O lines, atomic fine structure emission lines, and PAH dust features. Energetic feedback from AGN, young stars, and supernovae can regulate galaxy growth over a wide range in mass and be important for the enrichment of the interstellar and circumgalactic medium, yet the existence and type of feedback as a function of redshift, luminosity, and environment is poorly constrained. With OST we can directly observe the role of feedback in quenching galaxies, derive the wind kinetic energy and mass outflow rates, and correlate these with key galaxy properties (AGN or starburst power, environment, mass, age). We will explain how blind and targeted surveys with OST will have an enormous impact on our understanding of the duty cycle and basic physical properties of feedback in AGN and starburst galaxies over the last 12 Gyr of cosmic time.

E1.18-0026-18 INFRARED VIEW ON THE HOT MOLECULAR CORES IN THE M17-SW PDR

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We present the results of an extensive infrared study of the hot molecular cores in the massive star-forming region M17-SW PDR. The data cover information in the wavelength rage from 2 to 850 μm, kinematic motions of water masers obtained from the VERA parallax measurements, and the X-ray images from Chandra space telescope. From the VLT/JHKL multiband images, we identify two infrared counterparts of the two hot molecular cores, which are physically associated with water maser emissions. These two infrared counterparts are also associated with two Chandra/X-ray point sources within 1" radius. The compiled spectral energy distribution of the two infrared counterparts cover broad-band data in the K, L, Spitzer/IRAC1-4 bands. The infrared fluxes and the X-ray properties are favor of two high-mass protostars embedded in the two hot molecular cores. One infrared counterpart is found to be the driver source of a dozens of water maser spots, which show kinematic motions in expansion phase. From the kinematic motions of these water maser spots, we estimate the momentum rate of the flow as 3.7 × 10−4M0yr−1, which is comparable to that of outflow driven by massive protostars.

E1.18-0027-18 PDR ANALYSIS WITH FAR-INFRARED DIAGNOSTIC LINES IN M17-SW

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Photo-dissociation regions (PDRs) are the places where molecular clouds are destroyed by UV radiation of forming massive stars (eg. Hollenbach Tielens 1999). The molecular gas is photodissociated and then ionized by UV radiation. Photo-electric heating heats the gas in the PDRs. Cooling happens through the dust continuum and a handful of far infrared (FIR) fine-structure lines. FIFI-LS (Colditz et al. 2012), the FIR spectrometer onboard the US-German airborne observatory, SOFIA, can map these main cooling lines efficiently.

To study the heating, cooling, physical conditions and destruction rates, we observed the wellstudied edge-on PDR, M17-SW with high spatial resolution in all major FIR cooling lines of the ionized and neutral medium. In this presentation, we discuss the fine-structure line and continuum maps observed by SOFIA/FIFI-LS showing the layering in this edge-on PDR. The data allows us to infer physical conditions and the energetics of the interface regions. The continuum maps together with literature data allow us to construct complete spectral energy distributions of the PDR material and the sources embedded in the PDR.

The dataset presented here and its initial analysis is a comprehensive FIR view of the PDR M17-SW from the dense cloud into the ionized region at thempeak of the SED. It is a dataset to study the feedback of young massive stars on their parental cloud as it shows the ionization and dissociation front eroding the molecular cloud.

References: - Colditz, Fumi et al., 2012, Proc. SPIE 8446, 844617 - Hollenbach Tielens, 1999, Rev. of Mod. Phy., 71, 173

E1.18-0029-18 A COMPLETE QUANTIFICATION OF PHOTON-INDUCED DESORPTION PROCESSES: MORPHOLOGY EFFECT ON CO2 ICE

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According to literature, different deposition temperatures of CO2 ice lead to distinct structures of CO2, which possesses an amorphous structure below 35 K and a crystalline structure at temperatures higher than 35 K. In Öberg et al. 2009, the photodesorption yield of CO2 ice depends on its morphology. For the purpose of investigating the relationship between the photodesorption yield of CO2 ice and its morphology, the CO2 ice was deposited at 16, 30, 40, 50, and 60 K respectively, and all of these ices were irradiated with vacuum ultraviolet (VUV) photons at 16 K. In this work, we will introduce a novel method to quantify the photodesorption yield of CO2 ices by a calibrated quadrupole mass spectrometer (QMS). The experimental results show that the photodesorption yields of CO2 ices deposited at different temperatures mentioned above are almost the same, meaning that the photodesorption yield of CO2 ice is irrelevant to its morphology, which is inconsistent with what was reported in Öberg et al. 2009.

E1.18-0030-18 LAB AND ON-ORBIT CALIBRATION FOR THE KOREAN NEAR-INFRARED SPACE TELESCOPES

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Korea Astronomy and Space Science Institute (KASI) so far have developed two near-infrared space telescopes for astronomical studies. MIRIS (Multi-purpose InfraRed Imaging System), launched in 2013 November, had observed pole regions for near-IR background studies and the Galactic Paschen-alpha emission by 2015 May. NISS (Near-infrared Imaging Spectroscopy for Star forming history) will be launched soon and perform imaging spectroscopic observations for one year. As the name says, NISS is designed to survey extragalactic and Galactic objects to study star forming process over various scales. We calibrated the instruments and developed the data reduction pipelines based on the analysis of the ground lab experiment and the onorbit observation data. This contribution will report the efforts for calibration of the Korean near-IR astronomical space telescopes.

E1.18-0031-18 THEORETICAL AND OBSERVATIONAL STUDY OF PAHS UP TO TEN RING HEXAGONS

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The present study reports the theoretical infrared and optical absorption spectra of neutral hexagons. The one to ten membered hexagons have considered for the study. These hexagons have isomers based on the structural arrangements. The cata, peri-condensed and branched structures of these hexagons have considered for the study. The five member benzene ring has 22 isomers viz 02 branched, 10 peri and 10 cata-condensed structures. All these structures are optimized at B3LYP/TZVP level of theory to confirm lowest energy structure. The closed peri-condensed structure is the lowest energy isomer for five membered hexagons. This type of structures for one to ten membered hexagons have considered for the study. The significant change has been observed in their vibrational and electronic absorption spectra of ions. The geometrical parameters such as dipole moment, symmetry and energies for these isomers are reported. We have also reported the optical spectra of for one to ten membered hexagons using TD-DFT approach at the same level of theory. The electronic transition, oscillator strength, and HOMO-LUMO gap also reported. The present study also is to understand emission features of the 217 nm (2200) astronomical UV bump. We have compared this theoretical study with the available observational data.

E2.1-0001-18 UNDERSTANDING FORMATION AND STRUCTURE OF SOLAR PROMINENCES VIA MULTIDIMENSIONAL SIMULATIONS

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Solar prominences are one of the most common activities in the corona. The formation of magnetic and plasma structures of prominences is far from fully understood. Observations and theoretical studies suggest that typical prominences are hosted in helical magnetic flux ropes. With the aid of multidimensional magnetohydrodynamic (MHD) simulations, we provide numerical models to explain the formation of flux ropes driven by photospheric motion and magnetic reconnection at footpoints of sheared magnetic loops. The physical mechanism responsible for prominence plasma formation is believed to be thermal instability, which may be triggered by thermal nonequilibrium process with strong heating and chromospheric evaporation near footpoints of magnetic loops or by compression resulted from the topological change of magnetic field via coronal reconnection. Both scenarios are presented by multidimensional MHD simulations. The observed ubiquitous dense downflows and light upflows in quiescent prominences are difficult to interpret as plasma with high conductivity seems to move across horizontal magnetic field lines. Multidimensional MHD simulations on a local portion of prominence with parallel field lines, suggest magnetic Rayleigh-Taylor instability is responsible for the phenomenon. Our full prominence model, as a result of in-situ plasma condensations in a magnetic flux rope driven by continuous plasma evaporation from chromosphere, reproduced a fragmented, highly dynamic state with continuous reappearance of multiple blobs and thread structures that move mainly downward dragging along mass-loaded field lines, which may explain the dense downflows of quiescent prominences. With steady footpoint heating, the modeled prominence established a dynamic balance between the drainage of the prominence plasma back to the chromosphere and the formation of prominence plasma via continuous condensation.

E2.1-0002-18 FORMATION AND ERUPTION OF CORONAL FLUX ROPES

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Solar corona is frequently disrupted by coronal mass ejections (CMEs), whose core structure is believed to be a flux rope made of helical magnetic field. Although its presence after solar eruptions has been verified by spacecraft measurements near Earth, its formation process on the Sun remains elusive, yet is critical to understanding the physics of solar eruptions as well as a broad spectrum of heliospherical and astrophysical phenomena. Here we present the observations of dynamic formation and subsequent eruption of coronal flux ropes. The formation process can be either directly observed above the limb in the high corona or derived from the imprint on the surface. Based on these observations, we propose a new mechanism, in which the flux rope originates from the coalescences of plasmoids that are ubiquitously present in current layers. The buoyant rising of this seed flux rope induces plasma inflow underneath to drive magnetic reconnection, which establishes a positive feedback through which the seed flux rope grows into a CME.

E2.1-0003-18 CAN 3D WHOLE-PROMINENCE FINE STRUCTURE MODELS BE USED FOR ASSESSMENT OF THE PROMINENCE PLASMA MASS AND DISTRIBUTION PRIOR TO THE ONSET OF CMES?

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Two complex 3D models of entire prominences including their numerous fine structures were recently developed. The first 3D Whole-Prominence Fine Structure (WPFS) model was developed by Gunár and Mackay. The second 3D WPFS model was put forward by Gunár, Aulanier, Dudík, Heinzel, and Schmieder. These 3D prominence models combine simulations of the 3D magnetic field configuration of an entire prominence with a detailed description of the prominence plasma. The plasma is located in magnetic dips in hydrostatic equilibrium and is distributed along hundreds of fine structures. The assumed prominence plasma has realistic density and temperature distributions including the prominence-corona transition region.

These 3D WPFS models allow us to study the distribution and the mass of the prominence plasma contained in prominence magnetic field configurations. These can be crucial during the onset and early evolution of CMEs. Moreover, prominence plasma represents a bulk of the material ejected by CMEs into the interplanetary space. Here, we investigate the potential of using the 3D WPFS models for assessment of the role the prominence plasma plays in the initiation and evolution of CMEs.

E2.1-0004-18 DYNAMICS IN QUIESCENT PROMINENCES OBSERVED BY THE IRIS AND MSDP SPECTROGRAPHS

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Quiescent solar prominences are generally considered to be stable. However, these prominences consist of a multitude of small-scale structures or threads that are often significantly dynamic. To understand the nature of the plasma dynamics we use the high spatial, temporal and spectral resolution observations obtained by IRIS during coordinated campaign with the MSDP spectrograph at the Meudon Solar Tower. Mg II h and k lines observed by IRIS represent a good diagnostic tool for investigation of the prominence fine structure dynamics, as they are optically thick under the prominence conditions. We will present detailed IRIS observations of Mg II lines. We explain significant asymmetries in the observed Mg II spectra by the presence of several threads located along the line of sight with different velocities. In such a case, the decrease of the intensity of individual components of the observed spectra with the distance from the central wavelength can be explained by the Doppler dimming effect. To interpret the observed Mg II profiles in terms of dynamics we use 1D or 2D radiative transfer models including a prominence-corona transition region. We also show that the H-alpha line which is optically thinner than the Mg II doublet is an important constrain for the radiative transfer radiation modelling.

E2.1-0005-18 UNAMBIGUOUS EVIDENCE OF FILAMENT SPLITTING-INDUCED PARTIAL ERUPTIONS

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Coronal mass ejections are usually believed to be produced by the full eruption of a magnetic flux rope (MFR). However, it is recently recognised that the MFR may only release part of flux during once eruption, leading to a partial eruption. Here, we investigate two partial eruption events, the first one appears as a failed filament eruption, while the second manifests as a successful hot channel eruption. Thanks to the high resolution, high cadence, and multitemperature capability of the Atmospheric Imaging Assembly, it is found that both partial eruptions are a consequence of the splitting of an intact MFR-filament system caused by the internal reconnection. For the failed one, the internal reconnection, most likely induced by the rising and writhing motions of the filament, initially appears as EUV brightenings in the middle of the filament. Quickly, it evolves to the current sheet reconnection in the wake of the eruption of the upper filament. For the successful one, the internal reconnection initiates prior to the eruption, which is also evidenced by obvious heating in the middle of the filament. As the internal reconnection proceeds to the current sheet reconnection, the filament is split into two; the upper flux escapes as an erupting hot channel. As a result, regardless of being failed or successful, both of them produce hard X-ray sources and cusp-shaped loops below the erupting flux but above the surviving flux, as well as two ribbons at two sides of the latter.

E2.1-0006-18 MULTI-WAVELENGTH ANALYSIS OF A HELICAL PROMINENCE ERUPTION

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We use H image observed at Huairou Solar Observing Station of National Astronomical Observatories of China and multi-wavelength images observed by Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamics Observatory (SDO) to analyze a prominence eruption on 14 October 2012. During the rising phase of the prominence, some twist convert to writhe. The kink structure is obvious in AIA 131 Å and 94 Å images. The twist of the prominence is estimated at least three turns (6) which reaches up to the threshold of the kink instability. So we suggest the prominence eruption is triggered by kink instability. The cusp structure in AIA 131 Å and 94 Å images is coincident with the RHESSI X-ray source location which is the feather of magnetic reconnection.

E2.1-0007-18 MAGNETIC RECONNECTION WITHIN A MULTI-FLUX-ROPE SYSTEM DURING THE PRECURSOR PHASE OF A CONFINED FLARE

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The core structure of a solar eruption is believed to be a flux rope made of helical magnetic field. While the post-eruption “standard” picture of the flux rope has been largely studied, the flux rope formation and its evolution toward eruption remain elusive owing to subtle activity and emission during this phase. Here we investigate the pre-eruption morphology of a complex ejecta and associated activities during the precursor phase of a confined C1.1 SOL2015-06- 22T16:45 flare exhibiting multiple intermittent brightenings along the polarity inversion line (PIL). Spectral analysis of X-ray emission recorded during the precursor phase revealed the presence of non-thermal electron with a spectral index -6 while the plasma temperature during this phase reached to 20 MK as also confirmed by the DEM maps synthesized using EUV observations. The coronal magnetic-field topology, derived from the NLFFF extrapolations revealed a multi-flux-rope system comprising of at least five branches spanned across 25 Mm altitude. A combined map of magnetic twist-number and squashing factor revealed the release of the twist after the flare, confirming the reconnection taking place within the flux-rope system spatially linked with the excursions observed during the precursor phase. Further, EUV images revealed bi-directional outflows of the plasma blobs from the reconnection site. In summary, our investigation of a rare flare precursor with definitive signatures of magnetic reconnection within a system of multiple braided flux-rope branches with different degree of coherency signifies the importance of internal structure and reconnection in understanding CMEs.

E2.1-0008-18 COOL AND HOT FLUX ROPES, THEIR HELICITY

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We will review recent indirect and direct evidence for the existence of magnetic flux ropes in the solar atmosphere. Magnetic flux ropes may appear as S-shaped or reverse S-shaped (sigmoidal) structures in regions that are likely to erupt, and may also show in nonlinear force-free field extrapolations that use data from photospheric vector magnetograms as boundary condition. The availability of high sensitivity data recorded with unprecedented spatial and temporal resolution in hot EUV wavelengths by the Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamics Observatory (SDO) has revealed the existence of coherent structures identified as hot flux ropes. In this presentation, we will review the properties of both cool and hot flux ropes with an emphasis on the frequency of their occurrence in large flares and on their magnetic helicity content.

E2.1-0009-18 A STUDY OF EXTERNAL MAGNETIC RECONNECTION THAT TRIGGERS A SOLAR ERUPTION

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External magnetic reconnection (EMR) is suggested to play an essential role in triggering a solar eruption, but is rarely directly observed. Here, we report on a filament eruption on 2014 October 3 that apparently involves the process of an early EMR. A total of 1.7 × 1020M x flux was first canceled along the filament–related polarity inversion line over 12hr, and then the filament axis started to brighten in extreme ultraviolet (EUV). An impulsive EUV brightening began 30 minutes later, and we attribute this to EMR, as it is located at the center of a bidirectional outflow with a velocity of 60-75 km/s along large-scale magnetic loops from active regions NOAA 12178 and 12179, respectively, and over the filament mentioned above. Following the EMR, the filament was activated; then, partial eruption occurred 6 minutes later in the west, in which the decay index above the magnetic flux rope (MFR) reached the critical value of 1.5. The observations are interpreted in terms of underlying magnetic flux cancelation leading to the buildup and eventual formation of the MFR with a filament embedded in it, and the MFR is elevated later. The activated MFR rises and pushes the overlying sheared field and forms a current sheet causing the EMR. The EMR in turn weakens the constraining effect of the overlying field, leading to the arising of the MFR, and subsequently erupting due to torus instability.

E2.1-0010-18 MAGNETIC RECONNECTION DURING ERUPTIVE MAGNETIC FLUX ROPES

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Using highly resolved magnetohydrodynamic simulations, we follow the eruption of a kinkunstable magnetic flux rope in 3D. Our grid refinement allows to zoom in on the reconnection sites within the current sheet. At an estimated Lundquist number of 10000, we retrieve the 3D generalization of Petschek slow shocks, tubular substructures indicating tearing disruption, and turbulent interaction of the ejection flows with the closed magnetic structures above and below the extended current sheet. The 3D simulations allow synthetic views from varying line of sight orientations, and show many morphological aspects known from actual observations.

E2.1-0011-18 THE ORIGIN OF MAJOR SOLAR ACTIVITY - COLLISIONAL SHEARING BETWEEN NONCONJUGATED POLARITIES IN SOLAR ACTIVE REGIONS

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We present observations suggestive of a new scenario for the origin of activity in solar Active Regions (ARs). ARs that exhibit compact Polarity Inversion Lines (PILs) are known to be very flare-productive. However, the basis for this statistical inference has not been demonstrated conclusively. We show that such PILs can occur due to the collision between two emerging flux tubes within the same AR. The flux tubes may emerge simultaneously or sequentially, initially each producing two opposite conjugated polarities at the surface. The proper motions of the polarities lead the nonconjugated opposite polarities into a collision course, producing shearing and cancellation of opposite flux. We name this process "collisional shearing" to emphasize that the shearing develops due to the collision. Collisional shearing is a process different from the concept of flux cancellation occurring between conjugated polarities of a single emerging flux tube, a process that has been commonly used in many numerical models. High spatial and temporal resolution observations from the Solar Dynamics Observatory for two emerging ARs show the continuous cancellation of up to 20% of their unsigned magnetic flux, which occurs at the collisional PIL for as long as the sunspot collision persists. The cancellation is accompanied by a succession of solar flares and CMEs, products of magnetic flux cancellation along the contact layer. Our results strongly suggest that magnetic cancellation driven by collisional shearing is a primary process that needs to be taken into consideration for the improvement of predicting solar energetic events and space weather.

E2.1-0012-18 SOLAR PROMINENCE OSCILLATIONS

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Prominence oscillations have been observed for at least 80 years, yet their fundamental physics and implications for eruptive activity remain poorly understood. These oscillations not only provide a laboratory for investigating the competing processes of forcing and damping, but also open a window into determining filament properties that are difficult or impossible to measure directly (e.g. the magnetic field strength). Prominence oscillations have periods from few minutes to ultra long periods with more than 20 hours. The observed oscillation velocities range from 0.1 to 100 km/s. The oscillations damp quickly, in few periods, even for the most energetic events. In this talk, recent observational and theoretical discoveries on this topic will be presented.

E2.1-0013-18 CORONAL JETS: FORMATION, EVOLUTION, AND EFFECTS IN THE HELIOSPHERE

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Coronal jets are ubiquitous solar transients that supply the upper solar atmosphere with important mass and energy input. They are omnipresent regardless of the solar cycle phase. The debate on how they form and evolve in the corona and solar wind is very intense in the last decade. The size spectrum of jets spreads from structures close or at the limit of the current spatial resolution such as spicules and jetlets to narrow CME-like features. They are also critical to the formation and energy supply that maintain larger coronal structures for long periods of time (e.g., plumes). Jet phenomena may hint to basic processes for heating the corona and accelerating the solar wind. We present an overview of the formation, evolution, and effects of coronal jets in the heliosphere.

E2.1-0014-18 COMPOUND SOLAR ERUPTIONS AND THE CAUSES

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A compound solar eruption is a phenomenon of successive eruptions of two or more magnetic structures within a short period of time. The eruption of one magnetic structure may affect the other one through the interconnection of magnetic field in the corona. This is in contrast of singular eruptions, the concern of most theoretical and numerical models of solar eruptions. In this presentation, we will report a detailed study of the compound eruption occurred on 2012 March 10 from NOAA AR 11429. The eruption produced a GOES M8.4 flare that contained two distinct peaks with a separation of 12 minutes during the impulsive phase of the flare. The data from SDO, STEREO-A and GOES help identify that the two peaks are caused by eruption of two pre-existing magnetic flux bundles lying along a same polarity inversion line. The stereoscopic observations of pre-existing filaments show that these flux bundles are lying one above the other, separated by 12 Mm in height, in a so-called "double-decker" configuration. The high-lying flux bundle became unstable and erupted first, showing as a high-temperature hot channel in EUV wavelengths. About 12 minutes later, the low-lying flux bundle also started to erupt and moved at a faster speed. The two erupting flux bundles interacted with each other and appeared as a single coronal mass ejection in white-light coronagraph images in the outer corona. The "double-decker" configuration is likely to be caused by strong shearing motion and fast flux cancellation along a strong-gradient polarity inversion line. The successive eruption of two separate but coupled magnetic flux bundles, possibly in the form of magnetic flux ropes, lead to the compound solar eruption. The study of the compound eruption provides us a unique opportunity of revealing the formation process of erupting structures and the initiation mechanism of solar eruptions in general.

E2.1-0015-18 GENERALIZING THE RBSL-METHOD FOR FLUX ROPES WITH VARIOUS CURRENT PROFILES AND NONZERO EXTERNAL AXIAL FIELD

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Magnetic flux ropes (FRs) likely play a key role in prominence formation and solar eruptions. It is therefore important to develop methods for constructing FR configurations constrained by observational data. With this aim, we have recently derived a pair of regularized Biot-Savart laws (RBSLs; Titov et al. 2017) that allow one to efficiently calculate the magnetic vector potential of an FR with circular cross-sections and an axis of arbitrary shape. One of the RBSLs represents the axial component of the vector potential produced by the axial current of the FR, while the other represents the azimuthal component produced by the axial flux of the FR. The kernels of the RBSLs are regularized at the axis in such a way that, when the axis is straight, the RBSLs define a cylindrical flux rope whose structure is exactly force-free. Therefore, a curved thin FR defined by the RBSLs with the same kernels is approximately force-free.

Originally, we implemented the RBSLs only for FRs that have a parabolic profile of the axial current and a vanishing axial magnetic field at the FR surface. Here we present a twoparametric generalization of the method that describes FRs with various axial-current profiles and a nonvanishing external axial field existing in sheared configurations. To benchmark this generalization, we applied it first to simple configurations of a toroidal-arc FR embedded into a potential background field, which are geometrically similar to the model proposed by Titov & Démoulin (1999). We investigated the numerical FR equilibria reached in zero-beta MHD relaxations of these configurations in dependence of the initial axial-current profile and the strength of the external axial field.

We plan to apply the generalized RBSLs to more realistic and complex configurations. Our previous successful applications of the RBSLs for FRs with a parabolic axial-current profile suggest the following. The shape of the FR axis can be determined in more complicated cases by tracking the observed polarity inversion line of the eruptions' source region and estimating its height variation as well as other FR parameters by means of a potential field extrapolated from the observed magnetogram.

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E2.1-0016-18 3D MHD MODELING OF PROMINENCE FORMATION AND ERUPTION

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The formation of prominences in the solar corona is widely thought to be caused by plasma evaporation and condensation via thermal non-equilibrium. This process has been previously modeled by one-dimensional hydrodynamic simulations along individual field lines within static magnetic fields. A more realistic modeling of prominence formation can be achieved through the use of three-dimensional thermodynamic MHD simulations with time-dependent magnetic fields, which has only become feasible within the last few years. In this talk I will describe recent three-dimensional simulations that display the formation and eruption of prominencelike structures. The capabilities and limitations of these simulations will be discussed, along with the next steps that lie ahead.

E2.1-0017-18 MHD SIMULATIONS OF PROMINENCE ERUPTION

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We present MHD simulations of the eruption of a prominence carrying coronal flux rope under a coronal streamer, with the thermodynamics treatment including a simple empirical coronal heating, optically thin radiative cooling and the field aligned thermal conduction. We first initialize a quasi-steady solar wind solution with a coronal helmet streamer, using an initial normal flux distribution of a simple bipolar arcade field on the lower boundary. Then into this coronal streamer we impose at the lower boundary the slow emergence of a twisted magnetic torus. As a result a quasi-equilibrium flux rope is built up under the streamer magnetic field. We find that for a sufficiently long, significantly twisted flux rope, prominence/filament condensations of an elongated sigmoid morphology form in the dips of the twisted field lines due to run-away radiative cooling. A prominence cavity also forms surrounding the prominence when observed above the limb with a line-of-sight nearly along the length of the flux rope as shown by AIA synthetic EUV images. The prominence carrying field is found to be significantly non force-free due to the prominence weight despite being low plasma. The flux rope eventually erupts due to the development of the kink instability, and we obtain the eruption of the prominence, which shows substantial draining along the legs of the erupting flux rope displaying helical structures. We discuss the role prominence mass plays in the storage of the free magnetic energy and in the dynamics of the eruption.

E2.1-0018-18 MANIFESTATION OF CORONAL MASS EJECTIONS NEAR EARTH: A REVIEW

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Coronal Mass Ejections (CMEs) are launched from the Sun, as a result of magnetic instabilities, carrying away a huge amount of magnetic flux and helicity. Interplanetary CMEs (ICMEs) are their manifestations observed further away in the heliosphere. ICMEs contain different plasma and magnetic field properties, compared with those of the ambient solar wind. From the large number of observed ICMEs in the past years, we significantly increased our knowledge on several of their properties such as: their global 3D shape, the identification of the composing sub-structures, the amount of magnetohydrodynamical quantities transported, as well as how the plasma and magnetic field are typically distributed inside them. In the present talk we will present a general review of these aspects of ICMEs. In particular we will focus on the total amount of magnetic flux and helicity ejected by CMEs from the Sun along a solar cycle, and on plasma and magnetic properties of their shock/sheath/flux-rope/wake. These results can help to understand their interaction with the ambient solar wind and with planetary magnetic environments. They are particularly crucial for a better understanding of the Sun-Earth coupling.

E2.1-0019-18 THE BEST AND LAST OF SOLAR CYCLE 24 - THE GLOBAL EUV WAVE FROM THE X8 FLARE-CME ERUPTION ON 2017-SEPT-10: SDO/AIA OBSERVATIONS AND DATA-CONSTRAINED SIMULATIONS

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Global extreme ultraviolet (EUV) waves are commonly associated with coronal mass ejections (CMEs) and flares. One particular EUV wave that was triggered by the X8 flare-CME eruption on 2017 September 10 was extraordinary - one of the best EUV waves ever observed with modern instruments (e.g., SDO/AIA and GOES/SUVI), yet likely the last one of such magnitudes in Cycle 24 as the Sun heads toward the solar minimum. We present here detailed analysis of SDO/AIA observations of this event and comparison with high-fidelity, data-constrained MHD simulations using the University of Michigan Alfven Wave Solar Model (AWSoM). Observational highlights include: (1) The EUV wave traverses almost the entire visible solar disk and circumference, manifesting its truly global nature. This vast range is mainly due to the exceptionally large wave amplitude, with EUV intensity changes by up to a factor of 3 (as opposed to, e.g., 30% for moderate events). (2) The large wave amplitude also leads to the novel detection of strong transmission components (in addition to commonly observed reflections) into and through both polar coronal holes, at elevated apparent wave speeds up to 2600 km/s. (3) The wave also produces significant heating, indicated by long-lasting EUV intensity changes. As such, this EUV wave offers unique magnetic and thermal diagnostics of the global, CMEspawning corona. Our MHD simulations have largely reproduced the observed features. We find that the simulated EUV wave morphology and kinematics are sensitive to the orientation of the initial flux rope introduced to the host active region. An orientation with the flux-rope axis in the north-south direction produces the best match to the observations. This suggests that EUV waves may potentially be used to constrain the flux-rope geometry for such limb or behind-the-limb eruptions, whose source-region magnetic fields cannot be directly observed, and thus offer useful implications for space-weather predictions.

E2.1-0020-18 TWO-DIMENSIONAL MHD SIMULATION FOR PROMINENCE ERUPTION WITH RADIATIVE CONDENSATION

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We reproduced solar prominence eruption using 2.5-dimensional magnetohydrodynamic (MHD) simulations including nonlinear anisotropic thermal conduction and optically thin radiative cooling. Solar prominence eruption is a progenitor of coronal mass ejection and one of the important subjects in studies of solar physics and space weather. Only a few numerical simulation have been carried out for prominence eruptions due to difficulty in reproducing cool dense plasmas of prominence in the hot tenuous corona. In this study, we numerically modeled prominence eruption by combining prominence formation model (Kaneko Yokoyama, 2015, 2017) and flare trigger model (Kusano et al., 2012). In the present simulations, a flux rope is created by reconnections between coronal arcade fields and a newly emerging bipole. Radiative condensation is triggered inside the flux rope, leading to prominence formation. The flux rope hosting prominence erupts by MHD instability and reconnection. As a result of parameter survey, we found that momentum as well as mass in the coronal flux rope is condensed into prominence, facilitating the initiation of MHD instability responsible for eruptions. Our results suggest that the slow rise phase of prominence eruptions is maintained or extended by momentum condensation from the corona toward prominence.

E2.1-0021-18 HOT ERUPTING PROMINENCES IN CORES OF CME'S

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Coronal mass ejections (CME) associated with prominence eruptions exhibit relatively cool material in their cores. Such prominence plasmas were frequently detected in various spectral lines by SOHO/UVCS coronagraph and in the visible light by SOHO/LASCO as well as by STEREO coronagraphs. UVCS provided excellent spectra of CME-core prominences and an extended catalogue of these data is available. We will present recent results of a hot prominence diagnostics using the hydrogen Lyman lines and the CIII line. The erupting prominence parameters are further constrained by the visible light observations from LASCO-C2. A novel non-LTE modeling based on such observations will be presented and we will highlight the diagnostic potential of the UV and visible light for future space coronagraphs like Metis on board the ESA Solar Orbiter mission. The plasma parameters of such hot prominences are compared with those obtained from numerical MHD simulations of erupting flux ropes surrounded by CMEs. Finally, we will also mention synergies with stellar analogues.

E2.1-0022-18 DYNAMIC EVOLUTION OF FLARE RIBBONS OBSERVED BY THE SDO AND IRIS

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The shape, location, and dynamics of flare ribbons, as well as their relationship to magnetic fields provide a significant amount of information about the 3D magnetic configuration involved in the reconnection process. We anlalyed the X 1.6-class flare on 2014 September 10, and found that the flare ribbon consisted of a series of bright knots that simultaneously underwent a quasi-periodic slipping motion along the flare ribbon. The spectroscopic observations of the IRIS showed that the redshifts of the Si IV 1402.77 Å line at the locations of moving knots were larger than other locations of the flare ribbon, with a value of about 30-50 km/s. Similarly, the line profile became broader at the locations of slipping knots and the width increased to 40-60 km/s. Moreover, we report flare ribbons approach (FRA) during a multiple-ribbon Mclass flare on 2015 November 4 in NOAA AR 12443, obtained by the IRIS and SDO. The flare consisted of a pair of main ribbons and two pairs of secondary ribbons. The two pairs of secondary ribbons were formed later than the appearance of the main ribbons, with respective time delays of 15 and 19 minutes. The negative-polarity main ribbon spread outward faster than the first secondary ribbon with the same polarity in front of it, and thus the FRA was generated. Just before their encounter, the main ribbon was darkening drastically, implying the suppression of main-phase reconnection that produced two main ribbons. The FRA caused the deflection of the main ribbon to the direction of secondary ribbon with a deflection angle of about 60°. We suggest that there are three topological domains with footpoints outlined by the three pairs of ribbons. Close proximity of these domains leads to deflection of the ribbons, which is in agreement with the magnetic field topology.

E2.1-0023-18 EXTENDED KILOGAUSS BALD PATCHES IN THE SUPER-FLARING ACTIVE REGION 12673

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Magnetic field in the active region core holds the key to its eruptive potential. An interesting topological feature is the “bald patch” (BP) - a segment of the polarity inversion line (PIL) at which the photospheric magnetic field is directed from the negative to positive side, implying the presence of U-shaped magnetic loops in the immediate low corona. When accompanied by strong shear, coherent BPs can provide evidence for pre-eruption flux ropes (FRs). Here we report on an archetypical BP structure observed in the super-flaring active region 12673, which extends over 30 Mm with a typical field of 2-3 kG. The structure formed gradually over one day prior to an X9-class flare. Co-spatial photospheric downflow developed and sustained near the PIL. The coronal magnetic field inferred from a nonlinear force-free field model reveals textbook morphology of a low-lying, twisted FR. We discuss the formation mechanism of such extended BPs and its role in initiating major eruptions.

E2.1-0024-18 OBSERVATIONAL CONSTRAINTS ON STELLAR FLARES AND PROMINENCES

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Multi-wavelength surveys have catalogued a wealth of stellar flare data for stars representing a broad range of masses and ages. Young solar analogs inform our understanding of the Sun's evolution and the influence of its activity on early solar system formation, while field star observations allow us to place its current activity into context within a statistical ensemble of main-sequence G-type stars. At the same time, stellar observations probe a variety of interior and coronal conditions, providing constraints on models of equilibrium (and loss thereof!) for magnetic structures. In this review, I will focus on our current understanding of stellar flares, prominences, and coronal mass ejections as a function of stellar parameters. As our interpretation of stellar data relies heavily on solar-stellar analogy, I will explore how far into extreme stellar parameter spaces this comparison can be invoked.

E2.1-0025-18 NEW CORONAL SCIENCE FROM NASA WB-57F HIGH-ALTITUDE AIRCRAFT OBSERVATIONS OF THE 2017 TOTAL SOLAR ECLIPSE

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Total solar eclipses present rare opportunities to study the complex solar corona, down to altitudes of just a few percent of a solar radius above the surface, using ground-based and airborne observatories that would otherwise be dominated by the intense solar disk and high sky brightness. Studying the corona is critical to gaining a better understanding of physical processes that occur on other stars and astrophysical objects, as well as understanding the dominant driver of space weather that affects human assets at Earth and elsewhere. For example, it is still poorly understood how the corona is heated to temperatures of 1–2 MK globally and up to 5–10 MK above active regions, while the underlying chromosphere is 100 times cooler; numerous theories abound, but are difficult to constrain due to the limited sensitivities and cadences of prior measurements. The stability of large-scale coronal structures and the extent of their reach to the middle and outer corona are also not well known, limited in large part by sensitivities and fields of view of existing observations.

Airborne observations during a total eclipse provide unique advantages. By flying in the stratosphere at altitudes of 50 kft or

higher, they avoid all weather, the seeing quality is enormously improved, and additional wavelengths such as near-IR also become available due to significantly reduced water absorption. An airborne observatory can also follow the Moon's shadow, increasing the total observing time by 50% or more.

We present current results of solar coronal measurements from airborne observations of the 2017 Great American Total Solar Eclipse using two of NASA's WB-57 high-altitude research aircraft, each equipped with two 8.7" telescopes feeding high-sensitivity visible (green line and nearby continuum) and medium-wave IR (3–5 µm) cameras operating at high cadence (30 Hz) with 3 arcsec/pixel platescale and 3 Rsun fields of view. The aircraft flew along the eclipse path, separated by 110 km, to observe a summed 7.5 minutes of totality in both visible and MWIR. These observations enable groundbreaking studies of high-speed coherent motion

– including possible Alfvén waves and nanojets – in the lower and middle corona that could shed light on coronal heating processes and the formation and stability of coronal structures. Our MWIR observations of a cool prominence and hot coronal active region plasma will be combined with spectra from the AIR-Spec instrument, flown concurrently on NCAR's HIAPER GV. We review the WB-57 eclipse mission and the current results of analysis on the visible and IR coronal measurements, along with an outlook for future analysis and missions.

E2.1-0026-18 FINDING AND INTERPRETING STELLAR CORONAL MASS EJECTIONS

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The astrophysical study of mass loss, both steady-state and transient, on the cool half of the HR diagram has implications both for the star itself and the conditions created around the star that can be hospitable or inimical to supporting life. Stellar coronal mass ejections have not been conclusively detected, despite the ubiquity with which their radiative counterparts in an eruptive event (stellar flares) have. I will review some of the different observational methods which have been used and possibly could be used in the future in the stellar case, emphasizing some of the difficulties inherent in such attempts. I will provide a framework for interpreting potential transient stellar mass loss in light of the properties of flares known to occur on magnetically active stars. This uses a physically motivated way to connect the properties of flares and coronal mass ejections and provides a testable hypothesis for observing or constraining transient stellar mass loss. Finally I will describe recent results using radio observations to detect stellar coronal mass ejections, and what those results imply about transient stellar mass loss. I will give updates on prospects using future facilities to make headway in this important area.

E2.1-0027-18 WHAT OBSERVATIONS ARE REQUIRED TO SOLVE THE CME INITIATION PROBLEM?

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Despite extensive observations of solar coronal mass ejections (CMEs), the CME initiation mechanism remains unclear. The CME acceleration curve is currently measured using the combined observations taken by extreme-ultraviolet (EUV) imagers (e.g. STEREO/EUVI, SDO/AIA, PROBA2/SWAP) and white-light externally occulted coronagraphs (e.g. SOHO/LASCO C2 and C3, STEREO/COR2). The CME propagation in the gap between the fields of view of the two types of instruments is either interpolated, or measured using the data taken by internally occulted coronagraphs (Mk4, SOHO/LASCO C1, STEREO/COR1), which suffer from significant straylight. These heterogeneous observations with three different types of instruments do not allow distinguishing between different proposed mechanisms of the CME initiation. Measurements of the CME kinematics and detailed observations of the coronal restructuring during CMEs are required in the crucial region of the inner corona where the peak acceleration takes place. Future observational capabilities that will address the CME initiation problem in the next several years (e.g. Solar Orbiter, PROBA-3, Aditya-L1) will be discussed. In particular, low straylight and high spatio-temporal resolution of the ASPIICS coronagraph onboard the PROBA-3 mission will allow to determine the timing of occurrence of the fast eruption onset and the reconnection onset, which is necessary to distinguish between different mechanisms of the CME initiation, such as ideal (e.g. torus instability) and resistive (magnetic breakout) mechanisms.

E2.1-0028-18 EVOLUTION OF A MAGNETIC FLUX ROPE TOWARD ERUPTION

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A magnetic flux rope (MFR) is a critical component of many Coronal Mass Ejections (CMEs), yet it is poorly understood how the MFR is formed and what mechanism triggers the eruption of the MFR. To provide insight into this question, in this work, we study the dynamic evolution and magnetic structure of a MFR for five hours before its eruption on June 14 2012. The MFR is located in a sigmoidal active region (AR) 11504, which is characterized by significant sunspot rotation for two days. The CME is accompanied by a M1.9 two-ribbon flare, as well as coronal dimming adjacent to the two flare ribbons in magnetic fields of opposite polarities. The conjugate coronal dimming is therefore used to identify the feet of the MFR. We find persistent gradual coronal dimming coincident with the slow rise of a coronal structure for five hours before the eruption. This evolution appears to take place in a few stages, each preceded by a series of C-class flares, and the final eruption occurs at the onset of the M1.9 flare. We also calculate the vertical current at the feet of the MFR and estimate the mean twist of the MFR during its evolution. The sequence of observations suggests that flare reconnection plays a crucial role in the MFR evolution toward its eruption.

E2.1-0030-18 PHYSICAL CONDITIONS IN A PROMINENCE ERUPTION DURING ITS PREERUPTION AND ACCELERATION

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We rely upon the simultaneous observations of a CME-associated eruptive prominence which have been made by the Interface Region Imaging Spectrograph (IRIS), Atmospheric Imaging Assembly (AIA) of SDO, EUVI of STEREO and the ground-based K-COR coronagraph. We focus on the determination of mass flows in order to detect a possible mass loading. In order to derive the full velocity vector, we combine an optical flow method on the AIA 304 and IRIS SJI observations to compute the POS velocities in the prominence and a Doppler technique with the IRIS observations to compute the LOS velocities. Then we focus on the determination of densities through the combination of spectroscopic observations and NLTE modelling. We first characterize the Mg II h and k profiles (time and space-dependent!) through a grid of 6 typical profiles (reversed and unreversed). Then we compare them with the signatures of hundreds of prominence models through NLTE radiative transfer computations (I.A.S. PROM7 code). Much attention is paid to the exact incident radiation in various lines and continua. Having selected the best (fitting) models, we are able to derive the total (hydrogen) density and compute the mass flows. The derivation of physical parameters (e.g. velocity) also takes into account the STEREO observations to derive the 3D geometry of the prominence and K-COR to derive the density later on in the process of eruption.

E2.1-0031-18 THE RELATIONSHIP BETWEEN DYNAMICAL BRIGHT POINTS AND SURGES ON LIGHT BRIDGE OF SUNSPOT

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Using the detailed observations obtained by the New Solar Telescope of Big Bear Solar Observatory, we explored the motions of bright points (BPs) on the light bridge. It is found that there are three kinds of motions of the BPs on the bridge. The first kind of the BPs is along the axis of the light bridge, the second one along the direction perpendicular to the axis of the light bridge and the last one moving around a position without distinct displacement. Then we compared the dynamic properties of these three kinds of BPs with the surges on the light bridge. The first kind of BPs is tightly related to the severity of the surge. It is suggested that the formation of the surge maybe coming from the collision between the plasma on the light bridge and the moving BPs.

E2.1-0032-18 MAGNETIC FIELD DIAGNOSTICS IN THE SOLAR UPPER ATMOSPHERE AND FUTURE INSTRUMENTATION

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The solar upper atmosphere manifests the key role of the magnetic field in coupling and structuring of the different layers, energy flow and dissipation, plasma heating and acceleration, and the multi-scale, explosive solar activity. Understanding these phenomena and the related physical mechanisms cannot be achieved without comprehensive understanding of the evolution (both spatial and in time) of the magnetic field through the different atmospheric layers. We present an overview of the techniques used to determine the magnetic field in the solar chromosphere and corona. The development of future instruments will also be outlined.

E2.1-0034-18 LARGE-SCALE PATTERNS OF FILAMENT CHANNELS AND FILAMENTS

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In this review the properties and large-scale patterns of filament channels and filaments will be considered. Initially, the global formation locations of filament channels and filaments are discussed, along with their hemispheric pattern. Next, observations of the formation of filament channels and filaments are described where two opposing views are considered. Finally, the wide range of models that have been constructed to consider the formation of filament channels and filaments over long time-scales are described, along with the origin of the hemispheric pattern of filaments.

E2.2-0001-18 ENERGY PARTITION IN STELLAR FLARES

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The extremes of magnetic activity on stars in the cool half of the HR diagram exceed by large factors those exhibited by our Sun, making flares on these stars ideal probes of some of the processes which can be studied in detail on the Sun. The magnetic activity of stars helps to set the conditions present in the near stellar environment, and affects formation and evolution of planetary systems. I will summarize multi-wavelength observational constraints that point to stellar flares having the same physical processes underlying them as solar flares. I will next summarize results describing energy partition in solar and stellar flares. I will present multi-wavelength observations of two recent stellar super flares serendipitously observed by the Swift satellite and numerous ground-based facilities, and demonstrate how the multi-wavelength information is used to interpret the coronal radiation, particularly in light of what it reveals about the interplay between radiation observed in various bands, as well as energy flow by particle beams. I will examine what these flares reveal in light of continuation of solar flare scaling relations into the extremes of temperature and emission measure. I will present recent results on simultaneous radio and optical stellar flares and discuss the unique contribution to understanding the presence and action of nonthermal particles in stellar flares afforded by radio observations.

E2.2-0002-18 EXPLORING THE NON-THERMAL CHARACTERISTICS OF X-RAY EMISSION FROM SOLAR FLARES

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Observations of hard X-ray (HXR) emission provide the most direct diagnostics of energy release in solar flares. This paper presents the study of hard X-ray (HXR) emission from ten potentially geo effective solar flares (GOES X class) observed by "Reuven Ramaty High-Energy Spectroscopic Imager (RHESSI)" mission. The flare plasma is characterized in the energy range of 13 - 100 keV. To investigate spectral characteristics of X-ray emission from solar flares, the spectra are fitted with thermal and non-thermal functions over the observed duration of the flare. The thermal part of the spectrum is fitted with the isothermal model. The non-thermal hard X-ray emission is assumed to be due to a power-law distribution of electrons emitting hard X-rays via Bremsstrahlung in a thick target. The non thermal part of the spectrum is fitted with thick target function. The spectral analysis enabled us to study the spectro-temporal evolution as well as the range of the spectral parameters for Xclass flares. Employing the thick target spectral parameters, the total non-thermal energy content of X-class flares is estimated.

E2.2-0003-18 BLUE WING ENHANCEMENT OF THE CHROMOSPHERIC MG II H AND K LINES IN A SOLAR FLARE

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We performed coordinated observations of NOAA AR 12205, which produced a C-class flare on 2014 November 11, with the Interface Region Imaging Spectrograph (IRIS) and the Domeless Solar Telescope (DST) at Hida Observatory. Using spectral data in the Si IV 1403 Å, C II 1335 Å, and Mg II h and k lines from IRIS and the Ca II K, Ca II 8542 Å, and Hα lines from DST, we investigated the temporal and spatial evolution around a moving flare kernel. In the Mg II h line, the leading edge of the kernel showed intensity enhancement in the blue wing and difference between the blue-side peak and red-side one (Ih2v < Ih2r). Then, the drastic change of the intensity in the red wing occurred. The blueshift lasted for 9–48 s with a speed of 10.1 2.6 km s–1 and it was followed by the strong redshift with a speed of up to 51 km s–1

detected in the Mg II h line. The strong redshift was a common property for all six lines but the blueshift prior to it was found only in the Mg II lines. A cloud modeling of the Mg II h line suggests that the blue wing enhancement with such peak difference can be caused by a chromospheric-temperature (cool) upflow. We discuss a scenario in which an upflow of cool plasma is lifted up by expanding (hot) plasma owing to the deep penetration of non-thermal electrons into the chromosphere. In addition, at the leading edge of the final flare footpoints, the blueshift persisted in the Mg II h line, which was not followed by any large redshift

and intensity enhancement. Such long-lasting blueshift can be explained by cool upflow caused by small energy flux into the lower atmosphere.

E2.2-0004-18 A NANOFLARE EXPLANATION FOR PERIODIC VARIATIONS IN FLARE STARS

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Several studies have documented periodic and quasi-periodic signals from the time series of dMe flare stars and other stellar sources. Such periodic signals, observed within quiescent phases (i.e., devoid of larger-scale microflare or flare activity), range in period from 1-1000 seconds and hence have been tentatively linked to ubiquitous p-mode oscillations generated in the convective layers of the star. As such, most interpretations for the observed periodicities have been framed in terms of magneto-hydrodynamic wave behavior. However, we propose that a series of continuous nanoflares, based upon a powerlaw distribution, can provide a similar periodic signal in the associated synthetic time series. Monte Carlo simulations, embodying the nanoflare signals and modeled noise profiles, produces a time series consistent with previous observations of dMe flare star lightcurves. Through an examination of nanoflare decay timescales and differing powerlaw indices, we provide evidence that periodic signals found in stellar time series can be explained by low-energy nanoflares embedded within the noise envelope of a stellar lightcurve. Implications for spatially-resolved solar datasets, including those from SDO/AIA, will also be discussed.

E2.2-0005-18 MODELING FLARE-GENERATED QUASI-PERIODIC PROPAGATING FAST MAGNETOSONIC WAVES OBSERVED BY SDO/AIA

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Fast-propagating (phase speeds of 1000 km/s) quasi-periodic, fast-mode wave (QFPs) accompanying many solar flares have been discovered by SDO/AIA (Liu et al. 2011). They typically propagate in funnel-like structures associated with the expanding magnetic field topology of the active regions (ARs), driven by flare-pulsations duration of impulsive phase. The fast magnetosonic waves provide information on the magnetic, density, and temperature structure through coronal seismology. While all previously reported QFP waves originate from a single localized flaring source, we report the first AIA observation and 3D MHD modeling of counter-QFPs originating from two 'sympathetic' flares. The waves are excited at the two sources associated with flare locations and connected by magnetic loops, by time-depended forcing, constrained by the spatial (localized) and quasi-periodic temporal evolution of the flare pulsations. With the aid of 3D MHD modeling we investigate the excitation, propagation, nonlinearity, and interaction of the counter-propagating waves for a range of key parameters, such as the properties of the flaring sources and the background magnetic topology. In addition to QFPs, we find evidence of associated waves, such as trapped fast (kink) modes in coronal loops, and slow mode waves propagating along the AR loops. Our model results are in qualitative agreement with the AIAobserved counter propagating waves providing the first direct evidence of counter-propagating fast magnetosonic waves that carry significant energy flux in low-corona magnetic structures.

E2.2-0006-18 HYDRODYNAMICAL 1D MODELLING OF FLARING LOOPS DURING A B8.3 FLARE ON JULY 04, 2009

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Hydrodynamical evolution of flaring plasma is crucial in understanding the response of various layers of solar atmospheres and the role of plasma energy transport and radiative loss processes. Although the insights obtained from the analysis of multi-wavelength emission are limited by the sensitivity of the observing instruments, numerical modelling constrained by observable provides a comprehensive picture of the underlying processes. In this regard, we investigate the evolution of thermal characteristics of plasma during a B8.9 flare of July 04, 2009 using Palermo-Harvard (PH) 1D hydrodynamic (HD) model. The X-ray spectra during the event, observed commonly by SphinX (1-15 keV), SOXS (4-25 keV) and Fermi (6 keV) instruments, were analysed in order to derive thermal characteristics of flaring plasma. EUV images available from SOHO and STEREO-twin satellites were used to derive projection-free geometrical characteristics of flaring loop(s) which are provided as an input to the PH model along with a number of heating profiles varying spatially across the loop and in time. Resulting temperature and density profiles along the loop were convolved with the response matrix of GOES X-ray monitors to derive respective fluxes and then compared with that observed. The PH exercise which bestrepresented the GOES observations during the flare was further used in mapping the spatial distribution of emission along the flaring loop(s) as well as the evolution of flaring plasma on the diagnostic diagram (DD; log T against log EM) as determined from the EUV and Xray channels. Moreover, a comparison of differential emission measure distribution (DEM[T]) derived from the PH model were compared with that obtained by applying the WithbroeSylwester deconvolution algorithm on the combined observation of STEREO, SphinX, SOXS and Fermi instruments. This investigation provides an exhaustive comparison of spatial and temporal evolution of thermal characteristics of flaring plasma as determined from the HD modelling with that available from the EUV and X-ray measurements.

E2.2-0007-18 WAITING TIME DISTRIBUTIONS OF SOLAR AND STELLAR FLARES: POISSON PROCESS OR WITH MEMORY?

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The statistics of time interval between two successive flares provide information whether solar and stellar activities occur independently or with memory? Here we examine the waiting time distributions (WTDs) of solar flares recorded with the GOES satellite during solar cycle 23, as well as the stellar flares produced by a solar type star (KIC11551430) observed with the Kepler mission. Based on the Kolmogorov-SmirnovK-Stest, we make a quantity analysis of the departure of WTDs from the Poisson process as predicted by the self-organized criticality (SOC) theory. We then fit the WTDs with functions of the non-stationary Poisson distribution (Wheatland 2000; Li et al. 2014), the Levy function (Lepreti et al. 2001), and the Weibull function (Weibull 1951; Telloni et al. 2014). It is found that a certain amount of memory is characterized during periods of high solar activities, while the random Poisson process dominates during solar minimum. The production of "super flares" is statistically a random process.

E2.2-0008-18 NEW SOLAR DIAGNOSTICS ENABLED BY NOVEL SOFT X-RAY IMAGING SPECTROSCOPY, AND FUTURE MISSIONS

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Solar soft X-ray (SXR) observations provide unique diagnostics of plasma heating, during solar flares and quiescent times. Spectrallyand temporally-resolved measurements are crucial for understanding the dynamics and evolution of these energetic processes; spatially-resolved measurements are essential for understanding energy transport. A critical observational gap exists from 0.2 to 3 keV (4–60 Å), where spectrally-resolved stellar observations are plentiful but have not been routinely made for the Sun in many decades. This energy range includes spectral lines from highly-ionized atoms with both low and high first ionization potential (FIP), as well as thermal free-free (bremsstrahlung) and free-bound (radiative recombination) continua. These SXR emissions provide crucial diagnostics of plasma temperature distributions, as well as elemental abundances that probe plasma origins over a wide range of temperatures, that are not available from observations at other wavelengths. A better understanding of thermal plasma also informs our interpretation of hard X-ray (HXR) observations of nonthermal par ticles, improving our understanding of the relationships between particle acceleration, plasma heating, and the underlying release of magnetic energy during reconnection.

We discuss a proposed small satellite pathfinder mission, the CubeSat Imaging X-ray Solar Spectrometer (CubIXSS), to measure spectrallyand spatially-resolved SXRs from the quiescent and flaring Sun from a 6U CubeSat platform in low-Earth orbit during a nominal 1-year mission. CubIXSS includes the Amptek X123-FastSDD silicon drift detector, a low-noise, commercial off-the-shelf (COTS) instrument enabling full-Sun SXR spectroscopy from 0.5 to 20 keV with 0.15 keV FWHM spectral resolution with low power, mass, and volume requirements. Multiple detectors and tailored apertures provide sensitivity to SXR emission from deep solar minimum to >X5 flares. An X123-CdTe cadmium-telluride detector is also included for 5–50 keV HXR spectroscopy with 0.5 keV FWHM resolution. The precise spectra from these instruments will provide detailed measurements of the coronal temperature distribution and elemental abundances during flares and quiescent times, and, for large flares, context information of flare-accelerated electrons.

CubIXSS also includes a novel spectro-spatial imager – the first ever solar imager on a CubeSat – utilizing a custom pinhole camera and Chandra-heritage X-ray transmission diffraction grating to provide spatiallyresolved, full-Sun imaging spectroscopy from 0.2 to 10 keV (1–60 Å), with 25 arcsec and 0.25 Å FWHM spatial and spectral resolutions, respectively. Additional pinholes with tailored filters provide non-dispersed images with coarse spectral information to seed analysis of the dispersed spectro-spatial images and for improved sensitivity to quiescent conditions. MOXSI's unique capabilities enable SXR spectroscopy and corresponding temperature and elemental abundance diagnostics of individual flares and active regions over a spectral range never before accessed by any prior solar mission.

CubIXSS is a pathfinder for larger satellites with improved resolution and sensitivity. Through these groundbreaking new measurements, CubIXSS and future missions will improve our physical understanding of thermal plasma processes and impulsive energy release in the solar corona, from quiet Sun to solar flares.

E2.2-0009-18 RHESSI SWAP POST-FLARE GIANT ARCH SIGNATURES

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Recent observations from the SWAP EUV imager on board PROBA2, AIA on SDO and SXI X ray observations from the GOES satellite have shown that post flare giant arches and regular post flare loops are one and the same thing. However, it is still not clear how certain loop systems are able to sustain prolonged growth to heights greater than half a solar radii (> 400000 km). In this presentation we further explore the energy deposition rate above post flare loop systems through high energy RHESSI observations, combined with evidence of supra arcade down flows, indicating ongoing sustained magnetic reconnection.

E2.2-0011-18 EVIDENCE OF A DISTANT DECIMETRIC SPIKE SOURCE CONNECTED TO THE MAIN ELECTRON ACCELERATION SITE: FIRST HIGH TIME CADENCE GMRT OBSERVATIONS

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We present a study of decimetric radio activity, associated with two (GOES C1.4 and M1.0 class) flares and a coronal mass ejection (CME) of 20 June 2015, using the first high time cadence (0.5s) 610 MHz observations of the Giant Meterwave Radio Telescope (GMRT). The GMRT images show strong radio sources during the M1.0 flare and CME, which are located near the flaring site, while, in contrary, a strong spike radio source during the C1.4 flare, with no corresponding coronal or magnetic features, are rather located about 500 arcsec away from the flare site in soft X-rays. Although weak radio burst sources are located near the flaring site, during the C1.4 flare maximum, associated with the spike radio source, which show a good temporal correspondence with a metric type-III burst identified by the Solar Broadband Radio Spectrometer at Yunnan Astronomical Observatory. A multi-wavelength analysis, in combination with potential field source surface extrapolation, has been carried out to investigate the genesis of non-thermal radio emitting electrons, which revealed that the distant spike radio source, noticed during the C1.4 flare, is actually connected to the main electron acceleration sites and is generated by a plasma emission instead of a loss cone maser instability.

E2.2-0012-18 FLARE-PRODUCTIVE ACTIVE REGIONS: OBSERVATIONS, MODELING, AND THEIR APPLICATIONS

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Strong solar flares and coronal mass ejections are known to occur in complex active regions (ARs). Then, what kind of AR structures are important for producing these events, and how can we model them? This review talk aims at answering to these questions. First, we introduce the statistical analysis on various flare-productive ARs, in which we investigated all >M5.0- class events within 45 deg from disk center for six years from May 2010. We classified the total of 51 events into four categories based on their formation processes, namely, (1) SpotSpot, a complex AR with AR-sized polarity inversion lines (PILs), (2) Spot-Satellite, in which a newly-emerging flux appears adjacent to the pre-existing spot, (3) Quadrupole, where two emerging fields collide against each other, and (4) Inter-AR, the flares occurring between two apparently separated ARs. As a result, we found that the characteristics of the flare eruptions strongly depend on the groups; for example, the flare duration of the majority group (1) is four times longer than that of another majority group (2). Second, we show the numerical attempt to model various flaring ARs, where we reproduced these four types (1-4) by conducting a series of flux-emergence simulations. We found that the sheared PILs in these ARs are created through the stretching and advection of horizontal magnetic fields due to the large-scale flux emergence. As ARs develop, free magnetic energy becomes stored in the corona, which could be released through the flare eruptions. Finally, we explore the possibility to apply these works to some particular ARs by introducing our newest work on NOAA AR 12673, which appeared in September 2017 and produced numerous strong flares including the X9.3-class event. We show the numerical modeling of AR 12673 and comparison with observations, discussing the possible magnetic structures in the subsurface layers that eventually led to the series of strong flares in this AR.

E2.2-0013-18 COMPARING TWO ACOUSTICALLY ACTIVE SEPTEMBER 6 X-CLASS FLARES OF SOLAR CYCLE 24.

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Two of the larger X-class flares of the current cycle have taken place on September 6, one near the peak of the cycle in 2011 and the other one approaching the minimum in 2017. We show that both have been accompanied by two sun quakes exhibiting very different properties. We analyse both events and their photospheric impact using helioseismic techniques and SDO HMI data supplemented by atmospheric observations from GOES, AIA and Hinode, and consider energies and momenta to look at possible mechanisms of sun quake generation in each case.

E2.2-0014-18 COOL LOOPS ON COOL STARS

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Recently a significant effort has been devoted to systematic modelling of solar and stellar chromospheric flares which are typically manifested by bright ribbons embedded in the lower atmospheric layers. However, apart from ribbons detectable in a broad range of the electromagnetic spectrum, overlying loops are also frequently observed on the Sun. They appear in various spectral lines and can be well resolved in the so-called eruptive flares. We will show how their appearance depends on the loop plasma conditions and parameters. We will also briefly review the efforts to model the radiation properties of such loops and namely of those which cooled down to chromospheric temperatures. Light curves of the flaring ribbons may differ from time evolution of the loop brightness and this can be easily detected on the Sun. However, on cool stars the measured light curves may contain an unresolved information about the temporal evolution of both ribbons and cool loops and we will demonstrate how this can be modelled.

E2.2-0015-18 SHORT DURATION FLARES IN GALEX DATA

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Flares on cool stars indicate short time-scale magnetic reconnection processes that provide temporary increases in the stellar radiative output. While recent work has focused on longduration flares from solar-like stars and those of lower mass, the existence of short-duration flares in the ultraviolet has not been systematically probed before. We will present an interesting population of short duration flares we discovered in a sample of 37,000 light curves observed from 2009-2012 by the GALEX and Kepler missions. These flares range in duration from under a minute to a few minutes and are almost entirely distinct from a previous flare survey of Kepler data. We were able to detect this unique population of flares because the time resolution of the GALEX data allowed us to construct light curves with a 10 second cadence and thus detect shorter duration flares than could be detected within Kepler data. We applied algorithmic flare detection to a sample of 37,000 stars, and identified a final count of 2,065 flares on 1,121 stars. We discuss the implication of these events for the flare frequency distributions of solar-like stars.

E2.2-0016-18 PARTICLE ACCELERATION IN SOLAR FLARES AT DIFFERENT FREQUENCIES

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The multifrequency analysis of solar flares is necessary due to the great complexity it presents. We present the investigation of thirteen solar flares that occurred between 2011 and 2013, studied in radio from 5 to 212 GHz (RSTN, POEMAS, SST), and in X-rays up to 800 keV (FERMI and RHESSI). The goal of this work is to determine the population of accelerated electrons by studing the spectral index in radio and hard X-rays (HXR). Previous works have shown that the temporal profiles at both wavelengths are very similar which is indicative of a common accelerated electron population. In this work, the radio spectral index was calculated by fitting the radio spectra by gyrosynchrotron emission, whereas the hard X-ray spectra were fit by thermal emission plus non-thermal emission from accelerated electron with a power-law distribution, yielding the HXR spectral index. Finally, we compare the results of both spectral indices and discuss the results in light of the models of particle acceleration.

E2.2-0017-18 THE UV NEUPERT EFFECT: HEATING AND COOLING OF SOLAR FLARE PLASMAS

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Explosive energy release in solar flares is believed to be governed by magnetic reconnection usually occuring in the corona. Yet at the onset of a flare, the immediate and more significant response to reconnection energy release is often observed in the lower atmosphere. The chromosphere being the lower boundary of the corona, its radiation signatures in UV or optical wavelengths provide clues to understanding corona heating. The lower atmosphere is also the only place where reliable measurements of magnetic field are currently available. Therefore, reconnection events in the Sun's corona can be mapped, tracked, and measured with observations of the lower atmosphere during the flare.

In the past decades, high-resolution observations reveal that flare heating takes place in "quantas", or a cluster of flare loops and their foot-points. We have recently developed a method to construct the history of heating of numerous flare loops from the UV emission signatures at their foot-points, which can be used in hydrodynamic models to study flare plasma evolution and compare with coronal observations. The method helps improve the estimate of the amount of energy used in heating these loops, and explore the nature of heating. Our recent analysis and multi-loop modeling suggest that heating of a flare loop likely proceeds in two phases, an intense impulsive heating followed by a low-rate gradual heating. We discuss properties of the different phases of heating, and the distribution of heating events in a flare with their relation to magnetic properties in the active region.

E2.2-0018-18 RECONNECTION MEDIATED BY MAGNETIC FRACTURES AND THE SOLAR FLARE

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Reconnection of sheared magnetic fields is commonly treated by regarding the component perpendicular to the anti-parallel components as a largely inert guide field. In this paper an alternative is proposed in which the free energy residing in the shear field is being converted prior to reconnection. This happens in high-density, dissipative current sheets bordering the reconnection site. A global scenario is presented in which low-intensity currents out of the photosphere are converging into the narrow, high-intensity currents at high altitude. This is enabled by the obliqueness of the latter. The very short time-scale of the energy conversion causes a lateral propagation of the current sheets. In a quasi-stationary situation, it balances the reconnection rate, which turns out to be much lower than in guide-field approaches. Another important consequence of the obliqueness is the field-parallel emission of runaway electrons. Accelerated up to tens of keV, they are possibly important contributors to the production of hard X-rays during the impulsive phase of a flare, however only in areas of upward directed currents. Quantitative evaluation of the model predicts various potentially observable properties, such as width and propagation speed of the generated flare ribbons, spatial dependences of the electron spectrum, size of the area of energy deposition, and successive decrease of the shear angle between conjugate foot points. The presented theoretical model can account for the observed brightness asymmetry of flare ribbons with respect to the direction of the vertical currents.

E2.2-0019-18 MAGNETIC RECONNECTION FLUXES IN SOLAR FLARES AND THEIR IMPLICATIONS FOR SOLAR AND STELLAR SUPERFLARES

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We study the energy release process of a set of 51 solar flares which span almost four orders of magnitude in flare energy, from GOES class B3 to X17. 19 events of our sample are eruptive, i.e. have a CME associated, and 32 are confined (no CME associated). We use Hα filtergrams from Kanzelhöhe Observatory together with SDO HMI and SOHO MDI magnetograms to derive magnetic reconnection fluxes and reconnection rates. We find that the flare reconnection flux is strongly correlated with the peak of the GOES 1-8 Å soft X-ray flux (r=0.9, in log-log space), both for confined and eruptive flares. In the largest events, up to 50% of the total magnetic flux of the host active region (AR) is involved in the flare magnetic reconnection. Based on these findings, we extrapolate the properties of the largest flares that may be launched from our present day's Sun. A complex solar AR that hosts a magnetic flux of 2 1023 Mx, which is supported by the largest active-region magnetic fluxes directly measured, is capable of producing an X80 flare (corresponding to a bolometric energy of about 7 1032 ergs). Using a magnetic flux estimate of 6 1023 Mx for the largest solar AR observed, we find that flares of GOES class X500 could be produced (Ebol 3 1033 ergs). Our results lie on the lower end of the energies of superflares on solar-type stars recently detected in Kepler data. Furthermore, they suggest that the present day's Sun is capable of producing flares and related space weather events more than an order of magnitude stronger than observed in the past.

E2.2-0020-18 HIGHLY IONIZED CA X-RAY SPECTRA FROM FLARES SEEN WITH THE DIOGENESS SPECTROMETER

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X-ray lines of helium-like calcium (Ca XIX) and nearby Ca XVIII dielectronic satellites have been observed in solar flares with a number of high-resolution spectrometers. The DIOGENESS instrument on the CORONAS-F spacecraft, a scanning crystal spectrometer which operated in 2001, observed these lines but in addition satellites of lower ionization stages of Ca as well as ionized Ar lines in the spectral range 3.05–3.35 Angstroms. In this work, spectra from flares including the X5 flare on 2001 August 25 are analyzed and compared with synthetic spectra. The latter were generated with a specially written code based on various theoretical data including results from the Cowan Hartree–Fock pseudo-relativistic code run for satellite lines. Solar flare spectra taken with the P78-1 SOLFLEX instrument in 1980–1981 are also analyzed. There is close agreement between the solar flare and synthetic spectra for the Ca XIX lines and Ca XVIII satellites (3.17–3.21 Angstroms) and also the Ca XVII satellites at 3.215–3.235 Angstroms clearly seen in DIOGENESS and some SOLFLEX spectra. In addition, fainter line emission at longer wavelengths (Λ> 3.24 Angstroms) in DIOGENESS spectra is identified with Ca XVI satellites and with the Ca XVIII "o" and "p" satellites as well as a feature due to Ar XVI. These identifications are confirmed by recent analysis of X-ray Ar and Ca spectra from the Alcator-C Mod tokamak high-temperature plasmas. The synthetic code developed for this work will be used for analysis of X-ray spectra, recently characterized with new calibration data, from the Solar Maximum Mission Bent

Crystal Spectrometer, and spectra expected from the Polish high-resolution ChemiX spectrometer/dopplerometer, due to fly on the [two] Russian Interhelioprobe spacecraft in 2025/2026.

E2.2-0021-18 KELVIN-HELMHOLTZ INSTABILITIES: A NOVEL INGREDIENT TO THE STANDARD FLARE MODEL

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In the standard flare model, energy deposition near the chromosphere from downwards accelerated particles leads to evaporation flows that invade the flaring loop. We modeled this process in isolation of the overarching reconnection site, and found that one can frequently encounter situations where these upflows from both loop legs meet up in a loop-top localized, turbulent fashion. At the loop apex, Kelvin-Helmholtz instability (KHI) of the interacting flows sets in and thermal soft X-ray photons are abound in the interaction zone. This, together with the intrinsically fragmented magnetic field topology due to the vortical disruption can explain hard X-ray sources in loop apexes: electrons trapped and accelerated in the turbulent region can upscatter soft X-ray photons. A parametric survey in a magnetohydrodynamic setting finds that the trigger of KHI and the generation of turbulence are determined by the amount of energy deposited in the chromospheric foot-points and the time scale of energy deposition.

E2.2-0022-18 DIAGNOSING FLARE DYNAMICS THROUGH THE FE XXI 1354.08Å LINE

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The Fe XXI 1354.08 line is the only strong emission line formed above 10 MK in the spectral range of IRIS. It has been demonstrated to be very useful in diagnosing flare dynamics. For instance, the complete evolution of chromospheric evaporation has been well observed and it appears to correlate with the energy deposition rate in many flares, which provides critical constraint to models of chromospheric evaporation. With the Fe XXI line we have even observed multi-episode chromospheric evaporations in a flare. The Fe XXI line has also been successful in observing reconnection outflows, revealing important insight into the flare reconnection process. Moreover, global MHD oscillations have been detected in flare loops, both in the intensity and Doppler shift of the Fe XXI line, allowing more accurate mode identification that is crucial for coronal seismology.

E2.2-0023-18 HIGH-ENERGY ASPECTS OF SOLAR FLARES: RECENT ADVANCES IN OBSERVATIONS AND MODELS

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Solar flares are one of the most spectacular manifestations of solar activity with significant space-weather impacts. They also serve as a unique laboratory for probing the underlying physics of wide-ranging processes, including magnetic reconnection, generation of plasma turbulence and shocks, particle acceleration, and plasma heating. Solar flares thus bear important implications for physically similar phenomena elsewhere in the universe, such as laboratory plasmas, planetary magnetospheres, and flares on other stars or near compact objects. In this presentation, we review recent observational and modeling advances in solar flare research, with a focus on high-energy aspects. Special attention will be paid to imaging and spectroscopic observations, e.g., of long-duration and behind-the-limb gamma-ray flares detected by Fermi, of coronal reconnection sites seen by RHESSI, SDO, Hinode, and IRIS, and of the flaring lower atmosphere (chromosphere and transition region) seen by IRIS. We will discuss broad physical connections of flares to other phenomena on the Sun (to a much greater extent than conventionally thought), such as the correlation between quasi-periodic flare pulsations (seen from radio to hard X-rays) and various MHD waves (some are directly imaged). We will also review relevant modeling efforts to explain these observations, focusing on a hybrid model of stochastic (by turbulence) plus shock acceleration of particles, as well as combined kinetic and radiative hydrodynamic simulations.

E2.2-0024-18 SUPERFLARES ON SOLAR TYPE STARS

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Superflares are defined as flares which are over 10 times more energetic (1033 erg) than largest flares ever observed on the Sun, and many superflares have been found on many solar-type stars, i.e. G-type main sequence stars in the Kepler-spacecraft data. Statistical analyses indicate that the frequency distribution to the flare energy of the superflare is almost consistent with that of the Sun. Many of superflare stars show quasi-periodic variations with timescales of about 1 to 30 days. Spectroscopic measurements of the projected rotation velocity suggest that these variations are due to rotation of superflare stars with large starspots. The size distribution of starspots shows the power-law distribution which is on the same line of the size distribution of relatively large sunspots. The frequency-energy distributions for flares originating from spots with various sizes are the same for solar-type stars with superflares and the Sun. These results suggest that the magnetic activity on solar-type stars with superflares and that on the Sun is caused by the same physical processes. Long term monitoring of the chromospheric activity and research on possible coronal mass ejections accompanying with superflares will give us an insight on the effects of superflares on the planetary environment, and possible extreme space weather events on the Earth.

E2.2-0025-18 STATISTICAL STUDIES OF SOLAR WHITE-LIGHT FLARES AND COMPARISONS WITH SUPERFLARES ON SOLAR-TYPE STARS

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Recently, many superflares on solar-type stars have been discovered as white-light flares. Our statistical study found a correlation between their energies (E) and durations (t): t E0.39

(Maehara et al. 2015, EP&S), similar to those of solar hard/soft X-ray flares: t E0.2−0.33.

This indicates a universal mechanism of energy release on solar and stellar flares, i.e., magnetic reconnection. We here carried out a statistical research on 50 solar white-light flares with SDO/HMI and examined the correlation between the energies and durations, aiming to universally explain solar and stellar white-light flares. As a result, the t-E relation on solar white-light flares (t ∝ E0.38) is similar to that on stellar superflares (t ∝ E0.39). However, the durations of stellar superflares are one order of magnitude shorter than those expected from solar white-light flares. We proposed that the discrepancy can be understood by applying a scaling law (t E1/3B−5/3) which is derived from the magnetic reconnection theory (Namekata et al. 2017, ApJ, 851, 91). In this case, the observed superflares are expected to have 2-4 times stronger magnetic field than solar flares. Although there might be another effect like the cooling time of white-light flares, the scaling law has a potential to estimate coronal magnetic field strength of spatially unresolved stellar flares.

E2.2-0026-18 COLLISIONAL AND NON-COLLISIONAL KINETIC MODELING OF FLARING REGIONS WITH STOCHASTIC DIFFERENTIAL EQUATION METHODS

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The rapid energy release in solar flares and the formation of non-thermal electron distributions is widely believed to be caused by magnetic reconnection near the looptop region. Depending on the background plasma properties, an interplay of collisional and non-collisional processes can shape the energetic coronal population that may emit, for example, hard X-ray bremsstrahlung radiation. Both the finite background plasma temperature, as opposed to a simple cold target approach, and the turbulence properties in the flaring region, are crucial in shaping the emerging energy distribution of particles. Here, we present results of a newly developed kinetic simulation approach that models these processes in conjunction. It is based on a stochastic formulation of the underlying Fokker-Planck kinetic equation that is fully pitch-angle and time-dependent, to allow also detailed studies of the time evolution during acceleration, the relaxation to stationary solutions, and the escape from the acceleration region. In particular, we will discuss the relaxation to non-thermal kappa distributions in velocity. We present the results together with synthetic X-ray emission profiles that can be compared to observations of looptop and above-the-looptop signatures. Future extensions of the model to cross-field transport effects and the relation to solar energetic particle release are also addressed.

E2.2-0028-18 OBSERVING TURBULENCE EARLY IN A SOLAR FLARE WITH THE HIGH TIME RESOLUTION OF IRIS

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Wave and turbulent dissipation play a key role in the transfer of energy in magnetized plasmas. Here we report the first high time-resolution, <2 s, spectroscopic study of flare turbulence in the lower solar atmosphere, using the Interface Region Imaging Spectrograph (IRIS). We observe the line Si IV 1402.77 Å, formed at a transition region temperature of 80000 K, at the eastern flare footpoint, over a region of <0.3" during the flare duration. The non-thermal broadening indicates turbulent motions with velocities of 60-70 km/s. The line broadening rises sharply, and precedes the flare onset as indicated by its impulsive radiation signatures in Si IV intensity, extreme ultraviolet (EUV) and X-rays. The <2 s cadence shows that the line broadening oscillates with a period of 10 s before its decay, coinciding with motions in the Si IV line centroid position. The results are consistent with the dissipation of turbulent energy in the lower atmosphere, early in the solar flare, and before the flare brightening.

E2.2-0030-18 SOLAR FLARE OBSERVATIONS WITH INTEGRAL FIELD SPECTROSCOPY IN H-ALPHA SPECTRA AND SDO/AIA

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Integral field spectroscopy is a two dimensional spectroscopic technique, providing spectra simultaneously for each spatial direction of an extended two-dimensional field. Using the field integral spectroscopy made of microlenslet-array (30x30 lenslets) in H-alpha spectrum, GOES Cand M-class flares on 3 Nov 2011 were successfully observed with the 60 cm aperture Domeless Solar Telescope at Hida Observatory, Kyoto University. The data spatially sampled with 0.5 arcsec over 10x10 arcsec FOV and 1 nm wavelength band centered H-alpha line demonstrated that simultaneous 2D spectroscopic observations over extended solar structures, at a high spatial resolution and temporal cadence, are important to track and understand the physics of transient phenomena happening in impulsive flare bright kernels. We made monochromatic images at given wavelengths in the H-alpha line and nearby continuum to co-align the data with X-ray, UV images and magnetograms from SDO/AIA and HMI. To reveal dynamical properties of the flare kernels, we carried out line profile analysis and derived 2-D distribution of parameters such as line-of-sight velocity and line width. The results clearly show the rapid development of red asymmetry at the flare kernels, giving a large downward Doppler shifts of up to 50 km/sec. The accompanied formation of coronal dynamic flaring loop structures seen in SDO X-ray images are consistent with a scenario of downward motion of compressed chromospheric flare kernels due do impulsive heat flow from the corona to the chromosphere and simultaneous evaporation of the chromospheric material into the corona.

E2.2-0031-18 THE ACTIVE REGION 12673 X9 FLARE OBSERVED FROM THE SUBMILLIMETER TO MID-IR

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Active Region 12673 produced the most intense event of the solar cycle 24: in a few days of early September 2017, four X-class and eight M-class flares occurred. SOL2017-09-06T12:00, a GOES X9.3 flare, that also produced a two-ribbon white-light emission across the sunspot detected by SDO/HMI, was observed at 212 and 405 GHz with the arcminute-size beams of the Solar Submillimeter Telescope focal array while making a solar map, and at 30 THz, with a 17 arcsec difraction-limited IR camera. SST was observing far from the source when the maximum of the impulsive phase occurred and did not detect a significant flux excess. When the antenna was pointing close enough to the source, we derived the excess brightness temperatures by comparing with the quiet Sun and obtained 5900 and 1800 K at 212 and 405 GHz respectively. Images at 30 THz revealed that the sunspot gradually increased in brightness while the event proceeded, reaching a temperature similar to quiet Sun values. From the images we derive a 180 K flare peak excess brightness temperature assuming 5000 K for the quiet Sun. The peak occurred tens of seconds before the Soft-X Rays peak observed by GOES, afterwards the 30 THz source cooled and returned to the preflare level only almost 2 hours after the flare started.

E2.2-0032-18 X4.9 CLASS SOLAR FLARE ASSOCIATED WITH FILAMENT ERUPTION AND SOLAR ENERGETIC PARTICLES ON 2014 FEBRUARY 25

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We perform a detailed multi-wavelength study of an eruptive X4.9 flare and its associated halo CME-driven shock. On 2014 January 25, AR NOAA 11990 was situated close to the eastern limb at heliographic coordinates of S12E82. A major flare occurred in the time interval between 00:39 and 01:03 UT with maximum emission at 00:49 UT as recorded the GOES and RHESSI flux data. The flare light curves exhibit an abrupt rise of non-thermal emission with very high HXR bursts up to 300 keV evidencing an intense energy release in the form of non-thermal particles. The HXR time profiles displayed multiple peaks. Around the HXR impulsive peak (at 00:46 UT) temperature was about 30 MK which corresponds to the maximum temperature during the flare. This fact and SDO/AIA observations in the different (E)UV bands point that the observed plasma is multi-thermal. The non-thermal HXR emission was not very significant after 00:55 UT. The combined multi-wavelength (E)UV view of the flare exhibits a set of coronal magnetic loop structures with different orientations underwent a series of morphological evolutions at the AR. With the beginning of impulsive phase we can clearly recognize two localized structures as low-lying loops which are not associated with significant X-ray emission but show distinct bright (E)UV emission above the core region. These structures consist of rapidly expanding bright helically twisted loops associated with the erupting prominence and can be attributed to the portions of the heated prominence within the flux rope. Expanding bright loops displayed ejection in the form of Ω-like kinked eruption structure. The prominence along with its supporting flux rope had a successful escape through the overlying loops. The complete eruption of the filament proceeded symmetrically from the AR with a strong halo CME-driven shock but thereafter, the eruption evolved into an asymmetrically propagated fast huge structure which is one of the sources responsible for SEPs as recorded the in situ observations of the inner heliosphere from WIND spacecraft.

Key words: solar flare, CME and SEP; X-ray and (E)UV emissions.

E2.2-0033-18 INITIATION PROCESSES FOR THE 2013 MAY 13 X1.7 LIMB FLARE

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For the X 1.7 class limb flare on May 13, 2013 (SOL2013-05-13T01:53), its initiation processes were well observed and it incorporates following phenomena: an X-ray precursor that peaked sim 7 minutes before the onset of the flare, two J-shaped magnetic loops forming a Sigmoid magnetic structure, an expanding magnetic flux rope, and a contracting flare loop. We report that the two J-shaped magnetic loops were activated by the X-ray precursor. After the activation, magnetic reconnection occurred inside the Sigmoid structure, which produced the expanding magnetic flux rope and the contracting flare loop. For this flare, the real initiation time can be regarded as from the starting time of the precursor and its impulsive phase started when the magnetic flux rope began its fast expansion. In addition, we confirm that the phenomenon of contracting flare loop, which proceeds expanding post-flare loops, can be regarded as the signature of magnetic reconnection between sheared magnetic fields that produces magnetic flux rope.

E2.2-0035-18 HALPHA BRIGHTENING ON THE PROPAGATION OF EXCITOR OF CORONAL TYPE V SOLAR RADIO BURST

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This paper presents multiwavelength observations of a type V radio burst in the absence of solar flare in X-ray band. The kinematics of the speed derived from the type V closely match with a fast drifting radio emission seen in the dynamic spectra recorded in Kodaikanal Solar Observatory(KSO). It was initially observed in the KSO dynamic spectra after a delay in WINDS/ WAVES ultra low frequency radio spectrum recorded from space. The uniform and usual coronal density topology was revealed at the flare site studied using polarised brightness pB (LASCO). A small, confined filament eruption (sunspot area 300m) was also observed. We suggest that fast transport of energetic particles through open field lines responsible for the absence of flare or coronal mass ejection or Coronal shock.

E2.2-0036-18 THE FIRST STEPS OF A NEW SPACE SUN-TERAHERTZ PROJECT

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Development of a new space SUN-TERAHERTZ project started at the Lebedev Physical Institute of the Russian Academy of Sciences in 2017, in the scope of the Russian Space Agency Program. The SUN-TERAHETZ' device is planned to fly on board Russian segment of the International Space Station in 2021-2022. This paper reports on the details of the first stage of the SUN-TERAHERTZ space project. We discuss scientific goals of the future experiment and present specification of the proposed THz experimental device.

E2.2-0037-18 SCIENCE OBJECTIVES OF THE SOLAR-C_EUVST

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Solar-C WG

Shimizu T., Kawate T. et al.

Solar-C EUVST (EUV High-Throughput Spectroscopic Telescope) is designed to comprehensively understand the energy and mass transfer from the solar surface to the solar corona and interplanetary space, and to investigate the elementary processes that take place universally in cosmic plasmas. The proposed mission is a fundamental step for answering how the plasma universe is created and evolves, and how the Sun influences the Earth and other planets in our solar system. The two primary science objectives for Solar-C EUVST are: I) Understand how fundamental processes lead to the formation of the solar atmosphere and the solar wind, II) Understand how the solar atmosphere becomes unstable, releasing the energy that drives solar flares and eruptions. Solar-C EUVST will, A) seamlessly observe all the temperature regimes of the solar atmosphere from the chromosphere to the corona at the same time, B) resolve elemental structures of the solar atmosphere with high spatial resolution and cadence to track their evolution, and C) obtain spectroscopic information on the dynamics of elementary processes taking place in the solar atmosphere. In this talk, we will first discuss the science target of the Solar-C EUVST, and discuss the science topic associated flare in detail. Photospheric motions lead to the accumulation of free magnetic energy in the corona. This system eventually becomes unstable, releasing the energy through magnetic reconnection. This process of energy conversion heats the plasma to high temperatures and drives coronal mass ejections (CMEs). By measuring the properties of multi-temperature flaring plasma, Solar-C EUVST will investigate why the reconnection is fast despite the high magnetic Reynolds number. It will also monitor the temporal evolution of solar active regions and identify the triggering mechanism for the flare and eruption. Therefore two important science objectives are defined for the flare physics. The first objective is “Understand the Fast Magnetic Reconnection Process”. Magnetic reconnection is one of the fundamental processes for converting magnetic energy into the thermal and kinetic energy of the plasma. This process occurs much faster than is predicted by classical theory. Solar-C EUVST will observe the dynamics of magnetic structures to understand the mechanisms that lead to fast magnetic reconnection in partially or fully ionized plasmas. The second objective is “Identify the Signatures of Global Energy Buildup and the Local Triggering of the Flare and Eruption”. Understanding the accumulation and release of free magnetic energy in the corona is a fundamental problem. Solar-C EUVST will perform long-term monitoring of active regions to identify the signatures of energy buildup and high-resolution observations to understand the triggers of energy release.

E2.2-0038-18 DEFINING A SUN QUAKE: A STEP TOWARDS AUTOMATED DETECTION

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Using acoustic holography, we study the acoustic emission from near-surface layers in the photosphere: quiet Sun, flaring and non-flaring active regions and place the results in the context of known and newly discovered sunquakes. We demonstrate the existence of unique set of parameters allowing us to detect a sun quake based on the analysis of photospheric data only without a priori knowledge of the flare.

E2.2-0039-18 MODERNISED FLARE DETECTION ROUTINES FOR MULTI-WAVELENGTH TIMESERIES DATASETS

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We present a new method for the detection of solar flares in low cadence timeseries, based on modern peak-recognition signal processing techniques. Using both simulated and observational data we evaluate this method's performance against other techniques for detection qualitatively and quantitatively.

Applied to GOES XRS X-ray lightcurves, we show that this algorithm makes compelling improvements to detections as reported in the Heliophysics Events Knowledgebase (HEK), with specific breakdowns given on the resulting population of flares detected with variation of the input parameters and signal pre-processing. We extract flare parameters including peak, duration and estimated energy, establishing their dependence or independence on the input parameters for the method. The resulting distributions are compared with available observations and models.

Furthermore, we adapt the method to work on multi-spectral data, including solar white-light intensity data, presenting initial results of detection and analysis with Kepler datasets, with the latter cross-references and compared with GOES output.

E2.2-0041-18 MULTIWAVELENGTH STUDY OF 24 EQUATORIAL CORONAL-HOLE JETS

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We studied 24 equatorial coronal-hole (ECH) jets using SDO/AIA and HMI observations on 27-28 June 2013 and 8-10 January 2014. Out of 24 jets (i) 16 jets (67%) are associated with mini-filament eruptions; (ii) 8 jets (34%) are triggered without mini-filament eruptions but with mini-flare arcades and other CME-like signatures; (iii) 5 jets (21%) are apparently associated with tiny flux-cancellation events at the polarity inversion line; (iv) 3 events are associated with sympathetic eruptions of filaments from neighboring jet source regions. The potential field extrapolations of the source regions reveal that almost all jets occurred in the fan-spine topology, and most of the events are in agreement with the breakout model of solar jets. We will present selected examples of each type, and discuss the implications for the jet energy-buildup and initiation mechanisms.

E2.2-0043-18 SOLAR SOFT X-RAY OBSERVATION BY CHANG'E-2 SOLAR X-RAY MONITOR

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Solar X-ray monitor (SXM) was a part of X-ray spectrometer onboard CHANG'E-2 mission. It measured solar X-ray spectra in the energy band of 1keV 10keV, which could be helpful for the elemental quantitative analysis of lunar X-ray fluorescence. Meanwhile SXM also act as a scientific payload for solar flare studies. From October 2010 to May 2011, SXM was operated for more than 200 days in a 100km lunar orbit. During that time, more than 100 solar X-ray bursts (GOES level from B to X) were observed. In this paper, a summary of in-orbit operation and dataset status of SXM were present. Besides, several flare spectra were analyzed to achieve the fundamental parameters (e.g. electron temperature, EM) which could describe the evolution of solar coronal plasma in these flares.

E2.2-0044-18 SMALL SOFT X-RAY SPECTROMETER FOR THE FOCUSING OPTICS XRAY SOLAR IMAGER - FOXSI

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Spectrometer for Temperature and Composition (STC) will monitor solar X-ray flux between 0.8 keV and 15 with 0.2 keV emergency resolution. The instrument provide fast solar X-ray spectroscopy in the entire flux intensity range, variable seven order in intensity form quiet solar conditions to strongest flares. The exceptionally wide dynamic range of this instrument as well as its high spectral and temporal resolution and wide plasma temperature coverage will result in unprecedented measurements, crucial for energy release processes and space weather monitoring. In addition the data collected by STC will complement the main FOXSI instrument measurements and allow temperature, composition and emission measure analysis for structures seen in the solar corona.

E2.2-0045-18 ANALYTICAL STUDY OF X-CLASS FLARES RELEASED DURING THE DECLINE PHASE OF SC24

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Eruptive X-class flares occurring during the decline phase of the solar cycle 24 are stronger than those of solar cycle 23. We notice that the solar cycle 24 is the weakest in last 100 Years. The last two cycles are very weak compared to other cycles, except for the Dalton Minimum cycles 4, 5, 6 and 7; which means the appearance of a new Dalton minimum during 23, 24, 25 and 26. During the last 5 solar cycles, a new peak has appeared releasing high energetic particles and X-class solar flares which are called the secondary peak or the double peak of the solar cycle. The aim of this analytical study is to follow the X-class flares released during the decline phase of SC24, to predict, applying data analysis, when they would be released, and to compare it with other solar cycles. The causes of the release of such eruptive storms, through the year 2014, during the double peak of the solar cycle 24 were also discussed.

E2.2-0046-18 SOLAR FLARE NEUTRINO SIGNALS AND FLAVORS BY HYPER KAMIOKANDE IN JAPAN AND COREA: A NEW NEUTRINO ASTRONOMY

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The project and the near future building of a twin Megaton neutrino detector as HyperKamiokande both in Japan and possibly, in South Corea will provide in a near future the most advanced (in few MeV up to several GeVs energy windows) telescope of galactic and nearby (Andromeda, LMC.) Supernova (SN) thermal neutrino events by their SN neutrino burst. These rare SN must be located within one or a few Mpc. The underground HK may also better trace the atmospheric neutrinos signals testing their precise flavor mixing and their matter-anti matter component (or eventual asymmetry). In this flavor test the same elusive tau neutrino appearence (by atmospheric muon neutrino oscillation at several GeV) may be also be finally well probed. In addition to astrophysical and (atmospheric and fundamental) physics, the HK may also discover the first multiwave detection of X-gamma photons and their correlated tens MeV (up to GeV) neutrino signals during largest solar flare. Such a physics may combine the solar flare plasma physics with its inner proton proton scattering and with consequent, also via Delta resonances, pion and Kaon production. This expected discover, after SN1987A and Solar neutrino astronomy, will open a third independent solar Neutrino windows. The neutrino flavor mixing, might test better the neutral lepton parameters. The prompt and timed detection of solar flare may offer the most advances alarm system for satellite (and astronauts) survival. In particular when the solar flare occurs in the hidden solar side. Foreseen solar neutrino spectra, signature and rate in HK for each neutrino flavor will be shown in details. References: 1) D.Fargion, "Detecting Solar Neutrino Flares and Flavors"; JHEP 0406,045, (2004). 2) D. Fargion, "Anti-Neutrino Imprint in Solar Neutrino Flare", Phys.Scripta T127:22-24,(2006). 3) D. Fargion, P. Di Giacomo, Detecting Solar Neutrino Flare in Megaton and km3detectors;Nucl:P hys:P roc:Suppl:188: 142 - 145; (2009)

E2.3-0001-18 SOLAR POLARIMETRY - FROM TURBULENT MAGNETIC FIELDS TO SUNSPOTS

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Polarimetric measurements are essential to investigate the solar magnetic field. Scattering polarization and the Hanle effect allow us to probe the turbulent magnetic field and the still open questions of its strength and variability. Directed magnetic fields can be detected via the Zeeman effect. To derive their orientation and strength, so-called inversion codes are used, which iteratively modify a model atmosphere and calculate the resulting polarization profiles that are then compared to the observations. While photospheric polarimetry is well-established, chromospheric polarimetry is still in its infancy, especially because it requires a treatment in non-LTE, making it a complex non-linear problem. But some of the most important open questions concern the strength and geometry of the chromospheric magnetic field. In this talk, I will review different polarimetric analysis techniques and recent advances in magnetic field measurements going from the small scales of turbulent magnetic fields to changes of magnetic fields in an active region during flares.

E2.3-0002-18 EMERGENCE OF INTERNETWORK MAGNETIC FIELDS THROUGH THE SOLAR ATMOSPHERE

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Internetwork (IN) magnetic fields are highly dynamic, short-lived magnetic structures that populate the interior of supergranular cells. Since they emerge all over the Sun, these smallscale fields bring a substantial amount of flux, and therefore energy, to the solar surface. Because of this, IN fields are crucial for understanding the quiet Sun magnetism. However, they are weak and produce very small polarization signals, which is the reason why their properties and impact on the energetics and dynamics of the solar atmosphere are largely unknown. Here we use coordinated IRIS and SST observations of IN regions at high spatial and temporal resolution. They give us the opportunity to follow the evolution of IN magnetic loops as they emerge into the photosphere. For the first time, our polarimetric measurements provide a direct observational evidence of IN fields reaching the chromosphere. Moreover, we show that IN magnetic loops contribute to the chromospheric and transition region heating through interaction with preexisting ambient fields.

E2.3-0003-18 SPECTRAL LINE POLARIZATION IN THE SUN, THE LANGUAGE OF THE CHROMOSPHERIC MAGNETIC FIELDS

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The solid understanding of the solar chromosphere and its magnetic connection with the photosphere and the corona is, nowadays, one of the big challenges in solar astrophysics. Within the chromosphere, an extended region of about nine pressure scale heights, the temperature rises from few thousand kelvin to the million degrees of the low corona. Moreover, the dominant physics in this region changes with height from a medium dominated by hydrodynamics to a plasma dominated by the magnetic field. While the observed intensity spectrum mostly contains information about the thermodynamics of the emitting plasma, at least under quiet Sun conditions, the polarized spectrum of atomic lines contains key information to determine the strength and topology of the magnetic fields. In this presentation I will talk about our current capabilities and recent advancements on the theory and modeling of spectral line polarization in optically thick plasmas such as the solar atmosphere, in particular, for strong permitted chromospheric lines.

E2.3-0004-18 MAGNETIC FIELD MEASUREMENTS IN THE SOLAR CORONA: FACING THE CHALLENGE WITH GROUND AND SPACE BASED OBSERVATIONS

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Actual limitations in understanding physical processes occurring in the solar atmosphere are related with our poor capabilities in measuring magnetic fields in its layers. The knowledge of magnetic fields in the solar corona is crucial to understand the origin of solar flares and Coronal Mass Ejections, waves, coronal heating and solar wind acceleration. For these reasons many different techniques have been proposed to provide these measurements by analysing the emission related with many different physical phenomena (e.g.: radio observations of gyrosynchrotron and free-free emission, infrared observations of Zeeman effect, visible and infrared obervations of the Hanle effect, UV-EUV observations of CME-driven shock waves, etc.). In order to provide a continuous monitoring of coronal fields, new groundand space-based instrumentations are currently under development, as well as new techniques to infer the real fields from the line-of-sight integrated coronal emission. At the same time, the forward modelling of the expected emission starting from different possible coronal field configurations is being developed, allowing the definition of the required properties for future instrumentation and the verification of the data analysis results.

E2.3-0005-18 LINEAR LINE-POLARIMETRY: PROBING THE MAGNETIC FIELD MECHANISMS OF ENERGY DEPOSITION IN CORONA.

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Optically-thin, UV spectral lines in corona are linearly polarized by resonance scattering of chromospheric line-emissions off coronal ions. In the presence of coronal magnetic fields, the resontantly-scattered line-polarization is modified by the Hanle effect. Spectro-polarimetric UV observations from space of these line-emissions, interpreted in terms of the Hanle effects, are a powerful tool for the diagnostics of magnetic fields in the solar chromosphere/corona. Through the anisotropic Doppler-dimmng effect, the linear polarization of optically thin spectral lines is sensitive to anisotropic ion-velocity distributions that can be induced by the ion-cyclotron resonance between plasmas and MHD waves in corona. This effect is believed to influence some heavy ions in the solar corona. Thus, coronal polarimetry of resonantly scattered UV spectral lines can also serve as a powerful tool for probing the magnetic field mechanism(s) of energy deposition in corona.

This presentation reports the parameter study carried out by forward modeling of the linear polarization of the coronal UV spectral lines HI Lyman-α, 121.6 nm, and OVI, 103.2 nm. The study was based on the FORWARD numerical code developed by the High Altitude Observatory. The study used FORWARD to reproduce synthetic linear line-polarization maps for different MHD models of the corona.

The results from the parameters study indicate that the Hanle effect diagnostics is most effective within a few tens of solar radii from the solar limb in closed-field, active regions where the strength the coronal magnetic field is within the Hanle effect sensitivity for the HI Lyman-α and OVI lines (i.e., 2-60 gauss). On the other hand, the effect of anisotropic velocity field distributions of scattering ions on the line-polarization emitted by resonance scattering is most effective in open-filed regions of non-radial solar wind, such as the interface coronal holesstreamers.

E2.3-0006-18 CURRENT STATE OF UV SPECTRO-POLARIMETRY AND ITS FUTURE DIRECTION

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To obtain quantitative information on the magnetic field in low beta regions (i.e., upper chromosphere and above) has been increasingly important to understand the energetic phenomena of the outer solar atmosphere such as flare, coronal heating, and the solar wind acceleration.

In the UV range, there are abundant spectral lines that originate in the upper chromosphere and transition region. However, the Zeeman effect in these spectral lines does not give rise to easily measurable polarization signals because of the weak magnetic field strength and the larger Doppler broadening compared with the Zeeman effect. Instead, the Hanle effect in UV lines is expected to be a suitable diagnostic tool of the magnetic field in the upper atmospheric layers.

To investigate the validity of UV spectro-polarimetry and the Hanle effect, the Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP), which is a NASA soundingrocket experiment, was launched at White Sands in US on September 3, 2015. During its 5 minutes ballistic flight, it successfully performed spectro-polarimetric observations of the hydrogen Lyman-alpha line (121.57 nm) with an unprecedentedly high polarization sensitivity of 0.1% in this wavelength range. CLASP observed the linear polarization produced by scattering process in VUV lines for the first time and detected the polarization signals which indicate the operation of the Hanle effect.

Following the success of CLASP, we are confident that UV spectro-polarimetry is the way to proceed, and we are planning the second flight of CLASP (CLASP2: Chromospheric LAyer SpectroPolarimeter 2). For this second flight we will carry out spectro-polarimetry in the Mg II h and k lines around 280 nm, with minimum modifications of the CLASP1 instrument. The linear polarization in the Mg II k line is induced by scattering processes and the Hanle effect, being sensitive to magnetic field strengths of 5 to 50 G. In addition, the circular polarizations in the Mg II h and k lines induced by the Zeeman effect can be measurable in at least plage and active regions. The combination of the Hanle and Zeeman effects could help us to more reliably infer the magnetic fields of the upper solar chromosphere. CLASP2 was selected for flight and is being developed for launch in the spring of 2019.

Based on these sounding rocket experiments (CLASP1 and 2), we aim at establishing the strategy and refining the instrument concept for future space missions to explore the enigmatic atmospheric layers via UV spectro-polarimetry.

E2.3-0007-18 CONSTRAINING THE MAGNETIZATION AND GEOMETRICAL COMPLEXITY OF THE CHROMOSPHERE-CORONA TRANSITION REGION VIA RADIATIVE TRANSFER MODELING OF THE CLASP OBSERVATIONS

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On 3 September 2015 an international team of scientists from Japan, USA and Europe carried out succesfully a challenging measurement using a vacuum ultraviolet telescope and a spectropolarimeter called CLASP, launched by a NASA suborbital rocket (see the talk by R. Ishikawa et al.). For the first time, CLASP measured the linear polarization profiles of the hydrogen Lyman-alpha and Si III 120.6 nm lines produced by the scattering of anisotropic radiation in the enigmatic chromosphere-corona transition region of the Sun. Here we report about the radiative transfer investigations we have carried out for interpreting the Stokes Q/I and U/I profiles observed by CLASP in such ultraviolet resonance lines. We explain why the observed Lyman-alpha polarization does not show a clear center to limb variation. We show also that the observed Stokes profiles encode a rich information on the magnetization and geometrical complexity of the plasma of the upper solar chromosphere.

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E2.3-0008-18 SOLAR MAGNETIC FIELDS FROM LOW RADIO FREQUENCY OBSERVATIONS: OPPORTUNITY, STATUS AND CHALLENGES

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Though they are now understood to be the drivers of all solar activity and the reservoir of energy for coronal heating, coronal magnetic fields remain notoriously hard to measure. The low radio frequency (< 300 MHz) solar emissions originate at coronal heights of beyond 0.1R0 above the photosphere, and are intrinsically sensitive to the magnetic fields in this region due to a range of different phenomena. The type III solar burst emission, for instance, is believed to come from beams of accelerated electrons streaming along the magnetic fields; accordingly their imaging can potentially provide direct determination of coronal magnetic field structures, geometries, and magnetic reconnection. In a handful of instances, it has been possible to directly image the synchrotron emission from the semi-relativistic plasma in the Coronal Mass Ejections and constraints on their magnetic fields have been successfully obtained. The birefringent nature of the coronal plasma implies that even the unpolarized thermal free-free emission picks up a small amount of circular polarization, the measurement of which can provide a measure of the average coronal magnetic field. In spite of their unique and informative diagnostic capabilities, applications of radio observations have remained rather limited. This is primarily because of the limited capacity of the radio instrumentation available till recently to capture this information in sufficient detail. This is now rapidly changing with the new generation radio interferometers like the Murchison Widefield Array (MWA), the LOw Frequency Array (LOFAR) and the Long Wavelength Array (LWA). The high dynamic

range snapshot spectroscopic imaging capabilities of the MWA are much better matched to the needs of solar radio science. We have been working on systematically developing the tools needed to enable the scientific exploration of these high-SNR fine-grained data and pursue science opportunities with them. Our efforts have spanned the range from developing techniques for flux calibration and an imaging pipeline; to quantifying the strength and prevalence of weak impulsive nonthermal emissions; and detailed multi-wavelength analyses to elucidate the relationship between the magnetic structures and geometries seen in SDO UV-EUV bands and the type III bursts imaged by the MWA. Here we will briefly discuss the opportunity presented by the new generation low radio frequency arrays, present the current status of our efforts with some examples and touch upon the challenges ahead.

E2.3-0009-18 INTERPRETATION OF HANLE EFFECT MEASUREMENTS IN THE SOLAR CORONA: PROMISES AND DIFFICULTIES

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After having recalled the main features of the Hanle effect, and of its application to coronal lines, the promises and difficulties of the measurement interpretation in terms of magnetic field vector diagnostics, will be investigated, based on Bommier, V., Leroy, J.L., and Sahal-Bréchot, S., 1981, A&A, 100, 231, and in the light of the new instrumentation presently available or in project, as well as data-driven modeling present possibilities. The feasibility of measuring the Coronal magnetic field by interpretation of the Zeeman effect observed in the infrared, will also be investigated.

E2.3-0010-18 SELF-CONSISTENT MULTI-DIMENSIONAL INVERSION PROBLEM

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The main goal of solar spectropolarimetry is to infer reliable physical information about the plasma structures from the observed Stokes profiles of spectral lines. In order to solve the general multi-D inversion problem of optically thick spectral lines, one can take advantage of sparsity of the observed data. Additional regularization of the problem imposed by the need to satisfy the requirement of the NLTE self-consistent solution leads to a robust inference method. Coupling of the massivelly parallel forward solver taking into account the scattering polarization, Hanle, and Zeeman effects with a suitable inversion algorithm allows us to develop efficient inversion procedures for thermal and magnetic properties of the solar plasma. Here we show the first results of our numerical experiments.

E2.3-0011-18 THE MAGNETIC NEEDS FOR UNDERSTANDING (AND PREDICTING) SOLAR ENERGETIC EVENTS

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Energetic Solar Events – solar flares, coronal mass ejections, and the acceleration of high-energy particles – are all believed to be triggered at some level by the sudden reconfiguration of solar magnetic field lines, and powered at some level by stored magnetic energy. So, to understand and ultimately predict these events, we need to measure the magnetic fields on the Sun at all times, in all of space (with no uncertainty, of course). Is that even possible? No. So, what information is really accessible about this all-important magnetic field, how do we acquire it, and how can we best use what we've got? In this talk I will touch upon the diversity (and limitations) of our present resources and the wide range of questions they are being used to answer regarding solar energetic events. I will also review some outstanding questions and what these imply for future magnetic field observational requirements in the quest to further extend our understanding (and ultimately, the prediction) of these phenomena.

E2.3-0012-18 DATA-INSPIRED, DATA-CONSTRAINED AND DATA-DRIVEN MODELING OF SOLAR ACTIVE REGIONS

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Recent advances in numerical modeling have provided important lessons on the physics that cause solar active regions to erupt and flare. While the majority of past work has been datainspired (and based on somewhat idealized scenarios), improvements in observational coverage is beginning to facilitate data-constrained and data-driven modeling. Data-constrained models are those that use observational constraints in one instance in time, while data-driven models are evolved in response to changing boundary conditions (e.g. at the solar photosphere) consistent with observations. In this talk, we review some recent results from these three classes of models. The implications of the models for desired future instrumentation will also be discussed.

E2.3-0013-18 "BUILDING A MAGNETIC SKELETON OF THE SOLAR CORONA: TOWARDS BETTER 3-D CONSTRAINTS ON THE CORONAL MAGNETIC FIELD

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The energy stored in the solar magnetic field is what is powering many violent explosive events in the solar atmosphere, or the corona. Some of these events result in the coronal mass ejections (CME's) released into the interplanetary space. The magnetic field in the solar corona is therefore very important to know, yet it is very difficult to measure. Most of the time it is modeled with the magnetic maps at the solar surface used as boundary conditions. The magnetic maps on the surface are therefore also important to know, yet the full vector of the field on the surface is also difficult to measure. Once such measurements are made, constructing a model capable of predicting eruptive potential of a given region is on its own a complicated task. One of the problems arising is that that the equations for low-beta equilibria, which are often used to describe the coronal field, do not, strictly speaking, work for the solar surface. In short, we need better inputs to model the solar corona. The use of non-magnetic and nonsurface constraints on the magnetic field becomes increasingly popular. For example, the paths of filaments can be used to guide flux rope trajectories; the loops of active regions, seen in extreme ultraviolet (EUV) can be used to obtain 3-D trajectories of magnetic field lines and estimate electric currents flowing along them. We are currently exploring ways to use other sources of data, such as flows in prominences and coronal spectropolarimetric data, in a similar fashion. I will talk about this work, and about our project of aggregating many different sources of non-magnetic 3-D constraints on the magnetic field. The resulting 'skeleton' can be used to constraint global field models, or to validate models obtained in traditional ways. We intend to develop a pipeline and assemble several skeletons for several instances in time of the Sun, which we will then release to community.

E2.3-0014-18 DIAGNOSING THE MAGNETIC FIELD STRUCTURE OF A CORONAL CAVITY OBSERVED DURING THE 2017 TOTAL SOLAR ECLIPSE

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We present an investigation of a coronal cavity observed above the western limb in the coronal red line Fe X 637.4 nm using a telescope of Peking University and in the green line Fe XIV 530.3 nm using a telescope of Yunnan Observatories, Chinese Academy of Sciences during the total solar eclipse on 2017 August 21. A series of magnetic field models are constructed based on the magnetograms taken by the Helioseismic and Magnetic Imager onboard the Solar Dynamics Observatory (SDO) one week before the eclipse. The model field lines are then compared with coronal structures seen in images taken by the Atmospheric Imaging Assembly on board SDO and in our coronal red line images. The best-fit model consists of a flux rope with a twist angle of 3.1pi, which is consistent with the most probable value of the total twist angle of interplanetary flux ropes observed at 1 AU. Linear polarization of the Fe XIII 1074.7 nm line calculated from this model shows a “lagomorphic” signature that is also observed by the Coronal Multichannel Polarimeter of the High Altitude Observatory. We also find a ring-shaped structure in the lineof-sight velocity of Fe XIII 1074.7 nm, which implies hot plasma flows along a helical magnetic field structure, in the cavity. These results suggest that the magnetic structure of the cavity is a highly twisted flux rope, which may erupt eventually. The temperature structure of the cavity has also been investigated using the intensity ratio of Fe XIII 1074.7 nm and Fe X 637.4 nm.

E2.3-0015-18 PREDICTING SUNSPOT CYCLE 25 BASED ON CENTURY-SCALE CALIBRATED SOLAR ACTIVITY SIMULATIONS

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The cycle of sunspots modulates the electromagnetic and particulate environment of near-Earth space creating hazardous space weather. Space weather impacts satellite operations, telecommunications, polar air-traffic and electric power-grids. Predicting the sunspot cycle, however, has remained an outstanding challenge. No consensus was achieved among early forecasts for cycle 24 and the cycle strength was much lower than expected. Based on understanding gleaned in recent years, and utilizing a coupled solar surface flux transport model and a dynamo model, we perform the first ever century-scale calibrated, data driven simulations of solar activity to predict the strength and timing of the upcoming cycle – sunspot cycle 25. We present our results here.

E2.3-0016-18 SOLAR CORONAL MAGNETIC FIELD STUDIES WITH ADITYA-L1 MISSION

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Aditya-L1 is a first dedicated and approved solar mission from India. The main scientific objective of this mission is to study the solar coronal dynamics. The satellite will be placed at the Sun-Earth Lagrangian – L1 in order to observe the Sun uninterruptly. This mission carries seven payloads with four remonte sensing and three in-situ instruments. While the remote sensing payloads observe the chrmospheric and coronal dynamics, the in-situ payloads measures the particles and magnetic fields at L1 point which are modified by the activities originating from the Sun. One of the payload, called Visible Emission Line Coronagraph (VELC) is a coronagraphic instrument with four channels operating simultaneously. While one channel observe the coronal mass ejections closer to the solar disk (from 1.05Rsun to 3.0Rsun), the other three channels are spectroscopic channels carrying out the spectral diagnostics of the multi-temperature plasma. The spectral lines formed by the highly ionized Fe is used to diagnose the coronal plasma. Magnetically sensitive Fe XIII line at 1074.7nm is used along with a polarimetry for coronal magnetic field diagnostics. Spectro polarimetry is carried out to obtain all the Stokes parameters in order to estimate the coronal magnetic field. In this presentation, the VELC configuration for the coronal plasma diagnostics particularly the magnetic field diagnostics will be discussed. The design and measurement principle of the polarimetric mode of operation of VELC will be detailed. Ground based support along with the VELC coronal observations will also be carried out in order to understand the magnetic field connectivity from photosphere to corona. The plan for ground based observations will also be discussed along with the data handling methods for both groundas well as space-observations.

E2.3-0017-18 PROSPECTS FOR CORONAL MAGNETIC FIELD MEASUREMENTS FROM SPACE

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Despite its fundamental importance as a driver for the physics of the Sun and of the heliosphere, the magnetic field of our star's outer atmosphere remains poorly understood. This is due in large part to the fact that the magnetic field is a very dfficult quantity to measure. Our knowledge of its strength and orientation is largely based on extrapolations from photospheric observations, not from direct measurements. These extrapolations require strong assumptions on critical but unobserved quantities and thus fail to accurately reproduce the complex topologies inferred from remote-sensing observations of coronal structures in white light, EUV, and X-rays. Direct measurements of the coronal magnetic field are clearly identified by the international heliophysics community as a key element in the understanding of our star.

In the past ten years, reliable ground based coronal magnetic field measurements have emerged. However, these measurements wil always be limited by the difficulty to observe the corona from the ground. Much like routine coronagraphic observations from space by SOHO/LASCO have revolutionized our knowledge of the solar corona, space based polarimetric observations are expected to lead to major breakthroughs. In this perspective, we will review the past and future projects of space missions designed to measure the coronal magnetic field from space.

E2.3-0018-18 ASO-S: FOCUSING ON SOLAR MAGNETIC FIELD AND ITS RELATIONSHIP TO SOLAR ERUPTIONS

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ASO-S (Advanced Space-based Solar Observatory) is a mission proposed for the 25th solar cycle by the Chinese solar community. The scientific objectives are to study the relationships among solar magnetic field, solar flares, and coronal mass ejections. In the beginning of 2018, ASO-S has been officially set up and the approved time table is 4 years for the design and manufacture. This talk will extend the scientific objectives and introduce in brief the latest progress of Phase -B study.

E2.3-0019-18 THE ERUPTION OF A PROMINENCE CARRYING CORONAL FLUX ROPE: FORWARD SYNTHESIS OF THE MAGNETIC FIELD STRENGTH MEASUREMENT BY THE CORONAL SOLAR MAGNETISM OBSERVATORY LARGE CORONAGRAPH

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From a magnetohydrodynamic (MHD) simulation of the eruption of prominence hosting coronal flux rope, we carry out forward synthesis of the circular polarization signal V/I produced by the MHD model as measured by the proposed COronal Solar Magnetism Observatory (COSMO) Large Coronagraph (LC) and infer the line-of-sight magnetic field BLOS above the limb. With an aperture of 150 cm, integration time of 300 sec, and an observation pixel of 12 arcsec, the LC can measure a significant BLOS with sufficient signal to noise level, from the simulated flux rope with a peak azimuthal field strength of about 10 G. The measured BLOS is found to relate well with the axial field strength of the flux rope within the height range of the prominence, and can discern the increase with height of the magnetic field strength along the prominence that is a definitive signature of the concave upturning dipped field supporting the prominence. The measurement can also detect above the noise the outward rise of the BLOS due to the slow rise of the flux rope as it develops the kink instability, during the phase when its rise speed is still below 15 km/s and up to a height of about 1.25 solar radius. These results suggest that the COSMO LC has great potential in providing quantitative information about the magnetic field structure of CME precursors (such as prominences) and their early evolution for the onset of eruption.

E2.3-0020-18 THE PROBA-3 MISSION AND ITS CONTRIBUTION TO THE STUDIES OF THE MAGNETIC FIELD IN THE SOLAR CORONA

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PROBA-3 is the next ESA mission in the PROBA line of small technology demonstration satellites. PROBA-3, to be launched in 2020, is a mission dedicated to the in-flight demonstration of precise formation flying techniques and technologies. The PROBA-3 mission will place two small satellites in a highly elliptical orbit around the Earth. The two satellites will fly in a precise formation, producing a very long baseline solar coronagraph called ASPIICS (Association of Spacecraft for Polarimetric and Imaging Investigation of the Corona of the Sun). One spacecraft will carry the optical telescope, and the second spacecraft will carry the external occulter of the coronagraph. The inter-satellite distance of around 150 m will allow observing the inner corona close to the solar limb with very low straylight. The scientific objectives of PROBA-3 will be discussed. A particular emphasis will be put on the transition between the two physical regimes in the corona. The dynamics of the low corona is dominated by the magnetic field, and the dynamics of the high corona is dominated by the solar wind outflow. These two physically different regimes are typically observed respectively by soft X-ray/EUV imagers (Hinode/XRT, PROBA2/SWAP, SDO/AIA) and white-light externally occulted coronagraphs (SOHO/LASCO, STEREO/COR2). The transition between these two regimes is currently not well observed due to the gap between the observations of the low and high corona. It will be demonstrated that, due to its unique field of view and low straylight, PROBA-3/ASPIICS will provide a crucial information on the coronal magnetic field configuration. ASPIICS will allow tracking the connectivity of coronal structures to the solar surface and, in combination with state-of-the-art MHD models, allow us to determine reliably the large-scale coronal magnetic field configuration.

E2.3-0022-18 THE EFFECT OF MAGNETIC TONGUES IN THE DETERMINATION OF JOY'S LAW

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We study the emergence of 186 bipolar active regions (ARs) to determine the relation between the tilt angle formed with respect to the E-W direction and the latitude of emergence. This relation, known as Joy's law, plays a fundamental role to test the ability of dynamo models to explain, among other things, the equatorial flux cancelation and the inversion of the poloidal magnetic field between solar cycles. The methods used in recent works to determine this law are based on the automatic computation of the tilt angle from line-of-sight (LOS) magnetograms (Stenflo Kosovichev 2012; Wang et al. 2015). However, since those results show a large dispersion, the precise latitudinal depedence on the tilt is still a topic of discussion. We consider that an important part of this dispersion can be due to the effect of the so called magnetic tongues. These are produced by the line of sight projection of the azimuthal magnetic field of the twisted emerging flux-tubes that form ARs. The tongues are observed in LOS magnetograms as an elongation of the magnetic polarities. In Poisson et al. (2016, Solar Phys., 291, 1625-1646) we showed that the magnetic tongues affect the photospheric field distribution observed in LOS magnetograms and, consequently, impact on the determination of the tilt angle. In this work we test a novel method to remove the effect of the tongues on the tilt angle determination and we quantify the effect of this correction on Joy's law. Furthermore, we study the relation of the latitudinal dependence of the corrected tilt with other AR properties such as the magnetic helicity sign, the hemisphere of emergence, and the sense of rotation of the bipoles.

E2.3-0023-18 SCALING LAWS OF TOMOGRAPHICALLY RECONSTRUCTED PHYSICAL PARAMETERS OF QUIET-SUN CORONAL LOOPS

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The knowledge of the relation among different physical parameters of coronal magnetic loops allows us obtaining observational scaling laws to compare to those derived from theoretical coronal heating models. In previous works, theoretical scaling laws have been compared with observations of magnetic loops belonging to active regions (AR) (see Mandrini, Demoulin and Klimchuk 2000, ApJ, 530, 999). Since in the quiet-Sun corona loops are not directly observable the task is more difficult. In recent works, a technique called differential emission measure tomography (DEMT) was developed. This technique provides the three-dimensional distribution of the average temperature and density in the coronal volume from a series of observations from EUV telescopes throughout a solar rotation (see the review of Vasquez 2016, AdSpR, 57, 1286). The tomographic results are combined with magnetic field extrapolations to obtain average temperature and density of the plasma along the field lines. In this work, we study the scaling laws obtained from the analysis of parameters reconstructed tomographically for Carrington rotation 2081 (see Mac Cormack et al 2017, ApJ, 843, 70). We compare these scaling laws with the expected relations according to the most known models of coronal heating.

E2.3-0024-18 THREE-DIMENSIONAL STRUCTURE OF CORONAL STREAMERS OBSERVED BY SOHO/ LASCO AND STEREO/COR2

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Helmet streamers are a prominent manifestation of magnetic structures with current sheets in the Solar corona. These large-scale structures are regions with high plasma density, overlying coronal active regions. We investigate the 3D structure of coronal streamers, observed by white-light coronagraphs (SOHO/LASCO and STEREO/COR2). 3D reconstruction of coronal structures is often ambiguous. Inverse reconstructions are difficult, so we design a forward model based on plausible assumptions about the 3D streamer structure taken from previous physical models (a plasma sheet centered around a current sheet). The streamer stalk is approximated by a plasma sheet, with electron density that is characterized by three functions describing the radial, transverse and face-on profiles respectively. We simultaneously fit the observational data from SOHO and STEREO vantage points using a multivariate minimization algorithm. We demonstrate that our model can reasonably describe the observations.

E2.3-0025-18 RECONSTRUCTING NONLINEAR FORCE-FREE MAGNETIC FIELDS IN THE SOLAR CORONA

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It seems that the potential and linear force-free magnetic fields are inadequate to represent the observed magnetic events occurring in different regions of the solar corona. To reconstruct the nonlinear force-free fields from the solar surface magnetograms, various analytical and numerical methods have already been examined by different authors. Here, using the Lagrange multiplier technique, a new approach for reconstructing force-free magnetic fields is proposed. In the minimization procedure the solenoidal property is considered as a constraint on the initial nonforce-free field. It is shown that the Wheatland, Sturrock and Roumeliotis (2000) optimization method emerges as a special case of our approach. Other solutions are obtained and tested by the Low and Lou (1990) semi-analytic solution. During the iteration, the deviation of magnetic field from the solenoidal condition, caused by discretizing effect of the numerical solutions, is compensated by applying a divergence cleaning method to the updated magnetic field.

E2.3-0026-18 OPTIMUM MODULATION FOR CORONAL VECTOR FIELD MEASUREMENTS ON A SPACE BASED OBSERVATORY

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A vector magneto-graph of the coronal magnetic field provides insight into the orientation and strength of the field lines which in-turn helps in understanding the dynamics during events like CMEs and flares. There are several theoretical models on coronal field strength and their variation with solar activity and there have been indirect ways of measuring coronal field strength through models of non-linear force free field extrapolation to estimate upper chromosphere and coronal field strength from photospheric field. These results form the basis for expected field strength and estimates of 3-40 G from solar minima to maxima. Though statistical estimates of magnetic field using Stokes vector-V have been performed, the vector magnetic field measurements of the corona are yet to be done. As the corona is faint with weak fields, such measurements become extremely difficult for a ground based observatory while a higher SNR can be achieved using a space based observatory. Unlike a ground based instrument, a space based instrument has several constraints including mass, number of moving parts and shelf life of the components used in it. So for a typical vector magnetograph which consists of a spectrograph and a polarimeter, we chose a single crystal continuously rotating retarder as modulator and a pair of polarizing beam displacers as dual beam analyzer for the polarimeter unit.

We present a modulation scheme for the solar corona to measure the vector magnetic field of coronal loops. The design takes into account the crosstalk due to satellite jitter and minimizes the crosstalk from linear into weak circular polarization. A laboratory setup is made to verify the capabilities of the modulation scheme. Typical jitter of a low earth orbit satellite is recreated and linear to circular polarization crosstalk is measured. The results obtained from the experiments are comparable to the simulated crosstalk levels.

E2.3-0027-18 GALILEO SOLAR SPACE TELESCOPE MISSION: A CONCEPT FEASIBILITY STUDY

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Here we present the concept feasibility study of the Galileo Solar Space Telescope Mission (GSST Mission) proposed by the Space Geophysics Division (DIDGE) of the Brazilian's National Institute for Space Research (INPE). The study was conducted at the Space Missions Integrated Design Center (CPRIME - Centro de Projeto Integrado de Missões Espaciais) of INPE's Space System Division (DIDSE). The GSST shall contribute to the understanding of the evolution of the magnetic structure in the outer layers of the Sun and its influence on the Earth's space environment. The scientific observations requirements proposed for the mission include high spatial and temporal resolution observations. Those measurements involve observations of the magnetic structure of the photosphere and outer layers of the solar atmosphere through the solar cycle, observations of the variability of the total solar irradiance, and in situ observations of magnetic field and high energy particle fluxes within the Earth's magnetosphere. The concept feasibility study, which was carried out during the second half of 2017, included:

(a) the definition of the scientific objectives, requirements and restrictions of the mission; (b) the identification of the system drivers; (c) the definition of the candidate solutions for the system; (d) the conceptual design of the mission's architecture components, including the optical payloads; (e) the pointing accuracy analysis of the designed attitude control subsystem; (f) the simulation and verification of the mission operational concept; (g) the assessment of the ground segment required to fulfill the mission; (h) estimate of the schedule for the development of the mission; and (i) the risk analysis. The optical payload architecture, orbit and ground segment were identified as the main system drivers. The concept of two full disk telescopes and one high-resolution telescope for visible and ultraviolet spectropolarimetric observations have been the bases for the solution of the optical payload architecture selected for the scientific purposes. For optimizing the solar visibility and the data downlink, the study has considered two orbits as possible: a sun-synchronous Low Earth Orbit (LEO), and a Geosynchronous Orbit (GEO). Each solution implies an exclusive spacecraft layout development. We point out that the cost analysis is still preliminary due to the lack of a similar mission in INPE's portfolio. Finally, the limitations of the concept and future strategies to implement such mission in a challenging funding environment as the current Brazilian scenario shall be addressed.

E2.3-0028-18 A MAGNETOHYDRODYNAMIC RELAXATION METHOD FOR NON-FORCEFREE MAGNETIC FIELDS IN MAGNETOHYDROSTATIC EQUILIBRIA

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Various activities in the solar atmosphere are caused by the Sun's magnetic field. In order to predict those activities, information on the three-dimensional magnetic field distribution is indispensable. The magnetic field, however, cannot be directly observed with high accuracy except for the vector magnetic field on the photosphere at present. Therefore, various methods reconstructing the magnetic field in the solar atmosphere from the two-dimensional magnetic field on the photosphere have been proposed so far.

In particular, using a nonlinear force-free (NLFF) magnetic field model, the coronal magnetic fields have been reconstructed well. However, since the plasma beta on the photosphere is larger than unity, the vector magnetic field on the photosphere is not force-free. The magnetic field in the chromosphere whose plasma beta is not small also deviates from NLFF in general. Therefore, in this paper, we propose a new magnetohydrodynamic (MHD) relaxation method to reconstruct non-force-free (NFF) magnetic fields in the solar atmosphere including both the chromosphere and the corona. The method solves an additional time evolution equation for a scalar field, pseudo-pressure, and converges the magnetic field to a magnetohydrostatic equilibrium field. Theoretical studies and numerical experiments show noteworthy properties of the present method.

E2.3-0029-18 MAGNETIC FLUX EMERGENCE TRIGGERED LIGHT BRIDGE BRIGHTENING AND RECONNECTION JETS

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Light bridges (LBs) are elongated, bright, granular structures that divide the umbra of a large and complex sunspot into two or more umbral regions with the same magnetic polarity. Surgelike activities are common phenomenon appear above the LBs which always accompanied by the magnetic flux emergence process. Former works tried to interpret the triggering mechanism for them, however they often lacked the support of high spatial and temporal resolution vector magnetic measurement. Our recent Observation shows a strong magnetic flux emergence happened at the edge of a filamentary Light Bridge (LB) and accompanied by brightness enhancement of photospheric granulations at the endpoints of the emerged magnetic structure. We study the origin and dynamics of this magnetic flux emergence event with high resolution Fe I 1.56 μm polarimetry magnetogram, TiO photosphere image and Hα chromosphere image from the Goode Solar Telescope. The emerged magnetic structure was 1.5 Mm 0.3 Mm in size at its peak time and lasted for 17 minutes. Doppler map detected upflows before its formation and downflows during the destruction. The magnetic orientation change was obtained by calculating the shear angle and plotting the magnetic field vectors. The result indicates that the new emerged more transverse magnetic field reconnected with the pre-existing more vertical field, which triggered the fan-shaped jets. The expanding fields at the endpoints due to the flux emergence pushed and compressed the existing granulations and led to their enhanced brightness.

E2.3-0030-18 ELLERMAN BOMBS VS. UV BURSTS

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Ellerman bombs (EBs) are small brightening events in the solar lower atmosphere. Most authors found that the temperature increase of EBs around the temperature minimum region is in the range of 600K-3000K. With recent IRIS observations, people found UV brightening events called UV bursts or IRIS bombs. Some authors proposed that the temperature increase of EBs could be more than 10000K, and the UV bursts could, in some cases, related to EBs. Using non-LTE semi-empirical modeling, we investigate the line profiles, continuum emission and the radiative losses for the EBs, and compare them with observations. Our result indicates that if the EB maximum temperature attains more than 10000K around the temperature minimum region, then the resulted Hα and CaII 8542 Å line profiles and the continuum emission would be much stronger than that of EB observations. Moreover, due to the high radiative losses, the high temperature EB would have a very short lifetime, which is not comparable with the observations. Thus, our study does not support the proposal that the EB temperatures are higher than 10000K. Our non-LTE calculation also indicates that the UV bursts are not the same as the EBs. The former are probably at the higher layer of the solar atmosphere, while the latter are at the lower atmosphere with lower temperature.

E2.3-0031-18 SIMULATING THE SOLAR MINIMUM CORONA IN UV AND VISIBLE/IR WAVELENGTHS WITH FORWARD MODELING

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The magnetic field in the corona is important for understanding solar activity, but is difficult to measure due to the tenuous plasma. Therefore many alternative methods have been adopted to get the 3D magnetic field in the corona, such as extrapolation methods relying on the photospheric magnetograms. Such extrapolations make problematic assumptions about the force-free nature of the photosphere, and are highly sensitive to uncertainties in the photosphere magnetic measurements. Measuring the coronal magnetic field directly is thus to be desired, and linear polarization measurements in the visible/IR are already obtained by the CoMP telescope providing information about coronal magnetic direction and topology. However other observations such as circlar polarization in the visible/IR and UV unsaturated Hanle measurements are needed to better observe the 3D coronal field. Until such observations are available, we turn to the FORWARD model (Gibson et al. 2016) which simulates all of these polarization data. As a physical state to input into FORWARD, the analytic magnetic model in this work is adopted from Gibson et al.(1996), which gives a potential field with an exception at the boundary of the helmet streamer where current sheets are added between the open and closed fields. This analytic model has the benifit of matching white light and also photospheric magnetic flux observations at solar minimum. Given this model input of a 3D distribution of magnetic field and plasma, we obtain simulated polarization results in UV and visible/IR wavelengths. This allows us to consider how such observations might be used together in future to diagnose the coronal magnetic field.

E2.3-0032-18 PROJECT OF A NEW 2.5M SOLAR TELESCOPE

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A project of a 2.5m Solar Telescope has been worked out in China. It is the first facility in the world with a special innovation design and can conduct both high-resolution solar observations and the large-field of view (FOV) night survey. Its scientific objectives cover solar physics and time-domain astronomy, all of which are recent hot topics in astronomy. As a large onaxis solar telescope in the world with a larger FOV (7′) than all the large solar telescopes operating at present, it can provide unprecedented high-resolution solar imaging and magnetic field data, which can help us obtain breakthrough achievements on the study of solar active regions and solar eruptions. The data are also very useful for the study of space weather. As a large telescope in China, the telescope is very unique in continuously monitoring shorttime transient events by filling the gap in the specific time-zone. Moreover, the telescope can make essential contribution to training the graduate and undergraduate students majoring in observational astronomy.

E2.3-0033-18 PSEUDOSTREAMER TOPOLOGY REVEALED BY COMP OBSERVATIONS

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Pseudostreamers represent sources of the solar wind whose properties are a subject of active investigation. Their magnetic structure, and particularly the expansion of magnetic flux tubes associated with them, is a matter of current debate. Pseudostreamers are associated with magnetic nulls, which are known to be locations prone to magnetic reconnection that potentially facilitate eruptions. A recent study demonstrated the novel constraints on pseudostreamer topology provided by coronal spectropolarimetry, in particular linear polarization measured by the Coronal Muiltichannel Polarimeter (CoMP) telescope at the Mauna Loa Solar Observatory. That study for the first time provided a method for determining magnetic expansion in the corona independent from any extrapolation or global MHD model representation of the coronal field. It found that this expansion factor was larger and the magnetic null was higher for a pseudostreamer observed by CoMP than expected from a potential field calculation. In this work we extend our analysis to additional observations of pseudostreamers made by CoMP, for which we identify the magnetic nulls and quantify expansion factor. Our goal is to understand if there are systematic differences between these observations and predictions of a potential field model.

E2.3-0034-18 SOLAR MAGNETIC FIELD OSCILLATIONS AND ACTIVITY ON A MILLENNIUM TIMESCALE DERIVED WITH PRINCIPAL COMPONENT ANALYSIS

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Applying Principal Components Analysis (PCA) to the full-disk synoptic maps of solar magnetic field variations obtained by Wilcox Solar Observatory in solar cycles 21-24 we derive 4 pairs of eigen values and eigen vectors (Zharkova et al, 2015) and analytical expressions as the sums of periodic sin and cosine functions for the first pair of eigen vectors (principal components). The analytical expression for the summary curve of the pair is applied for prediction of solar magnetic field variations in the two layers of the solar interior in the past three millennia. Extrapolation of the summary curve of PCs in the past 3000 years confirms the eight grand cycles of 350-400-years superimposed on 22 year-cycles caused by beating effect of the two dynamo waves generated by dipole magnetic sources in the two (deep and shallow) layers of the solar interior. The grand cycles in different periods comprise a different number of individual 22-year cycles. Furthermore, the summary curve reproduces a remarkable resemblance to the sunspot and terrestrial activity reported in the past: known grand minimaMaunder Minimum, Wolf minimum, Homer minimum and many other grand minima occurring every 350-400 years, a medieval warmth period and Roman warmth Period. Temporal variations of the dynamo waves are modelled for dipole sources with the two-layer mean dynamo model with meridional circulation. The addition of quadruple magnetic waves in the inner layer allowed us to recover Dalton minimum and the other minima of Gleissberg's centennial cycle (Popova et al, 2017). The modelled dynamo waves reveal a remarkable resemblance of the temporal variations and butterfly diagrams to those derived with PCA and predict the upcoming modern grand minimum in 2020-2055 (Zharkova et al, 2017). We expand our summary curve back to 100000 years to discover further periods of activity of 11000 years confirmed by the terrestrial data.

E2.3-0035-18 DATA-DRIVEN MODELING OF SOLAR CORONA/INNER HELIOSPHERE BY A 3D MHD MODEL

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In this talk, the evolution of solar wind from the solar surface to the Earth's orbit during Year 2008 is simulated by a new three-dimensional (3D) magnetohydrodynamic (MHD) solar wind model. The time-dependent projected characteristic equations are used to updates the inner boundary conditions with high-cadence observed photospheric magnetic field data as input. The simulation results are analyzed and quantitatively evaluated by comparing model output with remote-sensing observation of the corona and in-situ observation at the Sun-Earth L1 point. The analysis demonstrates that our model reproduces the main pattern and the evolutionary feature of large scale coronal structures, including the shapes and distributions of the coronal holes, and the positions and shapes of helmet streamer and pseudostreamers. From the simulation result, we find that the height of the pseudostreamer X point is positively correlated with the distance of the coronal holes connected by the pseudostreamer. During Year 2008, the helmet streamer belt is found to have a net southward displacement from the equator while the pseudostreamer belts are biased to the northern hemisphere. Both helmet streamer belt and pseudostreamer belts exhibit a general trend of flattening towards the equator during most time of the year. The evaluation of the modeled results at L1 point shows that the general structures can be generated by the model, and the speed is the best among the solar wind parameters reproduced. However, the temperature of the fast solar wind and the magnitude of interplanetary magnetic field are underestimated. The success rate of prediction and arrival time error are also calculated for magnetic field polarity reversals and stream interaction regions.

E2.3-0036-18 DATA-OPTIMIZED CORONAL FIELD MODEL (DOC-FM): APPLICATION TO MAGNETIC FLUX ROPES

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Solar flares and coronal mass ejections (CMEs) are driven by the 3D evolution of the magnetic field in the solar atmosphere. Knowing the 3D magnetic field prior to the trigger of these flaring events is a key feature for predicting their onset. Multiple data-constrained techniques have been developed to reconstruct the pre-eruptive, 3D coronal magnetic field from remotesensing measurements. One that exploits line-of-sight photospheric magnetograms and X-ray and EUV observations of coronal loops is the flux rope insertion method. In this poster, we use the flux rope from a 3D MHD simulation, forward modeling from the SolarSoft package FORWARD, and a recently developed optimization method, to show that coronal polarimetric measurements of forbidden infrared lines can be used to further constrain the parameters of the flux rope insertion method when reconstructing the pre-eruptive magnetic field of CMEs. This synthetic test bed is performed in the context of the Fe XIII 10747 A line observed by the Coronal Multichannel Polarimeter (CoMP) and installed at the Mauna Loa Solar Observatory. We discuss the perspectives offered by coronal polarimetric measurements of the Daniel K. Inouye Solar Telescope (DKIST) and the COronal Solar Magnetism Observatory (COSMO) project.

E2.3-0037-18 3D MODELLING OF MAGNETIC FIELD AND PLASMA STRUCTURE OF ENTIRE PROMINENCES

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The 3D Whole-Prominence Fine Structure (WPFS) model allows us for the first time to simulate entire prominences/filaments including their numerous fine structures. This model combines a 3D magnetic field configuration of an entire prominence obtained from non-linear force-free field simulations, with a detailed description of the prominence plasma. The plasma is located in magnetic dips in hydrostatic equilibrium and is distributed along hundreds of fine structures within the 3D magnetic model. The prominence plasma has realistic density and temperature distributions including the prominence-corona transition region. This allows us to produce synthetic H-alpha images of simulated prominences both in emission on the solar limb and in absorption against the solar disk (viewed as filaments) using a single model.

Such 3D WPFS model provides us with consistent information about the prominence magnetic field configuration, prominence fine structure plasma and its radiative output. Moreover, we are able to follow the evolution of modeled prominences caused by changes of the underlying photospheric magnetic flux distribution. Thanks to these capabilities we can study links between the photospheric flux distribution, prominence magnetic field configuration, distribution and composition of the prominence plasma and its observable signatures. These relationships are important for interpretation of the observed imaging and spectral/spectropolarimetric data and for inference of the properties of the prominence magnetic field.

E2.3-0038-18 A SPACE CORONAL MAGNETOMETRY MISSION

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Direct measurement of the polarized spectra of forbidden coronal emission lines (CELs) is the most powerful tool for the study of the solar coronal magnetic fields. Due to its low optical density, simultaneous multi-sight-lines observations of the corona from space are needed for tomographic inversion to disentangle the 3D structure of the solar corona. This presentation will describe the mission concept and instrument design of a future space coronal magnetometry mission, consists of many clusters of small spacecraft in near-sun heliocentric orbits to observe the sun to enable tomographic determination of the 3D magnetic and thermodynamic structures of the corona. The spacecraft will be equipped with a wide field, super achromatic lens coronagraph equipped with two 100-slit, 4-channel spectropolarimeters optimized for measurement of the polarized CEL spectra from space. This instrument is tentatively named 'mxCSM'- the massively-multiplexed Coronal SpectroMagnetometer. A prototype mxCSM is currently under construction with funding from a 2017 National Science Foundation Major Research Instrument program grant. This space coronal space magnetometry mission will advance our knowledge of the corona and the physics of energetic coronal eruptions, and ultimately enable accurate space weather forecast.

E2.3-0039-18 OBSERVATION ON CURRENT AND HELICITY FROM PHOTOSPHERIC VECTOR MAGNETOGRAM IN SOLAR ACTIVE REGIONS

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A review of observation on electric current and current helicity in solar active regions by applying the photospheric vector magnetograms will be presented. A part is concerned with the statistical observation of net electric current in the region of isolated polarity. Another part is about the evolution of the variation of electric current, with some comparison with the corresponding time series of GOES X-ray flux.

E2.3-0040-18 MAGNETICALLY INDUCED CURRENT PISTON FOR GENERATING EXTREMEULTRAVIOLET FRONTS IN THE SOLAR CORONA

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EUV waves, also called EIT waves, were first observed in 1995 by the Extreme-ultraviolet Imaging Telescope (EIT). These ‘waves’ are single-pulse, globally-propagating coronal fronts and their physical mechanism has been a subject for debate for two decades. Two distinct types of theories have been used to describe EUV waves, depending on the presumed driving mechanism: wave or pseudo-wave. We propose a hybrid model where EUV waves are compressional fronts driven by a reverse electric current layer induced from the coronal mass ejections (CMEs). The CMEs are considered as erupting flux ropes that induce the layer of electrical current. The reverse electric current layer, flowing in the opposite direction with respect to the current in the driving CME, is an eddy current layer that is necessary to maintain magnetic flux conservation in the coronal regions above the layer. The opposing CME and reverse currents mutually repel via magnetic forces with the result that the moving induced reverse current layer acts as a piston that drives a compressional perturbation in the coronal regions above the layer. Given a sufficiently fast initial speed of the driving layer, the compressional perturbation becomes a shock that separates from the driving layer when the driving layer later slows down. Since the model relates the motion of the EUV front to CME properties, the model can provide a bound on the internal current of the erupting flux rope. This model is supported and motivated by detailed results from 3D ideal magnetohydrodynamics (MHD) simulations and from laboratory experiments.

E2.3-0042-18 MULTIFRACTAL DETRENDED FLUCTUATION ANALYSIS OF SOLAR WIND PARAMETERS DURING SOLAR CYCLE 23

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Multifractal analysis based approaches have been recently developed as an alternative framework to study the complex dynamical fluctuations in solar wind plasma. To reveal the multifractal characteristics of solar wind plasma parameters (i.e. temperature, density and speed) from January 1996 to December 2006 (Solar Cycle 23) are analyzed using wavelet based Multifractal Detrended Fluctuation Analysis (MFDFA) technique. MFDFA allows a reliable characterization of multifractal characterization of solar wind plasma parameters. Multifractality in solar wind plasma generate turbulence, which govern various anomalous processes in magnetosphere and interior of Sun. MFDFA analysis provide direct supporting evidence that the solar wind plasma parameters have multifractal structure. Keywords: Solar Wind Plasma Parameters, Magnetic field, Multifractal analysis and wavelet Transform Technique.

E4.1-0001-18 EARLY RESULTS FROM THE TRANSITING EXOPLANET SURVEY SATELLITE (TESS)

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The Transiting Exoplanet Survey Satellite (TESS) will discover thousands of exoplanets in orbit around the brightest stars in the sky. In a two-year survey, TESS will monitor 200,000 pre-selected bright stars for planetary transits in the solar neighborhood at a 2-minute cadence. The survey will identify planets ranging from Earth-sized to gas giants, around a wide range of stellar types and orbital distances. TESS will also provide full frame images (FFI) at a cadence of 30 minutes or less. These FFI will provide precise photometric information for every object within the 2300 square degree instantaneous field of view of the TESS cameras. In total, more than 30 million stars and galaxies brighter than magnitude I=16 will be precisely photometered during the two-year prime mission. In principle, the lunar-resonant TESS orbit will provide opportunities for an extended mission lasting more than a decade, with data rates of 100 Mbits/s.

An extended survey by TESS of regions surrounding the North and South Ecliptic Poles will provide prime exoplanet targets for characterization with the James Webb Space Telescope, as well as other large ground-based and space-based telescopes of the future. The TESS legacy will be a catalog of the nearest and brightest main-sequence stars hosting transiting exoplanets, which should long endure as the most favorable targets for detailed future investigations.

The launch as a NASA Astrophysics Explorer is to take place in April 2018 from Cape Canaveral on a SpaceX Falcon 9 rocket. First light results from the TESS mission will be presented.

E4.1-0002-18 EXOPLANET SCIENCE WITH A NANOSAT: DEVELOPMENT, OPERATION, AND FIRST RESULTS OF THE PICSAT FIBERED PHOTOMETER

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PicSat is a nanosatellite developed to observe the transit of the giant planet β Pictoris b, expected in 2018. The science objectives of the mission are: the observation of the transit of the giant planet's Hill sphere, the detection of exocomets in the system, and the fine monitoring of the circumstellar disk inhomogeneities.

Developping a payload to address these ambitious objectives with the specific constraints imposed by a nanosatellite platform is a challenge. The PicSat payload is based on a single mode optical fiber, which is used as spatial filter. This alleviates the need for a bulky baffle to protect the detector from contamination by scattered light. In this unique concept, the starlight is collected by a small aperture telescope, directly injected into the single-mode fiber, and brought to a temperature-regulated single-pixel avalanche photodiode. The stability of the light injection into the optical fiber is ensured by a fine pointing system based on a two-axis piezoelectric actuation system, driven by a taylor-made tracking alorithm. Overall, the system weights about 2 kg, and fits in a single CubeSat unit.

The PicSat nanosatellite is a 3 unit CubeSat platform, design to carry this ambitious payload. It was launched on the Indian PSLV-C40, in January 2018. The payload is currently (Feb. 2018) being commissionned.

This presentation will be focused on the ambitious opto-mechanical payload of the PicSat mission, and its science case. We will present the general concept of the fibered photometer, and show how a science instrument can be designed to fit on a small Cubesat platform, without sacrificing its science case. We will also present the results of the first months of flight of this instrument. Operating an astrophysical payload in the frame of a small Cubesat project comes with its own challenges, and we will give our return of experience on this.

E4.1-0003-18 PLANET IMAGING CORONAGRAPH TELESCOPE USING A REUSABLE EXPERIMENT FOR JUPITER (PICTURE-J): A HIGH ALTITUDE BALLOON EXPERIMENT TO DIRECTLY IMAGE EXO-JUPITERS

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We describe a research program consisting of two high-altitude balloon flights that will culminate in the first direct image of an exo-Jupiter in the visible band and at a distance of 1 AU from the parent star. In addition, it will also obtain a moderate resolution spectra of the observed planetary systems. The Planet Imaging Coronagraph Telescope Using a Reusable Experiment for Jupiter (PICTURE-J) will accomplish these tasks with a telescope that uses a non-circular primary mirror and a state-of-the-art coronagraph aboard the the Wallops Arc Second Pointer (WASP) platform. PICTURE-J takes the next logical step to the ultimate goals of exoplanetary studies - characterizing Earth-like exoplanets in solar system like systems and will serve as a pathfinder for these upcoming flagship missions.

E4.1-0004-18 ASTERIA: A CUBESAT ENABLING HIGH PRECISION PHOTOMETRY IN A SMALL PACKAGE

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ASTERIA (Arcsecond Space Telescope Enabling Research In Astrophysics) is a 6U CubeSat that advances the state of the art in nanosatellite capabilities for astrophysical measurements. The 6U CubeSat (approximately 10 x 20 x 30 cm, 10 kg) was deployed from the International Space Station (ISS) in November 2017 and has completed its nominal 90-day mission. ASTERIA's objective was to demonstrate enabling technologies for high precision photometry in a CubeSat form factor. Specifically, ASTERIA demonstrated arcsecond-level line-of-sight pointing stability and repeatability and highly stable milliKelvin-level focal plane thermal control.

Light spot motion over detector pixels can cause variations in measured stellar flux since both the between-pixel (interpixel) and within-pixel (intrapixel) responses vary across the detector. ASTERIA's pointing control is achieved through a two-stage approach. A set of reaction wheels provides coarse three-axis control of the spacecraft body, holding an inertial attitude that points the payload to a target star. Within the payload, a two-axis piezoelectric stage provides an additional level of fine control by making small, rapid adjustments to the detector position to keep the target star stationary.

The second technology demonstrated by ASTERIA is milliKelvin-level temperature stability of the imaging detector. The gain of each pixel is temperature sensitive, so tight thermal control reduces instrumental photometric variation that could otherwise be mistaken as an astrophysical signal. Precision thermal control is achieved by isolating the payload from the spacecraft bus and passively cooling the detector using a space-facing radiative surface. Thermal sensors and trim heaters located on the detector then act in closed loop to perform small temperature corrections over the course of an observation, maintaining stability to the required precision.

ASTERIA's design, operations, and technology demonstration results from the 90-day nominal mission will be described in this talk. I will also describe the photometric precision ASTERIA achieved for stars with known exoplanets. Finally, I will compare the photometric precision obtained with and without ASTERIA's fine pointing and thermal control systems active to highlight the value of these technologies for future small space telescopes.

E4.1-0005-18 THE CHEOPS MISSION - RATIONALE AND STATUS

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The CHaracterising ExOPlanet Satellite (CHEOPS) is a mission jointly led by Switzerland and ESA which was selected in October 2012 as the first small-class mission in the ESA Science Programme. CHEOPS will be the first space observatory dedicated to search for transits of exoplanets by means of ultrahigh precision photometry on bright stars already known to host planets. The CHEOPS telescope will have access to more than 70% of the sky, which will provide the unique capability of determining accurate radii for planets for which the mass has already been estimated from ground-based spectroscopic surveys. This, in turn, will allow a first order characterisation of the planets' internal structure (i.e. the determination of the mean density, which provides direct insights into its composition). CHEOPS will also provide precise radii for new planets discovered by the next generation of groundor space-based transits surveys. To reach its goals, CHEOPS is designed to measure photometric signals with a precision of 20 ppm in 6 hours of integration time for a 9th magnitude star and 85 ppm in 3 hours of integration for a 12th magnitude star. The CHEOPS payload consists in a single instrument, a space telescope of 30 cm clear aperture, which has a single CCD focal plane detector. The optical configuration consists of a Ritchey-Chrétien telescope, which provides a defocussed image of the target star on the focal plane. The main design drivers are related to the compactness of the optical system and to the capability to reject the stray light. The nominal CHEOPS operational orbit is a polar Sun-synchronous orbit (SSO) with an altitude of 700 km and a local time of the ascending node (LTAN) of 6 am; the orbit inclination is about 98° and the orbital period is 100 min. The nominal mission lifetime is 3.5 years, with a possible extension to a total of 5 years enabled by appropriate sizing of the consumables budget. The target launch date is end of 2018. With the launch coming up in less than a year, the instrument is already fully assembled and tested and the final steps for its delivery to the spacecraft premises are ongoing. This paper will review the scientific goals of the mission in combination with the expected performance of the instrument, the latter derived from the latest measurements taken during the calibration campaign.

E4.1-0006-18 CHEOPS SCIENTIFIC OPERATIONS - INSIGHT INTO TIME-CRITICAL OBSERVATIONS SCHEDULING

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A partnership between Switzerland and the Science Programme of the European Space Agency (ESA), the CHaracterising ExOplanet Satellite (CHEOPS) is ESA's first mission of the recently created S-Class type. CHEOPS will be launch-ready by the end of 2018, and it will be launched from Kourou's spaceport as co-passenger on-board a Soyuz rocket.

With its effective mirror size of 30 cm and its remarkable photometric precision of 20 ppm (over 6 hours), CHEOPS will be able to measure the bulk density of exoplanets known to transit bright host stars (Vmag = 6-12), thus providing suitable targets for spectroscopic follow-ups with spaceor ground-based observatories like e.g. the JWST or the E-ELT.

The CHEOPS Mission Consortium, under the leadership of the University of Bern, holds 80% of the observing time, with the remaining 20% being opened to the international community through ESA yearly Announcements of Opportunities (AO). The ESA AO is foreseen for summer 2018, and, by the time of the COSPAR meeting, the Guaranteed Time observing program will have been consolidated already.

Unlike other larger ESA missions, the development and operation of the CHEOPS Mission Operations Centre (MOC) and the Science Operations Centre (SOC) are under the responsibility of the Mission Consortium. The University of Geneva is hosting the SOC, where we will run science operations, including the phase-2 submission proposal handling, the mission planning, and the data processing, archiving and dissemination activities. The SOC will deliver scienceready data products through the CHEOPS archive, and all proprietary data will become public one year after their observation for the wider community to access.

In this contribution, we will present the CHEOPS Science Operations concept and its implementation at the Geneva Observatory. We will present all SOC activities, and in particular the challenging task of optimising the schedule of hundreds of time-critical observations making use of genetic algorithms.

E4.1-0007-18 THE COLORADO ULTRAVIOLET TRANSIT EXPERIMENT (CUTE): A NASA CUBESAT MISSION TO STUDY ATMOSPHERIC MASS-LOSS AND MAGNETIC FIELDS IN EXTREME EXOPLANETARY SYSTEMS

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Kevin France, Luca Fossati, Brian Fleming, Arika Egan

The Colorado Ultraviolet Transit Experiment (CUTE) is NASA-supported 6U CubeSat mission designed to characterize the interaction between exoplanetary atmospheres and their host stars. CUTE will search for: 1) enhanced transit absorption in atomic, molecular, and continuum tracers at NUV wavelengths (255 - 330 nm) and 2) evidence of transit asymmetries due to bow shocks ahead of the planet's orbital motion or trailing "tails". This dataset will provide an unprecedented look at the mass-loss mass-loss, which is key to our understanding of planetary evolution, and, potentially, magnetic properties of the most extreme exoplanetary systems. CUTE will observe 6 - 10 transits of 12 primary targets during a nominal seven-month science mission. The CUTE science mission is enabled by the dedicated mission architecture, an optical system employing a novel rectangular primary Cassegrain telescope, and a compact spectrograph. The system obtains a projected effective area of > 25cm^2 over the entire science band pass and a peak resolving power of R 3000. This talk will provide a summary of the CUTE science motivation, an overview of the instrument and spacecraft design, and a status update ahead of our planned 2020 launch date.

E4.1-0008-18 GLUV - A HIGH-CADENCE HIGH-ALTITUDE UV SURVEY

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GLUV is a 30cm ultraviolet survey telescope under development at ANU (Sharp et al. 2016) for a high altitude balloon platform. It will feature a 7 deg2 field of view and a limiting magnitude in near-UV of 22. The system is expected to fly in 2019 and build towards a constellation of telescopes flying in observation campaigns. GLUV will fly in campaigns with some campaigns being dedicated to provide high-cadence transients of exoplanets discovered by other sources (Kepler, TESS, etc) but in the UV.

E4.1-0009-18 FINDING AND CHARACTERIZING EXOPLANETS WITH THE JAMES WEBB SPACE TELESCOPE (JWST)

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The large diameter, low thermal background and broad suite of instruments will make the James Webb Space Telescope (JWST) the premier observatory for the characterization of exoplanets and, in some cases, for their discovery. Transit spectroscopy covering the 0.6 to 28 um range at resolutions varying from a few to few thousand will revolutionize the study of the atmospheric composition and physical properties of planets ranging from Hot Jupiters to temperate Super Earths like those discovered orbiting the nearby M dwarf Trappist-1. Coronagraphic and spectroscopic observations will target young Jupiter-mass planets to characterize their properties as well as to search for new planets with masses as low as that of Saturn or even Uranus. Coronagraphic observations will also study the debris disks associated with planets, studying their morphology and composition as well as looking for planets which might be responsible for structures such as rings, gaps and spiral arms. In addition to highlighting the Cycle 1 programs from the Guaranteed Time Observers and Early Release Science investigations, we will discuss some of the dramatic discoveries JWST might make as it achieves its full potential in the years after launch.

E4.1-0010-18 TWINKLE - A LOW-EARTH ORBIT VISIBLE AND INFRARED EXOPLANET SPECTROSCOPY OBSERVATORY

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Twinkle is a small, dedicated satellite that has been conceived to measure the atmospheric composition of exoplanets. This cost-effective spacecraft is being constructed on a short timescale in the UK and is planned for launch in early 2021. The satellite uses an existing platform designed by Surrey Satellite Technology Ltd. and instrumentation built by a consortium of UK institutes. Twinkle will carry a 45cm telescope with two instruments (visible and near-IR spectrographs - between 0.4 and 4.5μm with resolving power up to R=300) and will follow a Sun-synchronous low-Earth polar orbit. The mission implementation is based upon a commercial delivery approach that has been successfully applied in other demanding space disciplines by the satellite platform supplier.

Twinkle's science cases include observations of transiting exoplanets and of solar system objects. Twinkle will use visible and infrared spectroscopy to analyse the chemical composition and weather of at least 100 exoplanets in the Milky Way, including super-Earths (rocky planets 1-10 times the mass of Earth), Neptunes, sub-Neptunes and gas giants like Jupiter. It will also be capable of follow-up photometric observations of 1000+ exoplanets. The exoplanet targets observed by Twinkle will be composed of known exoplanets discovered by existing and upcoming groundand space-based surveys (e.g. K2, GAIA, Cheops, TESS). Solar system objects ideally suited for spectroscopic and photometric observations with Twinkle include asteroids and comet comae - Twinkle's broad wavelength range will allow the observation of key hydration, organic and volatile features in their spectra.

E4.1-0011-18 COMPLETING AN EXOPLANET CENSUS WITH THE WFIRST EXOPLANET MICROLENSING SURVEY

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The process of planet formation is far too complicated to calculate from first principles, which implies that our understanding of planet formation is largely dependent on observations that reveal the details of exoplanet systems and proto-planetary disks. Kepler has made the first step toward obtaining a statistical census of exoplanets of all sizes with its study of planets in short period orbits (1 year or less). WFIRST's exoplanet microlensing survey will complete this statistical census with sensitivity to planets in orbits down to the mass of Mars with orbital periods of 1 year more more, as well as unbound planets that have been ejected from the planetary systems of their birth. We expect that this planetary census will reveal important insights into planet formation scenarios that can produce habitable planets. We also briefly summarize some of the challenges to planet formation theory posed by recent ground-based microlensing results.

E4.1-0012-18 WFIRST CORONAGRAPH INSTRUMENT FOR EXOPLANET IMAGING AND CHARACTERIZATION

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The Wide-Field Infrared Survey Telescope (WFIRST) is a NASA observatory designed to perform wide-field imaging, slitless spectroscopic surveys of galaxies and supernovae for dark energy, and microlensing surveys to look for distant exoplanets in our galaxy. The use of an existing 2.4 m telescope enables the addition of the Coronagraph Instrument (CGI) for direct imaging and spectroscopy of nearby giant exoplanets and imaging of circumstellar debris disks. The CGI serves as a technology pathfinder for future exoplanet missions capable of detecting bio-signatures in Earth-like exoplanet atmospheres.

For more than 20 years, NASA has been studying coronagraph missions that could detect and characterize exoplanets. In addition, NASA's technology programs have resulted in the steady progress of coronagraph technology development in the laboratory. Direct imaging of exoplanets in reflected light requires 100 million to billions of times suppression of starlight because exoplanets are much fainter than their host stars and lie at small angular separations (typically much less than 1 arc second). The WFIRST CGI baseline design contains two types of coronagraphs, the Hybrid Lyot Coronagraph (HLC) and the Shaped Pupil Coronagraph (SPC), to suppress diffracted starlight. Nearly noiseless, photon-counting EMCCD detectors measure the faint signal from the planets. The angular resolution is determined by the diameter of the telescope.

Two of the largest challenges in coronagraphy are diffraction from the instrument aperture and wavefront errors in the optical beam train. The CGI employs active optics - actuated, highdensity deformable mirrors, a focus control mechanism, and a fast steering mechanism - to attain and maintain extremely high starlight suppression, allowing imaging and spectroscopy of exoplanets in visible light. These mechanisms, along with their control algorithms, correct both static and dynamic wavefront errors.

Most previous coronagraph design and technology development were based on unobscured monolithic telescopes; WFIRST's contributed 2.4 m aperture, however, is obscured aperture by a secondary mirror supported with 6 struts. The CGI's coronagraphs have been designed to accommodate the contributed, obscured aperture. Integrated modeling simulations of the CGI have been validated on a vacuum testbed to within a factor of 2. These validated models allow further optimization of the coronagraph designs.

The CGI consists of a stable structure supporting the optical bench, the electronics, and thermal control elements. It incorporates mechanisms to select a set of masks and filters to configure either a HLC or a SPC, optimized for direct imaging in two photometric bands or for spectroscopy with the integral field spectrograph. High order wavefront sensing with the imaging sensor is used to achieve the initial starlight suppression with the deformable mirrors. A low order wavefront sensor is used to sustain the starlight suppression in the presence of jitter and thermal drift via control of the deformable mirrors, focus correction mirror, and fast steering mirror.

In this presentation we give a detailed overview of the CGI design. Requirements and expected performance will be presented.

E4.1-0013-18 THE PLATO SPACE MISSION: REVEALING HABITABLE WORLDS

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PLATO is the third medium-class mission in ESA's Cosmic Vision programme. PLATO will combine the detection and characterisation of exoplanets with the study of their host stars, focusing on terrestrial planets orbiting in the habitable zone of solar-like stars. Thanks to the brightness of its core targets ($V < 11$), PLATO will allow us to determine the planetary bulk properties (mass, radius, mean density) and age with unprecedented precision. To achieve this, the satellite will carry out long-duration photometric observations to detect planetary transits and perform asteroseismology analysis of the host stars. The planets masses will be determined through radial velocities measurements at ground-based observatories, which, for the core targets, will be organised through an ESA coordinated programme. Moreover, the precision of PLATO will allow us to address a variety of additional exoplanet topics, like circumbinary planets, exo-moons, rings, misaligned planets or planets around young and evolved stars. For statistical studies, the PLATO stellar samples will extend to fainter targets ($V < 13$). To benefit from PLATO's photometric capabilities in other areas of astronomy, a guest observers programme will be set up in which the general community will be invited to submit proposals on complementary science topics. The PLATO payload consists of four groups of six cameras each, pointing at different directions of the sky with overlapping regions, and covering a total field of about 2230 deg2. Two additional cameras equipped with frame transfer CCD detectors will observe the brightest stars and act as fine guidance sensor. The satellite is planned to be launched in 2026 and operate in an orbit around the L2 Lagrangian point.

E4.1-0014-18 EFFORTS OF INDIAN CENTRE FOR SPACE PHYSICS FOR SEARCHING EXOPLANETS

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The Ionospheric and Earthquake Research Centre and Optical Observatories (IERCOO; 22.51N, 87.786E) under Indian Centre for Space Physics has two dedicated telescopes: A CDK24, a 24inch reflector from Planewave instruments, is named Vashista (Sanskrit name of Mizar) and an SN 10, a 10inch reflector from Meade, is named Arundhati (Sanskrit name of Alcor). These are on Ascension 200 and MyT mounts respectively. The field of views we scan for transit is about 12′ x 8′ and 30′ x 20′ minutes We use Transit method to detect exoplanets and have scanned several fields in our galaxy close to Gemini constellation and. We have revisited some known candidates and have isolated some candidates for further tests.

E4.1-0015-18 CHARACTERIZING THE ATMOSPHERE OF PROXIMA B WITH A SPACEBASED MID-INFRARED NULLING INTERFEROMETER

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As potentially our nearest rocky exoplanet, Proxima b represents a formidable opportunity for exoplanet science and possibly astrobiology. With an angular separation of only 35 mas (or 0.05 AU) from its hosts star, Proxima b is however hardly observable with current imaging telescopes and future space-based coronagraphs. To separate the photons of the planet from those of its hosts star, a solution is to use an interferometer that can easily resolve such spatial scales. In addition, its proximity to Earth and its favorable contrast with its host M dwarf (10E-5 at 10 microns) makes it an ideal target for a space-based nulling interferometer with relatively small apertures. In this talk, we present the main observational challenges to overcome in order to study the atmospheric composition of this planet and review what will be possible with current and/or planned facilities. Then, we describe the concept of a space-based infrared (5-20 microns) interferometer with relatively small apertures that can measure key details of Proxima b, such as its size, temperature, climate structure, as well as the presence of important atmospheric molecules such as H_2O, CO_2, O_3, NH_3, and CH_4. Finally, we illustrate the concept by showing realistic observations using synthetic spectra of Proxima b computed with coupled climate chemistry models.

E4.1-0016-18 A SPACE INTERFEROMETER ON A 6U CUBESAT: FIRST-S

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The FIRST-S project is an astronomical project in the context of exoplanet detection. The scientific objective of this mission would be to study the visible emission of exozodiacal light in the habitable zone around the closest stars. It requires high dynamic range (10e3) at moderate resolution (arcsec).

The proposed instrument is 60 cm baseline stellar interferometer with nulling capabilities based on single-mode fibers and $LiNbO_3$ (Lithium niobate) photonic ship on a 6U CubeSat. This nulling technique is currently developed in the context of FIRST project (Fibered Imager foR a Single Telescope), and is suitable for a nanosatellite application.

The first part of this challenge - controlling the injection of the star light in a single-mode fiber with a accuracy of 1 arcsecond - is addressed by the PicSat mission. PicSat is using a 2 stages pointing system: the Attitude Determination and Control System (ADCS) of the platform, and the control of a 2 axis piezo stage.

The design is based on two 9cm aperture telescope, inspired by the PicSat payload. The light collected by these two telescopes is guided with the single mode fibers to the integrated active optics. The active part of this ship controls the optical phase difference to a nanometer accuracy over few microns and allow to scan the null fringe. The interferometer itself is used as an OPD sensor and interacts with the ADCS of the platform to maintain this OPD lower to few microns.

In this presentation I will present the performances of PicSat on which be can base this design. The satellite design will then be described including the telescopes and injection into fibers and the recombination system. Finally the first results on a lab demonstrator with these parts will be shown.

E4.1-0017-18 THE ARIEL SPACE MISSION: EXPLORING THE COMPOSITIONAL FINGERPRINTS OF EXOPLANETS

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The Atmospheric Remote-Sensing Infrared Exoplanet Large-survey (ARIEL) has been selected by the European Space Agency (ESA) as the fourth medium-class science mission of its Cosmic Vision programme (http://sci.esa.int/ariel/). The first mission dedicated to investigating the atmospheres of planets orbiting distant stars, ARIEL's goal is to measure the chemical composition and thermal structures of about one thousand transiting exoplanets in order to address the fundamental questions on how planetary systems form and evolve.

Due for launch in 2028, during its four-year mission ARIEL will observe hundreds of exoplanets ranging from Jupiterand Neptune-size down to super-Earth and Earth-size in the visible and the infrared with its meter-class telescope. The main focus of the mission will be on hot planets orbiting very close to their star, as they represent a natural laboratory in which to study the chemistry and formation of exoplanets. In cooler planets, different gases separate out through condensation and sinking into distinct cloud layers. The scorching heat experienced by hot exoplanets overrides these processes and keeps all molecular species circulating throughout the atmosphere.

The ARIEL mission concept has been developed by a consortium of more than 50 institutes from 12 countries, which include UK, France, Italy, Germany, the Netherlands, Poland, Spain, Belgium, Austria, Denmark, Ireland and Portugal. The analysis of ARIEL spectra and photometric data will allow to extract the chemical fingerprints of gases and condensates in the planets' atmospheres, including the elemental composition for the most favorable targets. It will also enable the study of thermal and scattering properties of the atmosphere as the planet orbits around the star.

E4.1-0018-18 EXOPLANET SCIENCE WITH THE ORIGINS SPACE TELESCOPE

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For the first time in human history, our generation will have the technology needed to answer one of the longest-standing questions: "Are we alone?" Only recently have planet-hunting programs (such as TRAPPIST, MEarth, and Kepler) confirmed the first Earth analogues orbiting M dwarfs. However, it is unknown whether planets orbiting the most ubiquitous stars in our galaxy can support life. The Origins Space Telescope (OST), one of the four large mission concepts currently being studied by NASA in preparation for the Astrophysics 2020 Decadal Survey, will seek to answer that question. OST is extraordinarily sensitive in midto far-IR wavelengths, and will include an instrument designed to obtain spectra of both transiting and directly imaged exoplanets. In this talk I will discuss the challenges and opportunities of looking for biosignatures in transiting exoplanet atmospheres at mid-infrared wavelengths and argue that the only way to ascertain the truth is to make a measurement. I will also present how a survey of nearby mid-to-late M dwarfs could empirically determine the fraction of habitablezone planets that develop life. Additionally, I will highlight other exoplanet science discovery space to be opened up by OST, including the measurement of full-orbit thermal phase curves of potentially habitable planets, as well as the direct imaging of true Jupiter and Saturn analogs over a range of stellar ages.

E4.1-0019-18 EXOPLANETARY CANDIDATES TO OBSERVATIONS WITH MILLIMETRON

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Millimetron observatory, under development at the Lebedev Physical Institute, includes a spacebased 10-meter telescope operating at millimeter and infrared wavelengths from 0.02 to 17 mm (millimetron.ru). In the single-dish mode, it can detect exoplanets in the lowest spectral band. We provide the list of exoplanets that would be available to Millimetron according to its planned sensitivity. We take into account different sources of the candidates' radiation: reradiation of the energy of the host star and the proper flux, contribution of which is important for young and hot exoplanets. Also, we consider transits and the respective decrease in flux.

E4.1-0020-18 THE HABITABLE EXOPLANET IMAGING MISSION (HABEX): SCIENCE GOALS AND PROJECTED CAPABILITIES

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The Habitable-Exoplanet Imaging Mission (HabEx) is a candidate flagship mission being studied by NASA and the astrophysics community in preparation of the 2020 Decadal Survey. The HabEx mission concept is a large (4 to 6.5m) diffraction-limited optical space telescope, providing unprecedented resolution and contrast in the optical, with likely extensions into the near UV and near infrared domains.

The primary goal of HabEx is to answer fundamental questions in exoplanet science, searching for and characterizing potentially habitable worlds, providing the first complete "family portraits" of planets around our nearest Sun-like neighbors and placing the solar system in the context of a diverse set of exoplanets.

At the same time, HabEx will enable a broad range of Galactic, extragalactic, and solar system astrophysics, from resolved stellar population studies that inform the stellar formation history of nearby galaxies, to characterizing the life cycle of baryons as they flow in and out of galaxies, to detailed studies of bodies in our own solar system.

We report here on our team's efforts in defining a scientifically compelling HabEx mission that is technologically executable, affordable within NASA's expected budgetary envelope, and timely for the next decade. In particular, we present architectures trade study results, quantify technical requirements and predict scientific outcome for a small number of design reference missions, all with broad capabilities in both exoplanet science and cosmic origins science.

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

E4.1-0021-18 EXOPLANET AND SOLAR SYSTEM SCIENCE WITH THE LUVOIR MISSION

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This presentation will give an overview of the exoplanetary and planetary observing capabilities of the Large UV-Optical-Infrared (LUVOIR) Surveyor. LUVOIR is one of four large mission concepts for which the NASA Astrophysics Division has commissioned studies by Science and Technology Definition Teams (STDTs) drawn from the astronomical community, in advance of the next Astrophysics Decadal Survey. LUVOIR is a general-purpose space-based observatory with a wavelength range spanning from the far-UV to the near-infrared, and will support a broad range of astrophysics, exoplanet and Solar System studies. LUVOIR will operate at the Sun-Earth L2 point, and will be designed for extreme stability to support unprecedented spatial resolution and coronagraphy. It is intended to be a long-lifetime facility that is both serviceable, upgradable, and primarily driven by guest observer science programs.

One of the main science objectives for LUVOIR will be to directly image rocky-sized planets in the habitable zones of stars out to 20 pc, measure their spectra, analyze the chemistry of their atmospheres, and obtain top-level information about their surfaces. Such observations will allow us to evaluate the habitability of these worlds, and search for potential signs of life in their spectra. LUVOIR will also be capable of ultra-high spatial resolution imaging of Solar System bodies, and simultaneous spectroscopy between 300 nm and 2 microns. We will review the specific observational strategies needed for astrobiological assessments of both exoplanetary and Solar System environments, including the wavelength range and spectral resolution required for these habitability analyses and biosignature searches, and we will provide an overview of the LUVOIR instrument capabilities and planned survey strategy to achieve these goals. We will also describe the wide range of additional exoplanetary and planetary science that LUVOIR will accomplish, including high-quality spectroscopic analysis of hundreds of directly imaged Neptuneand Jupiter-class objects, transit spectroscopy of M-Earths and other transiting planets across the visible and near-IR, and high-precision time-domain astronomy of every planet in the Solar System.

E4.1-0022-18 PICSAT: A CUBESAT FOR BETA PICTORIS OBSERVATION

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PicSat is a nanosatellite that was integrated and operated by the Paris Observatory to observe the transit of the giant planet Beta Pictoris b, expected to happen in 2018. The satellite has been successfully put into a 505 km Sun synchronous orbit in January (PSLV C-40). The mission is based on a 3U CubeSat architecture, with a 2 kg opto-mechanical payload specifically designed for high precision photometry. While the platform has been provided "off-the-shelf" by ISIS (Innovative Solutions In Space), the payload (hardware and software), the flight software and the ground segment/station have been mostly developed in-house at the Observatory. The main scientific objective of the mission is the nearly continuous monitoring of the brightness of Beta Pic at a precision of up to 200 ppm per hour, with interruptions of at most 30 minutes, caused by the eclipse of BetaPic by the Earth in some fraction of the satellite orbit. This setup will allow Picsat to finely characterize the debris disk, the transiting exoplanet, its gravitational surroundings (the Hill sphere) and to detect exocomets in the Pictoris system. The payload is a telescope with a 3.5 cm effective aperture which injects the light in a single-mode fiber linked to an avalanche photodiode, operating in the visible spectrum. A two-axis piezoelectric actuator system, driven by a feedback loop control algorithm based on a Kalman filter, is used to lock the fiber on the center of the star in the focal plane. These actuators complement the attitude determination and control system of the satellite to maintain the sub-arcsecond pointing accuracy required to reach the excellent level of photometric precision. Overall, the mission raises multiple technical challenges: high temperature stability of the avalanche detector (achieved with a thermoelectric cooling device), high pointing accuracy and stability, and short timeframe for the development. The mission is also a technological demonstrator. By showing that we can inject light into a single mode fiber, using only a small (1U) payload, we pave the way for a more ambitious cubesat: FIRST-S, an interferometer based on two injecting telescopes and a beam combiner using integrated optics.

E4.1-0023-18 A NEW NUMERICAL INVERSION SCHEME OF M SIN I EXO-PLANET MASS DISTRIBUTION: ITS DOUBLE PEAK REMAINS AFTER INVERSION.

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The use of radial velocity (RV) measurements of stars has proven very successful at the indirect detection of planets orbiting other stars, since both the planet (unseen) and the star are orbiting around their common center of mass. Unfortunately the mass m of the exo-planet cannot be retrieved: only the product m sin i is derived from the amplitude of the RV wobble, where i is the inclination of the polar axis of the orbit on the line of sight (LOS) from the observer to the star. However, when a reasonable number of exo-planets are detected, giving an observed distribution of m sin i it is possible to retrieve the distribution function of planetary masses f(m) that will give the observed distribution fO(m sin i). One has to make the assumption that the orientations of orbital polar axis are isotropically distributed in space, and independent of the distribution f(m). We have developed a new representation of exo-planets in a 3D space, and established a formally exact solution to the inversion problem, based on spheres and cylinders. We have applied this method to the more than 700 known exo-planets masses. The observed distribution of m sin i shows two peaks, one around 0.025 Mjup (Jupiter mass) and one around 2 Mjup. After inversion, the true distribution of masses still present a double peak, showing that this double peak is not an artefact or shortcoming of the RV method. Our new inversion scheme will be presented and the double peak discussed. Coauthors from IKI acknowledge support from the Russian Government Grant 14.W03.31.0017.

E4.1-0024-18 POSTER SHORT PRESENTATION SESSION

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This slot is reserved to short presentations from poster presenters.

E4.1-0025-18 EARTHFINDER: A PROBE MISSION CONCEPT STUDY FOR THE PRECISE RADIAL VELOCITY DETECTION OF EARTH-MASS EXOPLANETS

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We are investigating the science case for a 1.0-1.4 meter space telescope to survey the closest, brightest FGKM main sequence stars to search for Habitable Zone (HZ) Earth analogs using the precise radial velocity (PRV) technique at a precision of 1-10 cm/s. Our baseline instrument concept uses two diffraction-limited spectrographs operating in the 0.4-1.0 microns and 1.02.4 microns spectral regions each with a spectral resolution of R=150,000 200,000, with the possibility of a third UV arm. Because the instrument utilizes a diffraction-limited input beam, the spectrograph would be extremely compact, less than 60 cm on a side, and illumination can be stabilized with the coupling of starlight into single mode fibers. With two octaves of wavelength coverage and a cadence unimpeded by any diurnal, seasonal, and atmospheric effects, EarthFinder will offer a unique platform for recovering stellar activity signals from starspots, plages, granulation, etc. to detect exoplanets at velocity semi-amplitudes currently not obtainable from the ground. Variable telluric absorption and emission lines may potentially preclude achieving PRV measurements at or below 10 cm/s in the visible and <50 cm/s in the near-infrared from the ground. Placed in an Earth-trailing (e.g. Spitzer, Kepler) or Lagrange orbit, the space-based cadence of observations of a star can be year-round at the ecliptic poles, with two 100-day "seasons" every 6 months in the ecliptic plane. This will provide a distinct advantage compared to an annual 3-6 month observing season from the ground for mitigating stellar activity and detecting the orbital periods of HZ Earth-mass analogs (e.g. 6-months to 2 years). Finally, we are compiling a list of ancillary science cases for the observatory, ranging from asteroseismology to the direct measurement of the expansion of the Universe.

E4.1-0026-18 LEARNING ABOUT EXOPLANETS' EXOSPHERES FROM THE LYMAN-ALPHA LIGHT CURVE.

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Earth's exosphere extends further than 38 Earth radii. The most abundant element in the exosphere is Hydrogen which is very sensitive to Lyman α (Lyα) radiation; a gas column of

NH < 1017 cm−2 suffices to block the stellar radiation. As a result Earth analogues orbiting around nearby M-type stars could be detectable by monitoring Lyα variability. In spite of the interstellar, heliospheric and astrospheric absorption, the transit signature would be detectable in M5 V type stars with a dedicated Lyα flux monitor implemented in a 4-8 m class space telescope. In this work, we present simulations of the Lyα profile for various models of planetary outflows and show how the contrast between the core and the wings of the line could be used to derive the properties of exoplanets' exospheres.

E4.1-0027-18 OBSERVING WITH CHEOPS: THE CHEOPS GUEST OBSERVERS PROGRAMME

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CHEOPS (CHaracterising ExOPlanet Satellite) is the first exoplanet mission dedicated to the search for transits of exoplanets by means of ultrahigh precision photometry of bright stars already known to host planets. It is the first S-class mission in ESA's Cosmic Vision 2015- 2025. The mission is a partnership between Switzerland and ESA's science programme, with important contributions from 10 other member states.

Foreseen to be ready to launch at the very end of this year, CHEOPS will provide the unique capability of determining radii of planets in the super-Earth to Neptune mass range to 10% precision. It will also provide accurate radii for new planets discovered by the next generation of ground-based or space transit surveys (from super-Earth to Neptune-size). The high photometric precision of CHEOPS will be achieved using a photometer covering the 0.33 - 1.1um waveband, designed around a single frame-transfer CCD which is mounted in the focal plane of a 30 cm equivalent aperture diameter, f/5 on-axis Ritchey-Chretien telescope.

20% of the observing time in the 3.5 year nominal mission will be available to the Community through the Guest Observers Programme that will be run by ESA. The call for proposals for the first year of observing will come out in Summer 2018.

In this poster I give an overview of observing with CHEOPS, with a particular focus on the ESA CHEOPS Guest Observers Programme.

E4.1-0028-18 DETECTION OF EXOPLANETS IN MULTISYSTEM STARS

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Detection of the exoplanets in multisystem stars represents one of the important tasks in the coming interval of time. Thousands of multisystem in particular triple systems have been observed. The detection of the nature of the third body as a planet represents a hard question to be answered in triple systems. In a previous theoretical trial, Morcos in 2013, derived a simple relation, in the framework of scale relativity (Nottale (1997)), to find the orbital period of solar system plants by using a quantized form. That formula has been adapted to calculate the quantum orbital number of some exoplanets (Morcos, et al (2016)). In this work, the previously mentioned relation has been reformed using Hill radius of Margot (2015) to detect exoplanets in multisystem stars. The results may through a light on detection of the third body as an exoplanet by using the quantization of the body's orbit.

E4.1-0029-18 THE CHEOPS GROUND SEGMENT AND OVERALL MISSION OPERATIONS CONCEPT - AN ESA MISSION OPERATED BY THE MISSION CONSORTIUM

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ASI Science Data Centre (IT), ASE (ES), AstroCast (CH), CAUP (PT), DEIMOS Engenharia (PT), ESA/ESOC, ESA/ESTEC, eSpace @ EPFL (CH), GMV (ES), INTA (ES), Laboratoire d'Astrophysique de Marseille (FR), University of Bern (CH), University of Cambridge (UK), University of Geneva (CH), University of Stockholm (SE), University of Vienna (AT).

A partnership between Switzerland and the Science Programme of the European Space Agency (ESA), the CHaracterising ExOPlanet Satellite (CHEOPS) is ESA's first mission of the recently created S-Class type. By the end of 2018 CHEOPS is planned to be ready for launch from Kourou's spaceport as co-passenger on-board a Soyuz rocket. The nominal mission lifetime is 3.5 years.

With its effective mirror size of 30 cm and its remarkable photometric precision of 20 ppm (over 6 hours), CHEOPS will be able to measure the radii of exoplanets known to transit bright host stars (Vmag = 6-12). CHEOPS will reveal very valuable as a high-performance follow-up of explanatory transits detected by, for example, NASA's TESS mission. Together with the mass measurements from other instruments like ESPRESSO at ESO's Paranal site, CHEOPS will provide well suitable targets for spectroscopic follow-ups with spaceor groundbased observatories like the JWST or the E-ELT.

The CHEOPS Mission Operations Centre (MOC) and the Science Operations Centre (SOC) are developed and operated by the Mission Consortium, which is lead by the University of Bern. The MOC development is under the responsibility of GMV, a world leader for satellite ground segments. Critical subsystems like the Mission Control System are provided as part of a turnkey system by ASE, the spacecraft prime contractor. The MOC is operated by INTA. As the leader of a team from 9 institutes and companies located in 6 ESA member states, the University of Geneva hosts the SOC. The SOC will deliver science-ready data products through the CHEOPS archive. All proprietary data will become publicly accessible to the scientific community at large one year after their observation.

20% of the CHEOPS observing time are open to the international community through Announcements of Opportunities (AO) operated by ESA. The fist AO is foreseen in summer 2018.

In this contribution, we will present the CHEOPS Ground Segment and the Mission Operations concept. Focus will be given to the challenges and benefits of CHEOPS' small mission character.

E4.1-0031-18 A COSPAR ROADMAP ON EXOPLANETS FOR THE NEXT DECADES

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The COSPAR Bureau has approved to initiate a new roadmap study on exoplanets, "as a multidisciplinary domain in full development, involving astronomy, planetary sciences, and ultimately life sciences, not to mention more philosophical questions". The roadmap will include several aspects related to exoplanets, including the planned missions for next decade and foreseen discoveries, the synergy with the large project from ground, the technological developments for future more challenging experiments, the status and foreseen development of models, the role of the host star and of the environment, the habitability definition, conditions and life, and the support of the laboratory activity to models and interpretation of observations. We are building the team covering a large range of competences and countries, with a good balance of senior - junior participants and gender. The time scale planned to deliver the roadmap is approximately one year and will be prepared by a working group in the context of the SubCommission E4: Exoplanets Detection, Characterization and Modelling https://cosparhq.cnes.fr/scientific-structure/scientific-commissions-e

E4.1-0032-18 IMPORTANCE OF POLARIZATION OBSERVATIONS TO SUPPORT WFIRST EXOPLANET SEARCHES WITH GRAVITATIONAL MICROLENSING

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As it was predicted by Mao and Paczynski (1991) gravitational microlensing is among the most efficient technique. Several dozens exoplanets have been discovered with this technique (some of them are located near the snow line) with relatively modest ground based facilities. However, there are degeneracies in theoretical modeling such binary planetary systems and some of these degeneracies can be resolved with polarization measurements. One of the primary goal of WFIRST mission is searches of exoplanets with gravitational microlensing. Therefore, it is important to design early warning system for microlensing event candidates observing with WFIRST and to build a world-wide ground network for follow-up polarization observations. It will allow to increase an efficiency of WFIRST observations for exoplanet searches.

E4.1-0033-18 EXOTRANS FOR THE ADVANCED DETECTION OF TRANSITING PLANETS IN STELLAR LIGHT CURVES

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The software package EXOTRANS was developed by the Rheinisches Institut für Umweltforschung (RIU-PF) to detect transits of exoplanets in stellar light curves monitored by space telescopes. EXOTRANS was first applied to the stellar light curves from the CoRoT space mission (2006-2013), on KEPLER light curves and it is currently used to detect candidates in K2 light curves as part of the KESPRINT collaboration.

The detection pipeline was improved with wavelet-based filter routines: the VARLET filter separates faint transit signals from stellar variation, orbital disturbances and instrumental effects without using a-priori information about the target star considering variations by frequency, amplitude and shape simultaneously; the PHALET filter separates periodic features with wellknown periods independent of their shape. PHALET is implemented in the "Advanced-BLS" detection algorithm to remove detected transits from light curves to search for additional faint transiting planets. EXOTRANS lowers the detection limit, reduces false alarms and simplifies the detection of faint transits in variable stellar light curves.

EXOTRANS works fully automatically (including candidate vetting), is fully scalable on several computer systems and is ready to process the large data volumes of future space missions like TESS and PLATO. Examples of candidates detected in K2 light curves as part of the KESPRINT collaboration shall be presented. The KESPRINT collaboration published 24 papers of confirmed K2 planets with determined radius and mass since 2016.

E4.2-0001-18 THE PHYSICS OF PLANET FORMATION

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This talk provides a broad overview on the physical processes governing planet formation and evolution. In the first part of the talk, current key observational constraints for theoretical models will be discussed coming from both ground and space-based observatories. Then, the most important physical mechanisms controlling planet formation will be presented, namely the accretion of solids and gas, orbital migration, and planet-planet interactions. Global planet formation models that include these effects and their statistical predictions for the planetary mass function, the radius distribution, the planetary luminosities at young ages, and the dependencies of system architectures on protoplanetary disk properties will be presented. In the end, I will address key open questions that need to be addressed in order to advance our understanding of how planets form. Here, a focus will be made on the opportunities arising from observing planet formation as it happens.

(solicited talk)

E4.2-0002-18 STARLIGHT RESHAPES PROTOSTELLAR DISKS

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Many protostellar disks show central cavities, rings, or spiral arms likely caused by low-mass stellar or planetary companions, yet few such features are conclusively tied to bodies embedded in the disks. Even small features on the disk's surface cast shadows, because the starlight grazes the surface. We therefore focus on accurately computing the disk's thickness, which depends on its temperature. We present models with temperatures set by the balance between starlight heating and radiative cooling, and that are in vertical hydrostatic equilibrium. The planet has 20, 100, or 1000 Earth masses, ranging from barely enough to perturb the disk significantly, to clearing a deep tidal gap. The hydrostatic balance strikingly alters the model disk's appearance. The planet-carved gap's outer wall puffs up under starlight heating, throwing a shadow across the disk beyond. The shadow appears in scattered light as a dark ring that could be mistaken for a gap opened by another planet. The surface brightness contrast between outer wall and shadow for the 1000-Earth-mass planet is almost an order of magnitude greater than a model neglecting the temperature disturbances. The shadow is so deep it largely hides the planet-launched spiral wave's outer arm. Temperature gradients are such that outer lowmass planets undergoing orbital migration will converge within the shadow. Furthermore, the temperature perturbations affect the shape, size, and contrast of features at millimeter and centimeter wavelengths. Thus, starlight heating and radiative cooling are key factors in the appearance of protostellar disks with embedded planets.

E4.2-0003-18 HEAVY ELEMENTS IN EXOPLANETS: PLANETESIMAL ACCRETION VS PEBBLE ACCRETION

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Better measurements of the mass and radius of exoplanets enable determination of the composition of planets, which provides invaluable insights about how planets form. The recent studies combine such a good quality of the data with the thermal and structure evolution model of planets and reveal a relationship between the total mass and the total heavy element mass of observed exoplanets. While the relationship is regarded as good evidence that the core accretion scenario is the dominant mechanism of forming these planets, it is still unclear how heavy elements are accreted onto planets. Here, we present a new analysis of the relationship in which core formation and accretion of solids such as pebbles and planetesimals are examined. We combine the semi-analytical formula of planetesimal accretion with the gas accretion recipe, and find that the relationship is regulated by the final stage of planet formation, where planets accrete solids from gapped planetesimal disks and the supply of gas onto the planets is limited by disk evolution. Our analysis also shows that the critical core mass for initiating gas accretion is about 4 Earth-masses that are much smaller than the canonical value of 10 Earth-masses often used in the literature. This in turn enables us to propose that exoplanets with the mass of 4 Earth-masses would be rocky super-Earths. The subsequent solid accretion onto planetary cores would be important to postpone the onset of efficient gas accretion for planets with the mass of 4 Earth-masses < Mp < 100 Earth-masses. These planets can be classified as gas-poor, sub-giant planets like Neptune in the solar system. The current understanding of pebble accretion is still premature, and a more detailed study of how simultaneous accretion of gas and pebbles proceeds is required for performing the same level of the analysis. We finally propose the classification of observed exoplanets based on our analysis to obtain better understanding of planet formation.

E4.2-0004-18 CATCHING PLANET FORMATION IN THE ACT: SIGNATURES OF PLANETS IN DISKS

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Interactions between forming planets and the young circumstellar disks from which they develop can result in large-scale structural changes to disks that are potentially observable. The observation of these signatures promises to be a direct probe of the planet formation process, provided that those signatures can be properly interpreted. As new observatories develop, we have begun to observe some of these features. In this talk, I will discuss theoretical predictions of planet formation signatures as well as some possible false positives. I will discuss how these predictions can be used to interpret observations, both from our current latest and greatest observatories as well as upcoming missions.

E4.2-0005-18 ASTROCHEMICAL OUTCOMES OF THE FORMATION OF GIANT PLANETS IN CIRCUMSTELLAR DISCS: THE CASE STUDY OF HD163296

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The observational capabilities of ALMA are providing an unprecedented view of circumstellar discs, revealing the signatures left in their gas and dust by the formation of giant planets. At the time giant planets form, planetesimals should still contain a significant fraction of the initial solid mass of the discs and their dynamical excitation by the planetary perturbations should lead to a significant collisional dust production. We investigate the dynamical and collisional evolution of the planetesimals in HD163296's circumstellar disc across the formation of its three giant planets to assess whether the second-generation dust produced by planetesimal collisions could refill the disc with dust, formerly depleted by the planetary formation process, and produce potentially observable features. We use N-body simulations and statistical methods developed for the study of the asteroid belt in the Solar System to estimate the dynamical and collisional response of the planetesimal population to the formation of the three giant planets. We took advantage of impact experiments and scaling laws to assess the outcome of the collisions among the planetesimals. Our results show that the formation of HD163296's giant planets should be followed by a global phase of dynamical excitation of the planetesimals, producing a violent collisional environment that should still be active today. The associated high impact velocities would cause a tenfold-to-hundredfold increase in the dust production by impacts, with a predicted peak in the region interior to the inner planet in agreement with observational data. The excited velocities of the planetesimals could result in the release of transient, non-equilibrium gas species like H2O due to ice sublimation during impacts and, being supersonic with respect to the gas, could produce bow shocks in the gas, possibly causing a broadening of its emission lines.

E4.2-0006-18 HIGH-CONTRAST IMAGING OF A NEW CIRCUMBINARY DISK AROUND A YOUNG SPECTROSCOPIC BINARY

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E. Choquet, T. Meskhat, J. Sahlmann, D. Mawet

Since the Kepler mission discovered extrasolar planets orbiting binary stars, we know that these circumbinary planets are relatively common. The scenario for their formation is however still unclear. Did they form in the perturbed environment close to their host stars or did they form further out and then migrate inwards? Solving this mystery requires detailed study of the morphology, composition, and dynamics of young binary-disk systems where planets may still be forming. We report the most detailed high-resolution images in scattered light of a new disk around a spectroscopic binary, embedded in a multi-stellar system. With a ring, a cavity, at least two spiral arms, and hints for temporal variability, the disk's structure indicates possible interactions with close stellar companions. The spatial constraints provided by these multispectral images, used in the context of radiative transfer modeling, give a more precise picture of this system. They also raise additional questions that may be addressed with JWST and ALMA follow-up.

E4.2-0007-18 IMAGING PROTOPLANETS

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Understanding the details of the planet formation process requires direct observations of protoplanets themselves. The distances to nearby young stars make these detections extremely difficult, pushing the limits of current facilities. However, instrumentation improvements have enabled the detection of some protoplanet candidates. I will discuss the candidates discovered so far, as well as the techniques that led to their detection. I will also discuss the expected advances in protoplanet detection and characterization from next-generation facilities.

E4.2-0008-18 DETECTING FORMING EXOPLANETS WITH A NEW VLTI HIGH-CONTRAST INSTRUMENT

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The scarcity of giant exoplanets discovered by ongoing single-aperture direct imaging surveys challenges our understanding and theories of planet formation. For the nearest population of young stars, these surveys are typically sensitive to planets further than 15-20 AUs from their host stars due to the limited angular resolution. Deep observations at higher angular resolution are therefore required to fully explore the range of possible orbits and bridge the gap with radial velocity surveys. In this presentation, we present the scientific motivations and expected science yield of a high-angular resolution and high-contrast thermal near-infrared (3-5 microns) VLTI instrument. The thermal near-infrared is ideal to provide deep mass sensitivity for intermediate age (several hundred Myr-old) systems as well as to image very young and still embedded (proto-)planets. We discuss the prospects for known giant planets and predict the number of possible new detections in young moving groups based on Monte-Carlo simulations. Synergies and scientific preparation for the Planet Formation Imager are also briefly discussed. This project is dubbed Hi-5, for High-contrast Interferometry up to 5 microns.

E4.2-0009-18 LINKING ASTROCHEMISTRY IN PROTOPLANETARY DISKS WITH THE ATMOSPHERIC COMPOSITION OF EXOPLANETS

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Recent advances in sensitivity have allowed us to begin to measure and even map the compositions of gas-rich protoplanetary disks. How these compositions are imparted into newly forming planets is still an open question that draws from topics of gas motions, dust dynamics, and, of course, chemistry. I will discuss how ALMA is shedding light on each of these topics, and how these parts fit into a newly emerging (and potentially dynamic) picture of chemistry during planet formation. I will finally discuss how what we've learned from the outer disk (> 10 AU) from ALMA may influence the compositional properties of the inner terrestrial planet formation region, and how we might test such ideas with future facilities such as JWST.

E4.2-0010-18 FUTURE MISSIONS AND SYNERGIES FROM GROUND AND SPACE MISSIONS

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The study of planetary formation and evolution is challenging from an observational perspective because of the very high angular resolutions and contrasts required. In the medium to long term, only formation flying long-baseline high contrast interferometry has the capability to image the full range of exoplanets needed to observationally understand planet formation from the terrestrial to giant planet range. However, there are many exciting intermediate steps, both from the ground and space. I will begin by outlining the scientific requirements for studying the key stages of planetary formation and young planetary system evolution, including accretion of the first planetary cores, runaway gas accretion, and dynamical planetary system evolution. The fundamental requirement for high spatial resolution drives even the study of wide giant planets beyond the spatial resolution of JWST to the ground-based extremely large telescopes and ground-based long baseline infrared interferometry. ESO's VLTI, using for example the VIKiNG beam combiner under the Hi-5 framework, offers the best opportunity over the next 5- 10 years to detect a wide range of giant exoplanets. Beyond that, the Planet Formation Imager (PFI) concept aims to resolve structures as small as giant planet Hill-spheres. Moving beyond this requires formation flying of a cooled beam combiner. I will discuss pathways for microsatellite formation-flying demonstrators that could enable unique planet formation science, and point the way towards km-scale space interferometry.

E4.2-0011-18 STUDYING THE BIRTH OF EXOPLANETARY SYSTEMS WITH THE PLANET FORMATION IMAGER (PFI)

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Despite recent advancements, many fundamental questions still surround the processes that are involved in planetary birth: Where in the protoplanetary disk do the planets form and how do they grow? What factors determine the final architecture of planetary systems? How are water and other volatiles delivered to the protoplanets and how does this affect the potential habitability of these worlds?

As part of the "Planet Formation Imager" (PFI) project we develop the roadmap for a future infrared high-angular resolution imaging facility that aims to answer these questions by witnessing the planetary formation processes on the natural scales where the material is assembled, which is the Hill sphere of the forming planets. PFI will detect giant protoplanets on all stellocentric radii, image their interaction with the ambient disk material, and trace their dynamical evolution during the first 100 million years, thereby reveal the processes that determine the architecture of planetary systems.

In this contribution we give an overview about the work of the PFI science and technical working group and present radiation-hydrodynamics simulations from which we derive preliminary specifications that guide the design of the facility. We will present a baseline PFI architecture that can achieve these goals, point at remaining technical challenges, and suggest activities today that will help make the Planet Formation Imager facility a reality.

E4.2-0012-18 CURRENT STATUS OF THE MILLIMETRON SPACE OBSERVATORY

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We present the current status of the Millimetron Space Observatory (MSO) -international space mission led by Russia. The unprecedented sensitivity and angular resolution of the cryogenically cooled 10-m telescope, placed in a L2 orbit, will provide unique capabilities for millimeter, submillimeter and FIR astronomy and astrophysics. There will be no cryogenic liquids on board, which will reduce the mass of the observatory. Instead the mission will be cooled passively by heat shields and actively by mechanical coolers. That combination will enable achieve on the observatory mirrors temperature less than 10K. One of the exciting opportunities is the possibility of MSO working in two different modes - as a single dish observatory and as an element of Earth-space VLBI system. The MSO payload equipment includes two direct detection instruments complemented by several heterodyne instruments. All of them are based on the state-of-the-art components. The current status of the MSO will be presented.

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Life Sciences as Related to Space (F)

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LIFE SCIENCES AS RELATED TO SPACE (F)

GRAVITY PERCEPTION AND RESPONSE IN PLANTS AND FUNGI: GROUND AND SPACE STUDIES (F1.1)

F1.1-0001-18 DIFFERENTIAL GENE EXPRESSION AND PHOTOTROPISM IN SEEDLINGS OF ARABIDOPSIS GROWN IN MICROGRAVITY

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Light and gravity play a substantial role in plant orientation and directed growth movements (tropisms). However, very little is currently known about the interaction between light (phototropic) and gravity (gravitropic) mediated growth responses. Utilizing the European Modular Cultivation System (EMCS) on board the International Space Station (ISS), we investigated the interaction between phototropic and gravitropic responses in three Arabidopsis thaliana genotypes, Landsberg wild type as well as mutants of phytochrome A and phytochrome B. Onboard centrifuges were used to create a fractional gravity gradient ranging from microgravity to reduced gravity to 1g. Two types of data resulted from these space experiments: (1) downlinked images of seedlings showing growth and tropistic curvature; (2) molecular analyses of seedlings which were frozen at the end of the experiment.

In terms of the tropism experiments resulting from imaging of the seedlings, a novel positive blue-light phototropic response of roots was observed during conditions of microgravity, and this response was attenuated at 0.1g. In addition, a red-light pretreatment of plants enhanced the magnitude of positive phototropic curvature of roots in response to blue illumination. Additionally, a positive phototropic response of roots was observed when exposed to red light, and a decrease in response was gradual and correlated with the increase in gravity. The positive redlight phototropic curvature of hypocotyls when exposed to red light was also confirmed. Both red-light and blue-light phototropic responses were also shown to be a product of directional light intensity.

In terms of the molecular analyses, seedlings were grown in µg or 1g and subsequently frozen at -80C. RNA-Seq analysis was conducted to identify genes differentially expressed between the µg and 1g growth conditions. This analysis (utilizing the HISAT2-Stringtie-Ballgown suite of bioinformatics tools) identified 11 highly-significant genes associated with growth in microgravity.

Two particularly interesting genes include AT3G12830 (SAUR-like auxin-responsive protein family) and AT4G02440 (F-box protein that functions as a negative regulator in phytochrome A). Phytochrome is an important photoreceptor molecule that plays a role in phototropism, and auxin plays an important role in the differential growth in gravitropism and phototropism.

These studies will be considered in the broader context of understanding gene expression of plants grown in the microgravity environment. In the long term, the results of our spaceflight experiments will help us to understand plant growth as part of bioregenerative life support, which is important for missions to Mars and other planets.

F1.1-0002-18 PLANT GRAVITY RESPONSES UNDER FRACTIONAL GRAVITY

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Plant growth shows a high degree of plasticity, with input from environmental conditions like temperature, light, and gravity playing a dominant role in determining plant form. These inputs result in directional growth responses in young seedlings that contribute to seedling establishment, water uptake, mineral acquisition, and the transition to fully autotrophic growth. Gravity is a principal cue influencing the direction of plant growth, but despite its importance, much remains unknown about how plants perceive and regulate their response to this pervasive signal. To further our understanding of gravity perception and response regulation, we have designed a spaceflight experiment for the European Modular Cultivation System (EMCS) the central aim of which was to determine the gravity perception threshold in roots. The EMCS, housed on the International Space Station, is a growth chamber capable of controlling all necessary conditions to support plant growth while supplying artificial gravity through the rotation of 2 independent centrifuge rotors, allowing the application of 0.003 - 2.0 g. Here we report the growth responses of roots of Arabidopsis thaliana wild type (Col-0) and starchless mutants (pgm-1) to a range of fractional g treatments. Starchless mutants lack functional statoliths, causing them to respond more slowly to gravity on Earth. Here we report on the differences in the threshold acceleration force required to activate gravity responses in the mutant relative to wild type roots, as well as differences in gravitropic response rates under varying g treatments. Finally, we report on the response of both types of roots to unilateral blue light treatments in microgravity. Our results will inform planning for plant growth facilities on future spaceflight missions as well as contribute to our overall understanding of plant gravity sensing, an important input governing plant form and productivity on Earth.

F1.1-0003-18 PROTEOMICS AND TRANSCRIPTOMIC ANALYSIS OF ARABIDOPSIS SEEDLINGS IN MICROGRAVITY REVEAL NOVEL REGULATORY PATHWAYS.

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Low earth orbit provides a wholly unique opportunity to study plant gravity response at the molecular level. Indeed, several studies over the past decade have assessed gene expression and protein abundance under microgravity conditions. However, RNA sequencing technologies have advanced substantially in recent years, and few if any studies have comprehensively examined gene expression with the resolution provided by next generation sequencing. Additionally, pairing RNAseq data with the assessment of individual protein abundances provides a far more complete picture of the molecular environment within plants subjected to microgravity. Here, etiolated seedling were grown for 3 days aboard ISS in BRIC hardware. Seedlings were fixed with RNAlater, frozen at -80 °C, and returned to Earth for analysis. A series of ground controls were conducted to correct for the effects of preservative and hardware. RNA and proteins were extracted and subjected to paired-end RNA sequencing and protein mass spec analysis, respectively, and protein data were further analyzed for post-translational modifications. In total, 1,974 genes, 94 soluble and 79 membrane proteins and were found to be differentially expressed between the space flown samples and ground controls. Further analysis revealed a general incongruity between the RNA and protein datasets, highlighting the value in using multiple molecular approaches to delineate the effects of microgravity environments. Considering all data collected, novel microgravity-induced molecular dysregulation was uncovered in post transcription regulation, light signaling, and growth-related pathways.

F1.1-0004-18 COMPARISON OF THE REGULATORY MECHANISMS FOR GRAVITROPISM AND HYDROTROPISM IN SEEDLING ROOTS

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Roots of land plants show gravitropism and hydrotropism due to gravity and moisture gradients, respectively, for controlling their growth orientation. It has been shown that gravitropism interferes with hydrotropism. We differentiated hydrotropism from gravitropism in cucumber roots by clinorotation and spaceflight experiments. Clinorotated or microgravity-grown cucumber seedling roots hydrotropically bent toward wet substrate in the presence of moisture gradients, but they grew straight along the direction of stationary 1G on the ground or centrifuge-generated 1G in space. The expressions of auxin-inducible genes were much higher in the high-humidity (concave) side than the low-humidity (convex) side of hydrotropically responding cucumber roots. Auxin transport inhibitors significantly reduced the hydrotropic response. The auxin efflux protein CsPIN5 was differentially expressed by reducing its expression in the convex side of cucumber roots following hydrostimulation. These results suggested that hydrotropic and gravitropic responses in cucumber roots were competitive one another, being mediated via auxin dynamics to be independently regulated in response to moisture gradients and gravity. However, the root cap was indispensable for gravitropism and dispensable for hydrotropism, suggesting a novel mechanism that induced asymmetrical transport and distribution of auxin in the elongation zone without the root cap in hydrotropically responding cucumber roots. Arabidopsis roots also displayed hydrotropism after laser-ablation of the rootcap cells. In Arabidopsis roots, MIZ1 and ABA functioned in cortex of the elongation zone, but auxin was not essential, for the induction of hydrotropism. Thus, our results revealed the regulatory mechanism unique to hydrotropism in roots, which could differ between plant species.

F1.1-0005-18 SPACE EFFECTS IN BRASSICA SEEDLINGS - GENE TRANSCRIPTION BY TISSUE TYPE

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An experiment that validated the role of amyloplast displacement as curvature-inducing process was used to examine the gene expression in space-grown and control seedlings. Brassica roots responded to High Gradient Magnetic Fields (HGMF) by curving in space and on a clinostat. Q-PCR data from root tip, root proper, root-shoot junction and cotyledons of 42 h old seedlings that were fixed in space in RNA-later was investigated for transcription of genes related to growth, auxin transport, cell wall biosynthesis and starch metabolism. Sixteen genes were analyzed for their variability in the different tissues and as to their sensitivity to physical stimulation such as high-gradient magnetic fields in space, clinorotation, and controls. Transcription studies showed greater differences between HGMF-exposed roots and space controls than between space and ground controls. Space grown roots showed stronger transcription of common reference genes such as actin and ubiquitin in HGMF than in non-magnetic space controls. In contrast, -amylase, glucokinase and PIN encoding genes were transcribed stronger under non-magnetic conditions than under HGMF. The available large number of comparisons between space, ground, and HGMF prompted the assessment of transcription differences between root segments, root-shoot junction, and seeds. Because presumed transcription of reference genes varied more than genes of interest, changes in transcription cannot be based on reference genes. Nonetheless, the different tissues show consistent variability in transcription. The highest variability was found in roots, the lowest variability occurred in the seed/cotyledon material. The data provide insight in gene regulation as function of physiological state rather than experimental treatment.

F1.1-0006-18 MECHANISMS OF PLANT RESISTANCE TO 1 G GRAVITY - THE ANALYSIS BY THE RESIST TUBULE SPACE EXPERIMENT

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Mechanical resistance to the gravitational force, termed gravity resistance, is a principal graviresponse in plants, comparable to gravitropism, and has sustained the evolution of land plants.

We have shown, with ground-based experiments using centrifugal hypergravity conditions, that cortical microtubules play an

important role in signal transduction and the cell wall in the final response to hypergravity. However, it is uncertain whether this hypothesis is as applicable to resistance to 1 g gravity as to the resistance to hypergravity. To confirm this point by using true microgravity conditions in space as the control, we conducted the Resist Tubule space experiment, consisting of three runs, on the Kibo Module of the International Space Station. The modifications by microgravity of the formation and orientation of cortical microtubules were analyzed with wild-type Arabidopsis seedlings, cultivated in the Cell Biology Experiment Facility (CBEF) onboard the Kibo and recovered to earth after chemical fixation, and by observing on-site seedlings of GFP-expressing Arabidopsis lines. In the epidermis of the growing region of hypocotyls, cells with transverse cortical microtubules were predominant, and their reorientation from transverse to longitudinal directions occurred in the region where elongation growth has almost ceased at 1 g. Under microgravity conditions, the percentage of cells with transverse microtubules increased, whereas that with longitudinal microtubules decreased in the transition region, as compared with on-orbit 1 g conditions. Such a modification of reorientation of cortical microtubules may contribute to maintain the capacity of cell elongation under microgravity conditions. On the other hand, we cultivated Arabidopsis alpha-tubulin mutants, it tua4 and it tua6 with different degrees of defects, in the CBEF, and analyzed growth and cell wall properties of inflorescence stems. Growth of both mutants was stimulated and their cell wall rigidity was lower under microgravity conditions, as compared with on-orbit 1 g controls. The decrease in levels of cell wall polysaccharides, as well as the modification of expression of cell wall-related genes, responsible for the decrease in cell wall rigidity, also occurred under microgravity conditions. These results support the hypothesis that both cortical microtubules and the cell wall play an essential role in resistance of plants to gravity in the range from 1 g to hypergravity.

F1.1-0007-18 ARABIDOPSIS THALIANA ROOT GROWTH UNDER SIMULATED MICROGRAVITY

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In the context of the space conquest, plants will constitute a life support system for long-term space missions which will provide oxygen and food. In this perspective, the spatial environment's effect, and more particularly the microgravity effect on plants, must be studied. This work concerns the action of microgravity on the development on Arabidopsis thaliana plant model at the level of its main roots. This study was carried out in three parts: (i) measur- ing the root length of plants grown in simulated microgravity, (ii) characterizing the action of microgravity on the cell cycle and (iii) observing the action of microgravity on the elongation of differentiated cells. The length of the roots subjected to microgravity, measured by DIC filter microscope, was shorter than the control 1g. The action of microgravity on the cell cycle was analyzed by flow citometry, expression of marker genes encoding the proteins of cell-cycle regulation by PCR quantitative and transgenic plant lines by histoenzymological test of glucuronidase. The results showed a dysfunction in the cell cycle and more particularly in the G1

/ S phase in microgravity. Cellular elongation and ploidy, measured by flow citometry, showed a decrease in the index of endoreplication of differentiated cells from plant in microgravity. Based on these results, we can conclude that microgravity disrupts the cell cycle, in particular by slowing down the G1 phase, decreasing the meristematic cell rate of proliferation and decreasing the endocycle index. These processes contribute to a decrease of the plant root growth subjected to microgravity.

F1.1-0008-18 EFFECTS OF LONG-TERM 3 G-HYPERGRAVITY ON THE FORMATION OF TISSUES IN THE PEDUNCLE OF ARABIDOPSIS

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To explore how gravity is involved in the formation of tissues in the plant stem including the ones having supporting functions, we have performed long-term microgravity experiments and obtained results indicating a possibility of an involvement of gravity in the formation of pith cavity and fibers. To verify the results of space experiment, we have developed a long term-hypergravity experimental system and performed a 3 G-hypergravity experiment for 30 days. In the present study, we have examined effects of this 3 G-hypergravity environment on the formation of tissues in the peduncle of Arabidopsis (Arabidopsis thaliana (L.) Heynh.). Though still preliminary, an anatomical observation showed that cross sectional areas of tissues generally increased under 3 G in the basal part and these areas tended to increase generally also in the apical part. Interestingly, however, that of pith cavity tended to decrease under 3 G, indicating a possibility that gravity suppress its formation. The formation of fibers also tended to be suppressed under 3 G in the apical part, indicating a relationship of between the formation of pith cavity and of fibers.

F1.1-0009-18 SPATIOTEMPORAL CONTROL OF FLOWERING GENE EXPRESSION USING A HEAT-SHOCK-ACTIVATED GENE SWITCH UNDER MICROGRAVITY ONBOARD SJ-10 RECOVERABLE SATELLITE

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The reproductive success of plants is often dependent on their flowering time being adapted to the territorial environment, in which gravity remain constant. Whether plants can follow the same rule to determine their flowering time under microgravity in space is unknown. Flowering time in Arabidopsis is controlled by the day-length specific expression of FLOWERINGLOCUS (FT) gene in leaves. In the present experiment, we developed transgenic Arabidopsis containing the heat shock (HSP 17.4)-inducible gene promoter to the green fluorescent protein (GFP) reporter gene (HSPpro:: GFP) and the FT gene (HSPpro::FT), respectively, to assess whether function of FT in regulating flowering time was similar to that on the terrestrial condition. The expression of HSPpro:: GFP and HSPpro::FT in Arabidopsis leaves at 37C under shortday conditions, were monitor by a plant GFP imager. In the same time, time-lapse images also documented the effect of microgravity on the flowering induction of Arabidopsis and rice plants under a long-day (16h light::8h dark) and a short-day (8h light::16h dark) conditions, respectively. 37C heating for 30 min induced strong expression of GFP and FT in the leaves of Arabidopsis plants in microgravity but flowering time apparently delayed. For the first time, the importance of gravity in expression of FT gene and its induction flowering in microgravity was unequivocally demonstrated. The network of transcriptional regulation of flowering gene expression are also analyzed.

F1.1-0010-18 REGULATION OF CORTICAL MICROTUBULE ORGANIZATION BY ASSOCIATED PROTEINS IN PLANT CELLS IN SIMULATED MICROGRAVITY

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Cortical microtubules (cMTs) are highly dynamic plasma membrane bound arrays that can undergo reorganization affected by internal or external stimuli, including gravity and mechanical stress. It still remains unclear how parallel orientation of MTs in cortical arrays is controlled, and what determines whether an array will be oriented transverse or longitudinal relative to the cell axis. CMTs are known to be stabilized by numerous MT associated proteins, among which are MAP65-1, CLASP and Phospholipase D delta (PLD delta) that can bundle antiparallel MTs, regulate MT plus-end dynamics and stabilize cell wall-plasma membrane-cytoskeleton continuum. Experiments with Arabidopsis thaliana seedlings grown on the 2D slow rotating clinostats have revealed a decreased expression of MAP65-1, CLASP and PLD delta under clinorotation. Pharmacological studies with oryzalin (inhibitor of tubulin polymerization) provided evidence that activity of MAP65-1, CLASP and PLD delta depends on the state of MTs and the decrease in their expression happened due to MT depolymerization. Contrary, under clinorotation, expression of the MAP65-1, CLASP and PLD delta was increased, and supposedly aimed at stabilization of cMT arrays, which could be disordered by stress stimuli. Each of these proteins stabilizes cMT in a special way referring to its functional activity and participates either in MT bundling and plus-end stabilization or promotes connection of MTs with plasma membrane. Our study contributes into understanding of plant cell growth regulation and cytoskeleton involvement in the mechanism of gravity signaling in plants.

F1.1-0011-18 PLANT ROOTS CHANGE THEIR GRAVITROPIC REACTION IN STATIC MAGNETIC FIELD OF DIFFERENT ORIENTATION COMBINED WITH ALTERNATIVE ELECTRIC FIELD OF DIFFERENT ORIENTATION

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It was shown before that the effect of the combined magnetic field on the plants' roots gravitropic reaction depended essentially on the initial orientation of roots and combined magnetic field and gravity vectors. Aim of the work was to summary the experimental results obtained in our previous works and to understand the common mechanism of these differences. So the experiments of simultaneous action of static magnetic field and alternative electric field of different orientations relatively each other were observed. The gravitropic reaction of cress roots was investigated in static both vertical and horizontal magnetic fields and alternative electric field of different directions. The alternative electric field was tuned to cyclotron frequency of Ca2+ ions in magnetic fields. It was shown that the direction of roots relatively both static magnetic field and alternative electric field is very important. The effect may be explained by membrane breathing caused by alternative electric field. The alternative electric field created the alternative magnetic field. The results in combined magnetic field coincided very well with the results obtained in static magnetic field combined with alternative electric field.

F1.1-0012-18 CELL CYCLE EVENTS IN PLANTS BY THE CONDITIONS OF ALTERED GRAVITY

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The leading areas of modern biology space are cell biology under conditions of altered gravity and definition the cellular and molecular mechanisms plants gravisensitive. The most investigations aimed at solving the fundamental problems of cell biology and are in the knowledge of basic metabolic processes in the cell, growth, development and reproduction of plant organisms in microgravity. One of them is research in the field of space biology contribute to a clarification of the fundamental problems of space biology and create the controlled human life-support systems in manned space flight including the biotechnology development. But the create of reliability of forecasting systems in living space flights possible by the base of deep and comprehensive study of the impact factors of space flight on living organisms and their adaptation responses. The obtained literature data of cell cycle events and duration by microgravity are contradictory and diverse, that is does not allow to understand the integrity of the process. We show known data of the processes of beginning plant cell cycle events by conditions of altered gravity (real or simulated) and our own results for understanding real state of plant cell in the same conditions and for identify future study areas.The conflicting data about the increase or decrease of proliferative activity caused by the different timing of cell cycle research. During the first cell cycle is an increase the transcription of certain cell cycle genes and delay of transition from G1- phase to phase of DNA synthesis, which leads to a decrease of the proliferative pool. In all experiments we can see that in microgravity conditions and under clinorotation the duration of first cell cycle more than in control. We suppose that this is due to prolongation of G1- phases (pre-synthetic) in the cycle. However, in the later stages of growth the increase of proliferative activity might indicate the work of recovery and adaptation mechanisms of cell's life support.

F1.1-0013-18 LIPID BILAYER OF THE PLASMALEMMA IN PEA SEEDLING EPICOTYL CELLS IS SENSITIVE TO SIMULATED MICROGRAVITY

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Lipid bilayer of the plasmalemma in pea seedling epicotyl cells is sensitive to simulated microgravity Olena Nedukha, Elizabeth Kordyum and Tamara Vorobiova Institute of Botany of NASU, Kiev, Ukraine. Tereschenkivska str., 2, 01601, Kiev, Ukraine. E-mail: o.nedukha@hotmail.com

Biological membranes, especially plasmalemma, and their properties and functions can be considered as the most sensitive indicators of the effect of gravitation or altered gravity on the cell. We studied the composition and content of lipids (glycolipids, phospholipids, triglycerides, sterols) and fatty acids in the plasmalemma isolated from epicotyls of pea 6-day old seedlings grown under slow horizontal clinorotation (2 rpm). The plasmalemma was isolated from epicotyl cells, using the two-phase water-polymer system with an ultracentrifuge Optima L-90K, and was studied with transmission electron microscopy. Lipids and saturated and unsaturated fatty acids were determined by liquid chromatography using a chromatograph Angilent 1100. A length of epicotyls of seedlings grown under clinorotation was less than in control seedlings. Under clinorotation, the content of glycolipids decreased nearly 2.5 times in comparison with control ones, while the content of sterols, increased twice. The common content and composition of phospholipids, saturated and unsaturated fatty acids did not almost change under clinorotation. However, there were some changes in the content of certain fatty acids, namely: the content of myristoleic (14:1), linolic (18:2), and oleic (18:1) acids decreased, the content of linolenic (18:3), dihomolinolenic (20:3), and palmitic (16:0) acids increased. An unsaturation index of fatty acids in the plasmalemma under clinotation was similar to that in the control. This event may be explained with a new balance which is settled between increasing and decreasing certain unsaturated and saturated fatty acids in the new conditions and it maintains the membrane fluidity at the normal level. As well known, the membrane fluidity is a decisive factor for cell functioning and integrity, in particular for activity of membrane-bound proteins, protein transport and other molecules across membrane in the signaling process and cell division, A balance between unsaturated and saturated fatty acids is a fundamental biophysical determinant of membrane fluidity. The obtained data show the sensitivity of the plasmalemma lipid bilayer to simulated microgravity on the one hand, on the other hand - its ability to maintain the fluidity at the normal level and thus to make contribution in plant adaptation to microgravity. .

F1.1-0014-18 HSP90 DEPENDENCE OF PLASTICITY RESPONSES TO CLINOROTATION AND LIGHT/DARKNESS IN ARABIDOPSIS SEEDLINGS

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Two main regulators of plant growth activity and orientation in space are gravity and light. Alterations of these factors affect significantly the growth pattern. Light-grown Arabidopsis thaliana seedlings have short hypocotyls and long roots, but dark-grown ones have elongated hypocotyls and shorter roots. Altered gravity, in particular, clinorotation disorients the growth. However, interaction of these effects is not well understood. It has been shown that a role in the networking different signal pathways and plasticity responses may play HSP90. This chaperone family is involved in many cellular processes through regulation of a diverse set of substrate proteins. In particular, it takes part in hormonal signaling, cell cycle control, dark and gravity responses, photomorphogenesis etc. In addition, there are evidences for its participation in restriction of stochastic development. In this study, involvement of two cytosolic HSP90s in plastic responses of A. thaliana seedlings to white light/darkness under horizontal clinorotation (2 rpm) has been tested. Athsp90-1 and Athsp90-4 loss-of-function mutants (NASC) were compared with Col-0 ecotype. Seedlings were grown for 6 d under the following conditions: 1) 1 g + light; 2) clinorotation + light; 3) 1 g + darkness; and 4) clinorotation + darkness, at 23±1°C. Measurement of hypocotyl, root and total length in 6-d-old seedlings demonstrated opposite effects of clinorotation in light and darkness in both the mutants and wild type. At lighting, clinorotation resulted in a decrease in the seedling length mainly due to lower root growth activity, when compared to the seedlings grown motionlessly. In contrast, in the dark, seedlings grown under clinorotation were longer than at 1 g due to more active growth of both the hypocotyls and roots. Thus, clinorotation seems to interact with the light and dark responses in different ways. At that, Athsp90-1 and Athsp90-4 showed some specific alterations in the plasticity traits. In Athsp90-1, the mean seedling length did not significantly differ from the wild type, but in the dark the hypocotyl/root ratio was lower. In Athsp90-4, a moderate reduction in growth activity at 1 g both in light and in the dark was determined, but this effect was absent under clinorotation. In addition, both mutants were characterized with higher variation of all the traits in all the variants that indicates increased development instability. Taken together, these results may suggest specific roles of AtHSP90-1 and AtHSP90-4 in the plasticity responses and, at the same time, their importance for stabilization of the growth at all the conditions.

F1.1-0015-18 DEPENDENCE OF THE GRAVITROPIC REACTION'S THRESHOLD ON THE DIRECTION OF MAGNETIC INDUCTION OF THE STATIC MAGNETIC FIELD RELATIVELY CRESS ROOTS

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It was revealed that the gravitropic reaction's threshold value (value of magnetic induction) of cress roots depended essentially on the relative location of roots and static magnetic field. Although in all cases the gravitropic reaction had the threshold character, the magnitude of the threshold essentially differed (by two orders) for different directions of roots relatively the static magnetic field. The explanation of the effects observed was proposed. It was based on the quantitative difference between the interactions of static magnetic field with ions and ion's magnetic moments. It was shown that both effects were possible. The difference was caused by ions downstream. All experiments were fulfilled under well reproducible magnetic conditions i.e. in μ-metal shield or superconductive shield with warm volume. The magnetic field of needed direction was created artificially.

F1.1-0016-18 ADAPTATION OF PEA PLANTS TO LOW LIGHT CONDITIONS UNDER THE INFLUENCE OF SIMULATED MICROGRAVITY

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It is well known that it is possible to obtain plant biomass and seeds in conditions of real microgravity while maintaining optimal parameters in the growth chamber. Providing optimal conditions for plant cultivation during long-range space missions can be disturbed. Providing optimal (high) light level in future space greenhouses of large size may be an excessive load on power supply systems. Therefore, it is important to know the adaptive rearrangements of plants under suboptimal and/or stressful conditions, which are likely to arise during long-term extraterrestrial missions. In addition, it is important to know the minimal sufficient quantitative parameters that are necessary for plants development, namely lighting, watering, mineral nutrition, and gas composition for designing feather onboard greenhouses. The aim of our work was to determine the respiration and photosynthesis response of peas plants on the vegetative growth phase under the influence of simulated microgravity (clinorotation 2 rpm/min) under sufficient light (180 mol m−2 s−1 PAR) and low light (20 mol m−2 s−1 PAR) conditions. The duration of clinorotation was 12 and 18 days. The ultrastructure of mitochondria and plastids, chlorophyll fluorescence parameters, tissue respiration, soluble sugar content and in vivo CO2 exchange under light/dark conditions were determine. Adaptive changes of plants under reduction of light level, namely, decrease of fresh and dry weight of plants, significant reduction of leaf thickness, change of the ultrastructure of chloroplasts and chlorophyll fluorescence parameters are observed in the conditions of simulated microgravity. At the same time independently of light conditions clinorotation caused to slightly increase of respiration and photosynthesis according CO2 exchange data and tissue respiration of mitochondria. It is suppose that an increase in the level of respiration can affected of the accumulation of nutrients in the seed of plants in the condition of microgravity.

F1.1-0017-18 STARCH CHARACTERISTICS OF POTATO MINITUBERS CHANGE UNDER SIMULATED MICROGRAVITY

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Starch characteristics of potato minitubers change under simulated microgravity Olena Nedukha and Elizabeth Kordyum

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Further understanding the gravisensitivity of basic cell processes and mechanisms of plant adaptation to microgravity is necessary for working out the technologies of the autotrophic chain in the Bioregenerative Life Support Systems and its reliability, since plants are considered as sources of oxygen and food for astronauts. We studied the behavior of starch in minitubers formed on potato mini plants grown during 45 days under slow horizontal clinorotation (2rpm). The content and composition of starch and soluble sugars were determined using Gilbert's method in the modification by Bolotova et al. (2001) with a spectrophotometer (SP-2000). Taking into account that potato taste properties depend on starch solubility in hot water and its boiling power, we studied these parameters with the method of Richter et al. (1975). Minitubers formed under clinorotation were larger in comparison with control ones owing to an increase in both the number of storage parenchyma layers and a size of its cells. Under clinorotation, the starch total content increased 1.4 times, while the content of monoand disaccharides decreased 1.5 times. The content of amylose in clinorotation tubers decreased 4 times, thereafter a ratio of amylose/amylopectin was 1:16, it was 1:3 in control samples. The swelling strength of starch decreased 4.6 times and its solubility in hot water - 4.5 times in comparison with those of starch in the control minitubers. These changes reflect the starch physical properties, in particular on the density and its swelling power. It is assumed, that starch becomes amorphous and loses its typical molecular structure owing to such changes. The obtained results indicate the possibility of plant vegetative reproduction and the formation of storage organs in simulated microgravity on one hand, on the other hand - the sensitivity of this process to altered gravity. As potato plants are defined the food components of Bioregenerative Life Support Systems for long-term space flights, the investigations of tuber formation and especially their quality (storage starch) by the methods of biochemistry, cellular and molecular biology require the further continuation. References Bolotova V., et al. Journal Plant Resources. (Moscow). 2001, 37: 109-112. Richter M., Aygustat C., Shirbaum F. 1975. The Selected Data of Starch study. Moscow, Eds. Kozmin

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LIFE SCIENCES AS RELATED TO SPACE (F)

TOWARDS SPACE EXPLORATION: RADIATION BIOLOGICAL BASIS (F2.1)

F2.1-0001-18 RADIATION MEASUREMENTS AND DOSIMETRY FOR DEEP-SPACE EXPLORATION

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Dosimetry and radiation monitoring are key factors for the planning of future human exploration on deep-space missions outside of Low-Earth Orbit (LEO), as radiation exposure poses one of the major health risks for astronauts in deep space. The amount of radiation dose astronauts would accumulate during typical mission scenarios and durations can potentially exceed currently allowable exposure limits within months.

In space radiation monitoring the three main areas of concern are: 1) high-energy and deeplypenetrating Galactic Cosmic Rays (GCRs); 2) impulsive Solar Energetic Particle (SEP) events with high flux intensities up to a few hundred MeVs; and 3) secondary neutrons created by interactions of primary radiation with spacecraft material or planetary atmospheres and soils. Furthermore, in-situ radiation measurements provide invaluable input for radiation transport models that are used to calculate

expected radiation exposures and shielding effectiveness, and subsequently potential health risks for future deep-space mission scenarios.

Here, we present an overview of dosimetry in LEO, lunar orbit, and in deep space, and place the findings from years of measurements in context of what our current state of knowledge of space radiation implies for future exploration missions. Because the planet Mars is a prime goal for future exploration, we will focus in more detail on measurements conducted on the Martian surface with the Radiation Assessment Detector (RAD) as part of the Mars Science Laboratory (MSL) mission. Since Mars lacks a global magnetic field and its atmosphere is very thin, the surface is only weakly protected from impacts of GCRs and SEPs. This makes understanding and assessing the Martian surface radiation environment a key goal for future exploration. MSL/RAD has been characterizing in detail the charged and neutral particle environment induced by GCRs, as well as during short-term radiation enhancements from SEP events arriving at Mars.

We will discuss the capabilities of the existing space dosimetry instrumentation, as well as highlight areas outside the current scope where we need to improve our understanding of the space radiation environment.

F2.1-0002-18 HIGHLIGHTS OF RECENT FINDINGS ON BIOLOGICAL CONSEQUENCES OF EXPOSURES TO CHARGED PARTICLE RADIATION

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COSPAR session F2.5 focuses on cross discipline aspects of space radiation and consequences for human health and long-term spaceflight mission success. In this presentation I will highlight findings in the last few years from ground-based accelerator research and spaceflight experiments that address the biological consequences of exposure to charged particle radiation typical of galactic cosmic rays and solar particle events. This is a broad topic that includes molecular damage and repair, cell signaling, systems biology, tissue and organ responses, and late pathological consequences to animal models and humans. It also includes the impact of radiation on microorganisms in the spaceflight environment, including microbiota of the body, which interact with host organisms, their life support systems and inform issues important to astrobiology. Health consequences range from acute radiation syndrome to cancer, cataracts, and impaired behavior and performance. Charged particle exposure regimens are evolving from single particle, moderate dose, acute exposures to multi-ion, low dose and dose rate schedules that represent the spaceflight environment with ever higher fidelity and are revealing complex dose effect relationships. Spaceflight in situ measurements have also evolved in their sophistication and address biological reactions to radiation in the context of other spaceflight stressors. The presentation will illustrate how the space radiation research community continues to refine its understanding of the biological processes underlying human health and safety in the context of spaceflight.

F2.1-0003-18 SPACE RADIATION INDUCED BIOLOGICAL EFFECTS AND THEIR MECHANISMS IN DIFFERENT ORGANISMS

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Space radiation biology is one of important parts of space biology, mainly focusing on space radiation induced biological effects and their mechanisms of the genetic variations in organisms. As well known, space radiation environment is extremely complex, including multiple primary radiation particles with different initial energies and various secondary particles in the spacecraft. Despite the low dose and dose rate of space radiation, there are strong evidences that space flight can induce a series of DNA damage and other stress responses in organisms.

There are more than 50 varieties of seeds of Oryza sativa on board recoverable satellites ("JB-1", "20th, 21th and Shijian 10 recoverable satellites") and spacecrafts ("Shenzhou-3", "Shenzhou4", "Shenzhou-6" and Shenzhou-8) since 1996. After landing from spaceflights, the phenotype variations, cytological effects, the characteristics of genomic mutations, and the changes of protein profiling and genomic methylation level were further studied, which indicating that space radiation could induce wide variations in different levels of organisms. In addition, the inheritable effects could also be observed in these results. In order to study on dose and different LETs dependent biological effects, we had also investigated the effects in the 24 japonica and indica varieties of O. sativa with different maturation periods induced by space radiation and γ-rays, which were the same radiation dose as spaceflight (2 mGy) but different LETs HZE ions by Heavy Ion Medical Accelerator In Chiba (HIMAC), respectively. In the levels of plant height and ripening rate, the results showed that the biological effects caused by space radiation in different varieties were equivalent to the mutagenic effects induced by 10 50Gy γ-rays. The phenotypic mutations, chromosomal aberrations and mitotic indexes of root tip meristem in 9 varieties of O. sativa showed that the mutagenic effects caused by space radiation were significantly higher than those of the same doses of the iron ions radiations (500keV/μm), neon ions radiations (31 keV/μm) and carbon ions radiations (13.3 keV/μm). The analysises of the genomic methylations showed that space flight and heavy ion simulated radiations could cause the changes of genetic methylations in genomic DNA, and the changes of methylations were more pronounced in the phenotypic variants.

To study the synergistic effect of space radiation and microgravity on organisms, dauer larvae of Caenorhabditis elegans, including dys-1 mutant, ced-1 mutant, and wild-type, were exposed to spaceflight and spaceflight control (in a 1×g centrifugal device). Functional genomics results indicated that, microgravity, depending on gravity sensor of organisms, enhanced the DNA damage response in the presence of space radiation, and probably play a vital role on DDR during short-duration spaceflight. These results indicated that space radiation biological effects were significantly different from those of ground-based irradiations. In addition, it can be seen that the space radiation biological effects cannot be described by a simple dose-effects relationship due to the complexity of the space radiation environment, and should be considered from the perspective of multi-dimensional and systematic views of point. Therefore, the further in-depth studies will focus on the systems biology approaches, which will be used to mine the biomarkers sensitive to the space radiation and the key factors or main mechanisms of the biological effects induced by space radiation.

F2.1-0004-18 INTERPLAY OF SPACE RADIATION AND MICROGRAVITY IN DNA DAMAGE AND DNA DAMAGE RESPONSE

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In space, multiple unique environmental factors, particularly microgravity and space radiation, pose constant threat to the DNA integrity of living organisms. Specifically, space radiation can cause damage to DNA directly, through the interaction of charged particles with the DNA molecules themselves, or indirectly through the production of free radicals. Although organisms have evolved strategies on Earth to confront such damage, space environmental conditions, especially microgravity, can impact DNA repair resulting in accumulation of severe DNA lesions. Ultimately these lesions, namely double strand breaks, chromosome aberrations, micronucleus formation, or mutations, can increase the risk for adverse health effects such as cancer. How spaceflight factors affect DNA damage and the DNA damage response has been investigated since the early days of the human space program. Over the years, these experiments have been conducted either in space or using ground-based analogs. We will review the evidence for DNA damage induction by space radiation and/or microgravity as well as spaceflight related impacts on the DNA damage response. We will also discuss the conflicting results from studies aimed at addressing the question of potential synergies between microgravity and radiation with regard to DNA damage and cellular repair processes. We conclude that further experiments need to be performed in the true space environment in order to address this critical question.

F2.1-0005-18 DETECTION OF DNA DAMAGE BY SPACE RADIATION IN HUMAN FIBROBLASTS FLOWN ON THE INTERNATIONAL SPACE STATION

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Although charged particles in space have been detected with radiation detectors on board spacecraft since the discovery of the Van Allen Belts, reports on the effects of direct exposure to space radiation in biological systems have been limited. Measurement of biological effects of space radiation is challenging due to the low dose and low dose rate nature of the radiation environment, and due to the difficulty in distinguishing the radiation effects from microgravity and other space environmental factors. In astronauts, only a few changes, such as increased chromosome aberrations in their lymphocytes and early onset of cataracts, are attributed primarily to their exposure to space radiation. In this study, cultured human fibroblasts were flown on the International Space Station (ISS). Cells were kept at 37 °C in space for 14 days before being fixed for analysis of DNA damage with the -H2AX assay. The 3-dimensional -H2AX foci were captured with a laser confocal microscope. Quantitative analysis revealed several foci that were larger and displayed a track pattern only in the Day 14

flight samples. To confirm that the foci data from the flight study was actually induced from space radiation exposure, cultured human fibroblasts were exposed to low dose rate rays at 37 °C. Cells exposed to chronic rays showed similar foci size distribution in comparison to the non-exposed controls. The cells were also exposed to lowand high-LET protons, and high-LET Fe ions on the ground. Our results suggest that in G1 human fibroblasts under the normal culture condition, only a small fraction of large size foci can be attributed to high-LET radiation in space.

F2.1-0006-18 DNA DAMAGE RESPONSE OF EX-VIVO PORCINE EYE LENSES IN ORGANCULTURE AND IN-VITRO CULTURED LENS EPITHELIAL CELLS TO IONIZING RADIATION

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Astronauts on space missions, especially on long-term missions to Moon or Mars have a higher risk for the expression of radiation late effects such as cancer or sub-capsular cortical eye lens opacities. This is due to higher dose and different patterns of cellular energy deposition from high-linear-energy-transfer (LET) components of galactic cosmic radiation in space than that of terrestrial low-LET radiation on Earth. The eye lens is considered to be a radiation sensitive organ with radiation induced cataract to occur with a threshold absorbed dose of 0.5 Gy of sparsely ionizing radiation. For terrestrial occupational radiation lens exposure limit is set to yearly 20 mSv by the International Commission on Radiological Protection (ICRP, Statement on tissue reactions, Ottawa, Canada, 2011). Doses perceived by astronauts are much higher: in average 150 mSv per year on the International Space Station (ISS) and 1.2 to 1.4 mSv per day on Apollo and Skylab missions (Cucinotta FA, Manuel FK, Jones J, Iszard G, Murrey J, Djojonegro B, Wear M. Space radiation and cataracts in astronauts. Radiat Res. 156:460-466, 2001).

Radiation-induced lens opacification is assumed to initiate from post irradiation proliferative activity of genetically damaged lens epithelial cells with alterations in cell cycle control, apoptosis, differentiation, and cellular disorganization, or other pathways controlling lens fiber cells' differentiation. As the porcine eye lens is similar to the human lens in size and anatomy DNA damage response was investigated in ex-vivo porcine lenses in organ culture, in in-vitro cultivated lens epithelial slabs (ES) and in porcine lens epithelial cells (pLEC). Cell survival of proliferative cells was calculated from colony forming ability (CFA) assay. The phosphorylated form of H2AX, known as γH2AX, was used as a molecular marker to visualize DNA double strand breaks (DSB) and their repair. The modified thymidine analogue EdU was efficiently incorporated into newly synthesized DNA and visualized by a photo-stable Alexa Fluor dye in a fast, highly-specific click reaction. Propidium iodide based DNA staining for cellular DNA content marked radiation-induced cell cycle disturbances.

Results for in-vitro cultivated pLEC are compared to in-vitro cultivated epithelial slabs and to ex-vivo porcine lenses in organ culture. The fraction of cells positive for DNA synthesis as documented microscopically for a 2 h EdU pulse was highest in pLEC, followed by ES > whole lenses. In pLEC the cell survival curve of immediate plated cells and after a recovery period of 24 h follow the equation S=1.40xD+ln 1.47 and S=1.59xD+ln 1.79, respectively. DNA DSB are induced in a dose-dependent manner (18 DSB/cell/Gy) and repaired during successive recovery (5 DSB/cell/Gy residual damage after 24 h). For doses >2 Gy a cell cycle arrest in G2 phase occurred 24 h after X-irradiation and persisted up to 72 h post-irradiation. DNA DSB induction and repair could as well be documented for ES and whole lenses after Xirradiation. In whole lenses, the amount of residual damage (after 24 h and 48 h) was highest in the equatorial zone while in the central epithelial zone DSB repair seemed to proceed with time in a manner comparable to in-vitro cultivated pLEC.

Summary: Lens organ culture allows cellular metabolism and DNA synthesis in whole lenses. Repair of DNA DSB takes place in the central epithelial layer and is reduced in the equatorial region of cultivated lenses.

F2.1-0007-18 PROTON AND FE ION-INDUCED EARLY AND LATE CHROMOSOME ABERRATIONS IN DIFFERENT CELL TYPES

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An early stage of cancer development from radiation exposure is believed to be genomic instability (GI), which accelerates the mutation rate in the descendants of the cells surviving the initial damage. To investigate GI induced by charged particles, we exposed human lymphocytes ex vivo, human fibroblasts, and human mammary epithelial cells to high energy protons and Fe ions, and collected chromosomes at different cell divisions after exposure. Chromosome aberrations were analyzed with fluorescence in situ hybridization (FISH) with whole chromosome specific probes. Comparison of chromosome damages immediately after irradiation to late damages after multiple cell divisions indicated that, after proton irradiation, the frequency of late aberrations was about half of the initial value for both the lymphocytes and epithelial cells. In contrast, after Fe ion irradiation, the late chromosome aberration frequency was about half of the initial value for human epithelial cells, but was significantly lower for human lymphocytes, suggesting different relative biological effectiveness (RBE) values between early and late chromosome aberrations and between different cell types. In addition to human cells, we isolated bone marrow cells from CBA/CaH and C57BL/6 mice, and irradiated the cells to charged particles for analysis of cell survival and chromosome aberrations after multiple cell divisions. After Fe ion irradiation, the late chromosome aberration frequency was similar to the early damages for CBA cells, but different for C57 cells. Our results suggest that RBE values can be different for different cell types, and for the same cell type of different mouse strains.

F2.1-0008-18 CHARGED PARTICLES AND MITOCHONDRIAL SIGNALING

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High energy and high charged particles are the major components of the natural radiation environment in space and their biological characteristics are of major concerns to space agencies for the purpose of radiation protection to the astronauts. The scientific basis for the biological effectiveness of these (HZE) radiation has been accumulated over several decades using a variety of cellular and molecular endpoints and with a range of laboratory model systems. Charged particles altered the dynamic equilibrium of mitochondrial fusion and fission and reduced oxidative metabolic function of cells. In contrast, human small airway epithelial (SAE) cells with depleted mitochondrial DNA (0) and, therefore, no oxidative metabolic functions, exhibited a significantly lower response. Mitochondrial dysfunction induced by targeted cytoplasmic irradiation led to activation of autophagy, which degraded dysfunctional mitochondria in order to maintain cellular energy homeostasis. The activation of autophagy was cytoplasmic irradiation specific and was not detected in nuclear irradiated cells. The autophagy was oxyradical-dependent and required the activity of the mitochondrial fission protein dynamin related protein 1 (DRP1). The resultant mitochondrial fission induced phosphorylation of AMP activated protein kinase (AMPK) leads to further activation of the extracellular signal-related kinase (ERK) 1/2 with concomitant inhibition of the mammalian target of rapamycin (mTOR) to initiate autophagy. Inhibition of autophagy resulted in delayed DNA damage repair and decreased cell viability, which support the cytoprotective function of autophagy. Our results reveal a novel mechanism by which dysfunctional mitochondria are degraded by autophagy to protect cells from toxicity induced by charged particle irradiation.

F2.1-0009-18 NF-KB ACTIVATION AFTER HEAVY ION EXPOSURE: INCREASING THE SENSITIVITY OF THE REPORTER SYSTEM

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Biological effects of ionizing radiation are strongly influenced by the radiation quality. The biological effectiveness of accelerated heavy ions (which constitute the biologically most important radiation type in space) with medium to high linear energy transfer (LET), for affecting DNA damage response pathways as a gateway to cell death or survival, is of major concern for space missions. The transcription factor Nuclear Factor κB (NF-κB) can be activated during the DNA damage response. In order to determine NF-κB activation after exposure to different radiation qualities, a reporter system was constructed, in which the destabilized variant of a reporter gene (DD-tdTomato) is controlled by a synthetic promoter containing four κB binding sites for NF-κB. The current study aims to analyze NF-κB activation after exposure to space-relevant radiation qualities including 16O (95 MeV/n, LET 51 keV/mum), 48Ti (1000 MeV/n, LET 108 keV/mum), 36Ar (95 MeV/n, LET 272 keV/mum) and 12C (95 MeV/n, LET 73 keV/mum) ions by means of the HEK-pNFκB-DD-tdTomato-C8 reporter cell line. The fluorescent protein DD-tdTomato encompasses the ProteoTuner system: DD-tdTomato is rapidly degraded in human cells, but in the presence of the synthetic molecule Shield-1, the fluorescent protein is stabilized and a stronger fluorescent signal is achieved. The fluence and dose of heavy ions and the number of hits per cell nucleus that double the NF-κB-dependent DD-tdTomato expression were investigated in absence and presence of Shield-1. In absence of Shield-1, 44 hits of 16O ions and 12 hits of 48Ti per cell nucleus were required to double the NF-κB dependent DD-tdTomato expression whereas only 3 hits of 36Ar were sufficient. In presence of Shield-1, even single particle hit of 36Ar with LET 272 keV/mum doubled the NF-κB-dependent DDtdTomato expression. In the presence of Shield-1, the fluorescent protein DD-tdTomato was accumulated inside the cell and the detection limit for activation of NF-κB-binding site containing promoter activity after 36Ar ion exposure was lowered. In conclusion, stabilization of the reporter protein can increase the sensitivity for NF-κB activation

detection by a factor of three and the effect of single particle hits was detected. With this sensitive HEK-pNFκB-DDtdTomato-C8 reporter system, agents counteracting heavy ion induced NF-κB activation can be screened at low cost.

F2.1-0010-18 BIOLOGICAL EFFECTS OF RAPID SEQUENTIAL EXPOSURE TO MULTIPLE ION BEAMS IN MAMMALIAN MODEL SYSTEMS: CANCER-RELEVANT AND NON-CANCER ENDPOINTS

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The biological consequences of exposure to space relevant radiations have generally been examined with acute exposure to accelerated ion beams with one or at most two ion species employed in ground-based studies. However, the radiation environment in deep space includes ions from protons to uranium across a wide energy range. Recently, it has become possible to deliver high energy protons, He ions, and heavy ions in rapid succession at the NASA Space Radiation Laboratory. A standardized GCR simulator model is still under development, however it has been suggested by others that the best field to simulate a GCR environment would be derived from a local tissue model that takes into account shielding and fragmentation of the free GCR spectrum as it is transported through relevant materials. To this end, feasibility studies have been designed using high energy protons, which represent a majority of the ions in a model local tissue field, together with two other high energy ions delivered in rapid succession. In murine tissues and cells, cancer-relevant endpoints have been examined with cytotoxicity and autosomal mutations as indicators of genotoxic effects, and non-cancer endpoints have focused on cognitive and behavioral changes. Additional studies have examined the impact of rapid, sequential exposure to three ion species (a majority of high energy protons and lesser contributions from two heavier ions) on endpoints

that are indications of cardiac risk in rats. This presentation will compare and contrast the effects of exposure to single ions with the effects of combined exposure to three particle beams using the relevant model systems.

F2.1-0011-18 EFFECTS OF MODELED MICROGRAVITY ON NON-TARGETED RADIATION EFFECTS IN ARABIDOPSIS THALIANA

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Particle radiation and microgravity are two important space environmental factors which have inevitable impacts on organisms during space missions. A remarkable characteristic of space radiation is chronic exposure at a low dose and fluence, which gives rise to two critical nontargeted radiation effects: radiation-induced bystander effects (RIBEs) and radio-adaptive responses (RARs). To date, almost all experiments of RIBEs and RARs, however, have been demonstrated under the earth-based conditions. This brings forward the need for evidence regarding the effect of microgravity on RIBE and RAR. For this purpose, a two-dimensional rotation clinostat was used to model the microgravity, in which the RIBEs and RARs in Arabidopsis thaliana (A. thaliana) was investigated. It was shown that the modeled microgravity affected the RIBE in intra-plants, exhibiting the repressive effects on the expressions of the genes in HR repair pathway, ROS level, and alleviation of transcriptional gene silencing (TGS) in the bystander tissues. Similarly, the alleviation of TGS could not be effectively induced by irradiated neighboring plants in modeled microgravity, suggesting a repressive effect of microgravity on RIBE in inter-plants. The low-dose priming irradiation can attenuate the repression of following high-dose irradiation to root growth of A. thaliana. However, in the modeled microgravity, the attenuation was not initiated by the priming radiation, indicating a modulation of modeled microgravity on the RAR in plants. These results indicate that the non-targeted radiation effects experimented on the earth cannot completely reflect their real manifestations in space environments.

F2.1-0012-18 CREMIR914 REGULATED UVB ADAPTATION IN CHLAMYDOMONAS REINHARDTII

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UV radiation is one of the factors that may harm earth organisms in space exploration, and algae have developed highly efficient adaptations to UV radiation through the course of evolution. To date, studies investigating the mechanisms of UV adaptation in algae have focused on physiological regulation and associated protein coding genes, with no reports on associated protein non-coding genes. In a previous study, we found that Cre-miR914 was significantly down-regulated in Chlamydomonas reinhardtii in response to heat shock. Additionally, bioinformatics analysis and degradom sequencing indicated that the target gene of Cre-miR914 is RPL18 (ribosomal protein L18). In the present study, we want to know whether Cre-miR914 and RPL18 play roles in response to UV-B radiation. We measured the expression of CremiR914 and RPL18 in response to UV-B radiation through Q-PCR analysis. Then, we constructed cell lines overexpressing Cre-miR914 or RPL18, and performed survival experiments under UV-B stress. The results showed that Cre-miR914 overexpression depressed resistance while RPL18 overexpression enhanced tolerance to UV-B radiation. These results indicate that Cre-miR914 and its target gene RPL18 are involved in the adaptation to UV-B in C. reinhardtii, which represents a new regulatory pathway for UV-B adaptation in algae.

F2.1-0013-18 CHANGES IN NEURONAL FUNCTION AND COGNITIVE PERFORMANCE FOLLOWING EXPOSURE TO VERY LOW DOSES OF HELIUM PARTICLES

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Helium (4He) particles will form a significant portion of the radiation environment on exploratory class missions, such as a mission to Mars. Because the linear energy transfer (LET) of 4He particles is low (0.9 keV/µm), they might be expected to produce less damage to neuronal tissue as they pass through the brain. As such, they might be expected to have little effect on cognitive performance.

Sprague-Dawley rats weighing between 200-225 g were given either head-only or whole-body exposures to 4He particles (1000 MeV/n) at doses ranging from 0.01 to 0.5 cGy. Following exposure, the brains were removed from a subset of the rats for analysis of oxidative stress by measuring NADPH oxidase (NOX2) expression. Measurements were also made of phosphorylated-cyclic AMP (cAMP)-responsive element-binding protein (CREB) and nuclear factor E2-related factor 2 (Nrf2). The remaining rats (n = 10/dose) were shipped to UMBC for behavioral testing, including elevated plus maze (baseline anxiety); novel object and novel spatial recognition (learning and memory); and operant responding on an ascending fixed-ratio schedule (motivation to work for reward).

The results indicated that changes in behavioral endpoints could be observed following exposures to 4He particles at doses as low as 0.01 to 0.025 cGy. Differences in neurochemical endpoints were observed following exposure to doses as low as 0.05 cGy (the lowest dose tested). There were no significant differences between head-only and whole-body exposures on behavioral performance. Analyses of the neurochemical data suggest that whole body exposures may not have been as effective in producing changes in neuronal functioning as were head-only exposures.

Because 4He particles will constitute a significant fraction of the radiation dose to which astronauts will be exposed, the present results suggest the possibility that astronauts on exploratory class missions may be at a greater risk for HZE-induced cognitive deficits than anticipated.

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F2.1-0014-18 NEUROCHEMICAL CHANGES IN SPECIFIC REGIONS OF RAT BRAIN FOLLOWING PARTIAL OR WHOLE BODY EXPOSURES TO 56FE PARTICLES

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Exposing young rats to particles of high energy and charge (HZE particles), a ground-based model for exposure to cosmic rays, disrupts cognitive performance, possibly via production of oxidative stress and inflammation and disruption of the functioning of neuronal communication in critical regions of the brain. Furthermore, these changes in neuronal function are similar to those seen in aging. Although it is known that radiation exposure can cause long-term damage to the brain, it is unknown if this exposure needs to occur directly to the brain or if hits restricted to the body will also cause residual damage. The present experiments were designed to evaluate the neuromodulation of oxidative stress and inflammation following head-only, body-only, and whole-body exposures to 56Fe particles in two areas of the brain critical for cognitive function, the hippocampus and the frontal cortex.

Male, Sprague-Dawley rats were given either head-only, body-only or whole-body exposures to 56Fe (600 MeV/n; 50cGy) particles at the NASA Space Radiation Laboratory at Brookhaven National Laboratory. Tungsten bricks were used to shield either the head or the body, as required; the bricks were removed for whole body exposures. The non-irradiated control rats (0 cGy) were taken to the NSRL, but not exposed. Rats were euthanized 60 days following irradiation.

Results indicated a significant ($p<0.05$) increase in NF-B, a pro-inflammatory transcription factor, in the hippocampus of rats exposed to 56Fe irradiation, regardless of the target of exposure. An indication of dysfunctional autophagy (i.e., accumulation of ubiquitinated p62)

was also increased in hippocampus and frontal cortex, regardless of target of exposure. Two endogenous antioxidant enzymes, GST and SOD, showed increased activation in head-only exposure, but decreased activation with body-only and further significant decrease with wholebody exposure. Nuclear factor E2-related factor 2 (Nrf2) expression, a transcription factor for antioxidant enzymes, and a possible link between oxidative stress, neuroinflammation and autophagy mechanisms, showed differential effects depending on the area of the brain and the target of exposure.

These results show that exposures restricted to the body can still disrupt neuronal function, as some measures were directly affected by body-only radiation, while other measures showed greater change following whole-body exposures. Oxidative stress and inflammation caused by radiation seem to be critical factors in these neuromodulatory changes, as well as in the behavioral disruptions seen following irradiation with cosmic rays.

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F2.1-0015-18 NEUROBIOLOGICAL EFFECTS OF HIGH ENERGY PROTONS AND CARBON IONS 12C IMPACT ON MONKEY'S BRAIN

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The greatest danger for astronauts in interplanetary spaceflights is the galactic space rays (high energy protons and heavy ions), that may cause to the significant disorders of central nervous system functions and, in accordance, to disorders of astronauts performance capability and operator performance. These disorders determine risk of astronaut's death immediately during spaceflight as contrasted with delayed stochastic effects. Consequently the neurobiological effects of two components of galactic space rays - high energy protons and carbon ions 12C in model ground experiment with rhesus monkeys (Macaca mulatta) upon indicators of cognitive functions, that modeling of basic elements of operator performance, and monoamines and their metabolites in peripheral blood were investigated. The monkey's head irradiation by protons in dose 3 Gy did not caused significant changes of cognitive functions and monoamines and their metabolites in peripheral blood. But the carbon ions impact in dose 1 Gy were provoked the significant decreasing of cognitive functions and dopamine metabolites concentration in blood of monkeys with excitable unbalanced type of higher nervous activity. It is expected that the decreasing of monoamines concentration in the blood plasma may be indirectly speak for corresponded decreasing of neurotransmitters concentration in the key brain structures that may be provoke of deficit of dopamine-depend behavior and cognitive functions disorders. The study was funded by the RFBR, research project № 17-29-01002.

F2.1-0016-18 SENSORY ILLUSIONS PRODUCED BY PROTON IRRADIATION

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Deep space human exploration is associated with health risks also due to the presence galactic cosmic rays (GCR: protons and higher Z ions, with spectra peaking in the high energy region) and solar particle events (SPE) mostly protons, with lower energies than GCR. Protons are used throughout the world in radiotherapy centers for cancer therapy, providing distinctive capabilities for treatment of difficult brain and head and neck tumors.

A number of anecdotal reports have suggested the exposure of the brain to irradiation either during therapy or during space travel can elicit anomalous visual responses. Astronauts have reported light flashes (phosphenes) of different colors, shape and movement, in absence of light, and correlations with particle fluxes suggested that these visual effects derive from single particle traversals, probably of the retina or optic nerve (Sannita et al 2006, Narici 2008 and references therein). Recently observations from heavy ion or proton therapy patients have reported visual illusions for which time structure has been noted associated with the pulsed nature of the radiation sources (Narici 2008, Khan et al. 2010, Schardt et al. 2013, Chuard et al. 2016). The current interpretations of mechanisms underlying these sensory illusions include the possibility of neural stimulation through the action of radiation-induced free radicals (Narici et al. 2009).

Mechanisms to describe radiation interactions with sensory and non-sensory neurons or cortex that gives rise to acute visual and other sensory illusions, especially at low doses, are not well understood and investigations into these topics have largely lapsed since the early work undertaken in the 1970's.

To approach this issue, we explored the occurrence of reported sensory events during the treatment of central nervous system tumors using the large patient database available at the Loma Linda University's Medical Center, proton treatment center.

A retrospective review of 300 proton radiotherapy patient records identified 29 reports from 19

patients who spontaneously reported visual, olfactory, auditory and gustatory illusions during treatment. Our results suggest that small numbers of protons can evoke neuronal responses on a 0.1 sec time scale sufficient to elicit conscious illusionary experiences analogous to those from normal sensory inputs. The regions of the brain receiving the highest doses corresponded with the anatomical structures associated with the type of illusion.

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F2.1-0017-18 TRADE STUDY OF RADIATION SHIELDING OF RE-ENTRY VEHICLE USING BIO-MASS

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The study deals with the spacecraft reentry. In this we come across design problems faced during reentry of space and recent researches along with some of the solutions proposed by us. Along with completion of the mission, spacecraft must also be able to return its human passengers safely to the earth's surface. In the earliest crewed spacecraft, this problem was solved simply by allowing the vehicle to travel along a ballistic path back to the earth's atmosphere. Later spacecrafts were modified to allow pilots some control over their reentry path. Perhaps the most serious problem encountered during reentry is the heat that develops as the spacecraft returns to the earth's atmosphere. Friction between vehicle and air produces temperatures that exceed 3,000°F (1,700°C). Most metals and alloys would melt or fail at these temperatures. To deal with this problem, spacecraft designers have developed a class of materials known as ablators that absorb and then radiate large amounts of heat in brief periods of time which are made out of a variety of materials, including phenolic resins, epoxy compounds, bio material and silicone rubbers. The force of deceleration and the heat generated during re-entry increase with the steepness of the angle relative to the atmosphere. If the angle is too steep, the spacecraft burns up, and anyone unlucky enough to be inside is crushed. If the angle is too shallow, on the other hand, the spacecraft skims off the edge of the atmosphere. The ideal reentry trajectory is a narrow band between these two extremes which is the Re-entry Corridor. When the object enters the upper extremities of the atmosphere, the frictional interaction with air molecules begins to slow it down, and the lost momentum gets converted into heat. Temperatures can reach 1,650 degrees Celsius (3,000 degrees Fahrenheit), and the force of deceleration can be seven or more times greater than the force of gravity. Deceleration for atmospheric reentry, especially for higher-speed Mars-return missions, benefits from maximizing the drag area of the entry system. An inflatable aeroshell provides one alternative for enlarging the drag area with a low-mass design. This could also be achieved by using high temperature tolerant parachute for atmospheric air braking. Next big problem is that of Cosmic rays. Without sufficient protection, galactic cosmic rays would penetrate spacecraft and astronaut's bodies, damaging their DNA, mutations of cells ,cancer ,disrupting nerve cells in their brains over the long-term. Shielding is necessary, but it is always a trade-off between human protection and spacecraft weight, so aluminum is used for making space crafts which is 25 percent effective at blocking heavy ion radiations particles. But the need of the hour is to look for compounds like antioxidants because they can soak up certain harmful molecules caused by this radiation. In the nutshell, this can be concluded that the reentry of space is the most dangerous part of any space derbis but it could be handled safely if proper emphasis is given. Our approach to solve this problem is by using shielding property of natural biomass against gamma rays. On a density basis, it has been observed that the cyanobacteria absorbs more of the incoming energy than Lead. In this research paper we have done a trade study and analysis on the biomass material versus different available shielding materials. Cyanobacteria is capable of living in extreme conditions, By analyzing and comparing the radiation shielding properties of existing materials and cyanobacteria, we'll test the effectiveness and efficiency of this process.

F2.1-0018-18 GROUND SIMULATION EVALUATION ON MUTATION EFFECTS INDUCED BY HEAVY IONS IN SWEET SORGHUM

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With the development of space research, plant becomes an excellent model to investigate the biological effects of ionizing radiation for assessing the damage of the space environment. Sweet sorghum is a C4 plant, making it an attractive model plant for functional genomics because of its small genome (730 Mb). In our research, the dry seeds of sweet sorghum were irradiated by carbon ions with different doses, generated by the Heavy Ion Research Facility in Lanzhou (HIRFL) facility, Institute of Modern Physics, Chinese Academy of Sciences. The results showed that the survival fraction presented "saddle like model" that the survival rate decreased, then increased and decreased again with irradiation doses increased. Although the differences between doses were small at 10, 20 and 30 Gy for the phenotypic variations, the carbon ions had a marked stimulatory effect on the survival rate at low doses, with the value at 30 Gy being 86%, higher than that of non-irradiated seeds. After carbon ion irradiation, some abnormal mutants, such as growing point vanishing, tip curling, plant withering and etiolation, were obtained at the seedling stage. At the same time, an early-maturity mutant, KFJT-1, was isolated at 80 Gy, which the growth period was shortened by about 20 days compared to the wild type KFJTCK. Physiological analysis showed that the proline content of KFJT-1 was increased by 11.05% while the malondialdehyde content was significantly lower than that of KFJT-CK. Regarding to the characteristic of KFJT-1, the expression of the circadian rhythm genes was investigated by RNA-seq analysis, which indicated that a critical photoreceptor PHYA gene was significantly up-regulated in leaf and root of KFJT-1, suggesting the mutation could occur on the genomic upstream of PHYA. In conclusion, our work will provide helpful insights to further understand the mutation effects of heavy ions and assess the damage of the space environment in the future.

F2.1-0019-18 BIOLOGICAL EFFECTS ON PLANT MATERIALS BY HEAVY ION BEAM ON GROUND

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Heavy ions irradiation, predominantly present in space, is known to have stronger biological effects than low-LET radiations, such as Xor rays, resulting in lethality, mutation, chromosomal aberrations and other biological endpoints. Therefore, heavy-ion radiation is the most dangerous radiation for astronaut in space environment. Generally speaking, ionizing radiation is known to have several effects on plant growth and development, ranging from stimulatory effects at very low doses, harmful consequences at intermediate levels and pronounced detrimental outcomes at high doses. Firstly, the biological effects of wheat seeds irradiated by 48 MeV/ and 20 MeV/ 14N7+ beams were studied, respectively in our research. The results revealed that heavy ion irradiation could induce a lot of free radicals and inhibit seedling growth of wheat seeds, leading to a great variety of chromosomal aberrations in root tip cells of irradiated seeds and high aberration frequencies compared to the corresponding control. Secondly, wheat dry seeds were exposed to various doses of 12C6+ beams and the biological endpoints reflecting plants growth and root apical meristem activities were investigated in order to analyze the relationship between plant growth and cytological effects. The results showed that the plant survival rate descended at higher doses and various types of chromosome aberrations were observed in the mitotic cells. The frequencies of mitotic cells with lagging chromosomes and these with anaphase bridges reached the peak around 60 Gy, while the frequencies of fragments increased as the irradiation doses increased up to 200 Gy. Thus, the total frequencies of mitotic cells with chromosome aberrations induced by irradiation increased significantly with the increasing doses. Thirdly, Liu et al. comparatively studied the differences of pollen viability and pollen mother cells meiosis between KFJT-1 and KFJT-CK in sweet sorghum, which KFJT-1 was isolated from KFJT-CK after carbon ion beam irradiation, aiming at investigating the mutagenic mechanism. The results showed that the total number of pollens and pollen viability of KFJT-1 were more than that of KFJT-CK. Triad, unequal separation of chromosome and asychronization of chromosomes segregation were found in KFJT-1 meiosis, but the most of chromosomal aberrations induced by carbon ions were repaired, the aberration rate of KFJT-1 being only 4.5In conclusion, our research will provide basic data for assessing potential damage by space radiation.

F2.1-0020-18 EVALUATION OF THE TOXICITY OF IRON-ION IRRADIATION IN MURINE BONE MARROW DENDRITIC CELLS VIA INCREASING THE EXPRESSION OF INDOLEAMINE 2,3-DIOXYGENASE 1

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High linear energy transfer radiation is known to deposit higher energy in tissues and cause greater toxicity compared to low-LET irradiation. Local immunosuppression is frequently observed after irradiation (IR). Dendritic cells (DCs) play important roles in the initiation and maintenance of the immune response. The dysfunction of DCs contributes to tumor eva- sion and growth. However, molecular mechanisms underlying the establishment of immune tolerance induced by heavy ion IR through this DC population are poorly understood. Therefore, here we report our findings on the dysfunction of bone marrow-derived dendritic cells (BMDCs) induced by 1 Gy iron ion radiation and promotions of expressions of JNK1/2/3, indoleamine 2,3-dioxygenase 1 (IDO1), p-ERK1/2 and p38/MAPK; and decrease of IDO2, MHC class II, CD40, CD80 expressions and IFNand TNFsecretion after totalbody IR in mice. JNK+IDO1+ BMDCs showed up-expression of p-ERK1/2 and p-p38/MAPK, reduced expression of MHC class II and CD80, and were not able to effectively stimulate allogeneic spleen T cells. The inhibition of IDO1 expressions could partly restore the function of BMDCs. In all, our study shows that elevated JNK and IDO1 expression induced by Fe ion IR could result in dysfunction of BMDCs via p-p38/MAPK and p-ERK1/2 signal pathway, and it may represent a new mechanism in radiation-induced immune tolerance.

F2.1-0021-18 INVESTIGATION OF PLANT GENOME STABILITY IN RADIOACTIVE ENVIRONMENT OF SPACE FLIGHT

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Planning of interplanetary missions makes it necessary to investigate impact of radiation on plants since radiation is known to break genomic DNA and distort plant development. Due to sessile nature plants should evolve robust system allowing DNA-protection against damage, which is a challenge for science. The aim of our research is to investigate pathway of plant genome protection in microgravity. We perform experiments under clinorotation (2rpm) and treat Arabidopsis thaliana with heavy metal Cd^{2+} known to cause oxidative stress similar to impact of low doses of radiation. Our aim is to find out to what extent DNA is damaged in simulated microgravity. For estimation of DNA damage we applied method of single cell gel electrophoresis (comet assay). Our preliminary experiments have shown decrease of DNA damage by Cd^{2+} under clinorotation suggesting activation of the protective mechanisms. Part of the experiments is devoted to investigation of cytoskeleton involvement in pathways promoting plant genome protection. For this purpose, A. thaliana seedling were treated with actin disrupting drug cytochalasin D (CD) and then grown on Cd^{2+} containing medium. Estimation of DNA damage has shown its enhancement in plants treated with CD in microgravity which means actin participation in signaling pathways regulating genome protection. Besides, impact of radiation and clinorotation cause retardation of plant root growth meaning affection of cell elongation, the process in which actin is also actively involved. To reveal the mechanism of plant genome protection we are investigating expression of genes, involved in DNA damage repair pathways (BRCA, Lig4, Rad51) and actin regulation (formins). Our investigations provide unique information for researchers working on plant growth in space and data obtained will be a good contribution into biotechnology of stress tolerant plants capable to grow in harmful environment.

F2.1-0022-18 STUDY OF SPACE ENVIRONMENT ON PLANT CONDITION: ACTION OF COSMIC RADIATION

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The space flights carried out so far have shown that living organisms are able, under certain relatively well-controlled conditions, to live for several months in space vehicles in low orbit. In the context of the space conquest to Mars, the duration of space flights will be extending between 2 and 3 years. In this frame, it is essential to design and set up a life support where plants have a crucial role as a source of food, in air renewal and in the recycling of waste. The two major challenges associated with space flight are radiation and microgravity effects on living organisms and, as the duration of space flights become longer, radiation doses and time of exposure to microgravity will become higher. It is therefore important to study the action of these factors on plant development. One of the characteristics of space radiation is the chronic exposure at low doses. The primary effect of low doses of radiation is a free radical formation and damage to DNA. Then, cells stop the cell cycle and initiate the mechanisms of DNA repairs. If the repair is incomplete, it can lead to mutations or cell death. Plants have an important post-embryonic development. Indeed, the growing apices of plants contain meristematic cells that continually produce tissues. These cells remain active throughout the plant's life and are particularly exposed to environmental factors that cause DNA damage and mutations. The impact of radiation exposure on plants may be described in terms of short-term effects and long-term risks. Here, we studied the short-term adaptation of plants to radiation during its early vegetative development. Plants of Arabidopsis thaliana have been exposed to low dose of chronic radiation (0.4 mGy/day) and to simulated microgravity (10-4g) using a Random Positioning Machine (RPM). A morphometric analyze, a study of oxidative stress and a characterization of cell cycle have been carried out on root apices of seedlings exposed during 6 days to radiation and / or simulated microgravity. Space is a complex and new environment to which plants must adapt. This study contributes to a better understanding of the effects of the short-term space environment on vegetative development of plants, as well as the interplay between radiation and microgravity on the adaptation of plants to this new environment.

F2.2-0001-18 LEASONS LEARNED FROM THE RADIATION MEASUREMENTS OF THE MARS SCIENCE LAB RADIATION ASSESSMENT DETECTOR (MSL-RAD)

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The Radiation Assessment Detector (RAD) was designed to characterize the radiation environment on the Mars surface and to contribute to an improved assessment of radiation risk for a future human mission to Mars. The flight was chosen to cover a period of solar maximum activity to allow besides the measurement of the galactic cosmic rays an intense study of exposures by solar particle events. The Mars Science Laboratory spacecraft (MSL), containing the Curiosity rover, in which RAD was integrated, was launched to Mars on November 26, 2011. Although not part of the mission planning, RAD was operated already during the 253 day and 560 million km cruise to Mars and made the first time detailed measurements of a radiation environment comparable to that inside a future spacecraft carrying humans to Mars and in other deep space missions. Exactly 100 years after the discovery of cosmic rays on August 7, 1912 RAD makes the first observation of the radiation environment on the surface of another planet and is still gathering data until today. Meanwhile the maximum activity of the current solar cycle has been passed and the solar activity is decreasing. Unfortunately the present solar cycle was an unexpected weak cycle. As a matter of fact only very small solar particle events could be observed during the still ongoing RAD measurements. The paper highlights the achievements of RAD by presenting selected data measured during the cruise and on the Mars surface and describes its impact on predictive models for health risks of astronauts during space missions.

F2.2-0002-18 ISS4MARS, INTEGRATED SIMULATIONS OF MARS FLIGHTS ON THE ISS: THE RADIATION ISSUES

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The human quest towards the exploration of the solar system and beyond will likely begin with the exploration of the planet Mars in the next few decades. Many scientific and technological challenges are still to be approached and solved to enable long deep space human exploration. Once solutions to these challenges are ready, these will be integrated in the flight plans as ad hoc operational strategies.

The International Space Station (ISS) can be considered the only available integrated analogue, where the impact of microgravity, radiation, living and psychological conditions that astronauts will face during a deep space cruise, can be mimicked at the same time, in part or in full. It is conceivable to use the deep space analogue features of the ISS to perform integrated tests of those operational strategies needed to allow for deep space voyages, toward a possible final integrated space test of the entire voyage to Mars, with a fidelity as high as achievable. This utilization strategy for the ISS (ISS4Mars) would help in focusing research and technology on enabling issues for deep space exploration, pushing them to provide a clear deadline for a final test of their solutions. It will also provide the ISS the rank of springboard towards deep space also for the general public, increasing the awareness for human space exploration. Among the many topics to face, obtaining the due mitigation of the radiation risk is certainly a major issue.

In this talk the strategy to fulfill these needs, including, for example monitoring and mitigation of the effects due to Galactic Cosmic Rays (GCR) and Solar Particle Events (SPE) using on vessel solar events now-casting monitors, re-arrangement of the items in the vessel, reorientation of the vessel, shelter modeling, pharmacological countermeasures and the ability to tailor duties and countermeasures to each crew member will be discussed. The need to move the radiation related decisional process from ground (Mission Control) to space is going to be addressed, as well as the the strong benefit in validating all the foreseeable solutions of these issues in synergy during a full dry run of the Mars voyage in the ISS.

The related needs in hardware development (detectors, habitat, shielding, etc), simulation capability and intelligent systems will be discussed, with the goal to assess how far we are to be able to conduct the ISS4Mars dry run from the radiation standpoint.

F2.2-0003-18 INDIVIDUAL RADIOSENSITIVITY: BIG CHALLENGE FOR THE FUTURE OF MANNED SPACE FLIGHTS

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Radiation exposure is a major limiting facto for long duration manned space flights. Radiation protection standards are based on the assumption that all members of the population are equally sensitive to ionizing radiation. However when people are confronted with exposures to IR, they have been asking questions not only about how much the general population but also how much individually, each person, has been adequately protected against IR related health risks. Indeed, the studies of secondary effects post-radiotherapy have shown a great variability among individuals. However, there is insufficient information on the influence of individual radiation sensitivity on health risk estimates, in particular, data at different dose levels, dose rates and with radiation of different qualities are scarce. The gold standard of biodosimetry, ie scoring of dicentrics, have described large discrepancies among cosmonauts after the same flight (Testard et al, IJRB, 1996). Variations into individual exposure or radiosensitivity, the questions are open. Our recent results on the effect of radiation quality have shown that individual radiosensitivity exists among healthy individuals following irradiation with carbon ions and -rays, and individuals may not be equally sensitive to different types of IR (Shim et al, Frontier in Oncology 2016). Thus, a bottleneck is to identify useful biomarkers for the detection of highly sensitive individuals in human polulations (Hall et al, Mut Res, 2017). Biomarkers will be discussed as regards as individual radiation sensitivity versus long term susceptibility (Shim et al, Mut Res 2014).

F2.2-0004-18 ADVANCED DEPTH-DOSE CURVES FOR FAST SPACE RADIATION DOSE CALCULATION IN A SPACECRAFT WITH COMPLEX GEOMETRY

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Space radiation is one of the main concerns in planning human space missions. Radiation environment isn't fixed and varies in time. That's why it is very important to predict radiation dose rate according to current the state of radiation environment. Complicated geometry of a spacecraft and variety of astronaut position inside it make impossible fast and detailed calculations with Monte-Carlo codes. More perspective are methods that apply shield distribution function for spacecraft description and dose-depth curves for dose calculations. We report on improved depth-dose curves method for fast calculations of the radiation dose during the space flight.

Radiation dose calculations using depth-dose curves consist of two parts. In the first part real spacecraft geometry is processed into shielding distribution function. This function is calculated for each point of interest using ray-tracing method. In the second part shielding distribution function is convoluted with the depth-dose curves. Depth-dose curve is a dependence of the radiation dose in a very small tissue volume on the shield thickness and composition.

We take into account backscattering from the shield behind the point of interest and assuming the front and behind shields as a double layer aluminum/water structures. Because, we take into account shield composition, shielding distribution function is replaced with shielding and composition distribution function. Aluminum-water shield is a good simplification of the real geometry, as water is good equivalent for biological tissues and aluminum is the major material for a spacecraft wall. We demonstrate that this ratio has influence on the depth-dose curves in the thickness rage over 10 g/cm^2.

Depth-dose curves were calculated using GEANT4 Monte-Carlo code in one-dimensional slab geometry. We calculated contribution of primary, secondary and albedo radiation. Secondary and albedo radiation was additionally separated according to particle type (gammas, protons, neutrons, nucleus, leptons, mesons and baryons).

To validate the results we apply this method to calculate dose distribution in a spherical water phantom placed in an aluminum spherical spacecraft shell. We compare the results with direct Monte-Carlo simulations for the same geometry.

F2.2-0005-18 EXPOSURE DOSE CALCULATION INSIDE JEM USING PHITS AND 3D ISS GEOMETRY

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The International Space Exploration Coordination Group (ISECG), a forum set up by 14 space agencies including Japan Aerospace Exploration Agency (JAXA), is planning future human space missions following the International Space Station (ISS) mission, such as long-term stay onboard the lunar orbital station called "Deep Space Gateway" and exploration on the Moon and Mars. One of the problems to solve for realizing such missions is space radiation effects on human health. In space, high liner-energy-transfer (LET) radiation that causes significant biological damage flows from outside of the solar system and the sun. Especially, outside of the geomagnetic field where the future missions will be undertaken, the radiation flows at high dose rates. Establishment of radiation protection technology is required for conducting the future missions while ensuring astronauts safety. The radiation protection technology includes accurate estimation of exposure dose and optimization of shielding design. We expect computer simulation using a radiation transport code as a method to estimate exposure dose for the future missions. In order to perform the simulation for actual missions, it is needed to evaluate the accuracy of the transport code (including nuclear reaction models and nuclear data libraries) and the radiation environment models, and the appropriate setting of calculation geometry. This time, we calculated the exposure doses inside the ISS Japan Experiment Module (JEM, called "Kibo") using PHITS (Particle and Heavy Ion Transport Code System) code and the ISS 3D-CAD model. The ISS 3D-CAD model, that includes JEM 3D-CAD model, was created for these calculations. The ISS CAD model (except the JEM model) describes simplified geometry of the ISS. And, the JEM CAD model consists of the geometry of the Pressurized Module (PM), the Experiment Logistics Module Pressurized Section (ELM-PS), and the Exposed Facility (EF) model. The PM and the ELM-PS models reproduce the approximate geometry of the outer shell structure, the debris bumpers, the racks, and so on. This ISS 3D-CAD model was converted to PHITS input format by using SuperMC (Super Monte Carlo simulation program for nuclear and radiation process) software system. The radiation environment model developed by Mattiä et al was employed for calculating the galactic cosmic ray (GCR) fluxes, while AP8 and AP9 model was used for calculating the trapped proton fluxes in the geomagnetic field.

The calculated doses were absorbed dose and dose equivalent of the virtual dosimeters placed inside JEM geometry. In this presentation, we show the calculation results of the exposure doses inside the JEM, and discuss the method to estimate dose based on the comparison between the calculated data and the flight data.

F2.2-0006-18 NEW DEVELOPMENTS IN THE LIèGE INTRANUCLEAR MODEL (INCL4) FOR HIGH ENERGY NUCLEAR COLLISIONS.

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The new developments of the Liège Intranuclear (INCL4) cascade model for nuclear collisions will be presented. The INCL4 model has originally been proposed for modeling of nucleoninduced spallation reactions in the incident energy range spanning from a few MeV to 2 GeV, with special emphasis for applications in transmutation of nuclear waste. The performances of this nuclear model are remarkable. They are testified by the intercomparison of cascade+evaporation codes carried by IAEA a few years ago [1], which showed that INCL4 is generally the best one for describing an exhaustive set of (particle and residue) cross-sections. A general view of the physical aspects of the model are contained in Ref. [2], where it is explained also that INCL4 is well suited to study radiation effects (particle production, gamma production, energy deposits, etc) when included in nuclear transport codes such as MCNPX, Geant4 and PHITS. The purpose of this presentation is to report on the developments which have taken place since the work of Ref.[2]. They pertain to the extension of the model to light to medium-heavy nuclei as incident projectiles, to the inclusion of many inelastic nucleon-nucleon and pion-nucleon reactions, including strange particles production and interactions, allowing a realistic description of nuclear collisions up to 20-30 GeV incident energy, improvements of the nuclear density distributions (allowing in particular a strong improvement of single-nucleon removal cross sections), etc). These new developments make the INCL code quite suitable for the study of radiation effects produced by cosmic rays in the atmosphere and/or space mission vehicles. Particular attention will be brought to the validation of the mode first on individual cross sections in nucleus-nucleus collisions, but also to the description of test experiments relevant for light ion induced reactions in medical and space applications. 1.IAEA-intercomparison:

http://www-nds.iaea.org/spallations (2009) 2.D. Mancusi et al, Phys. Rev. C90, 054602 (2014)

F2.2-0007-18 HELIUM AND HEAVY ION ABSORPTION AND FRAGMENTATION CROSS SECTIONS AND TRANSPORT DESCRIPTIONS IN THE GERMCODE

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The Galactic Cosmic Ray Event-based Risk Model code (GERMcode) is a fast Monte-Carlo based stochastic simulation of the passage of hydrogen, helium, and heavy ions through shielding and tissues. Stochastic models that go beyond deterministic descriptions of average fluence and absorbed doses are needed to support new approaches to risk assessment and to understand uncertainties. The GERMcode uses a 190 particle isotopic grid to describe energy dependent interactions of GCR particles. We review recent developments in the theoretical description of helium and heavy ion cross sections used in the GERMcode. A second-order optical model of absorption cross sections, which considers two-body correlations, has been extended to include the mass and charge number dependence of nuclear one and two-particle densities. The model has been extended to low energies (<100 MeV/u) by addition of improved descriptions of Coulomb scattering and two-body medium effects. We consider the impact of these corrections on helium and heavy ion fragmentation cross sections, which are constrained by the total absorption cross sections. Comparisons to experiments for thin and thick target measurements are described for a large number of projectiles and target materials.

F2.2-0008-18 NEW HUMAN ANATOMICAL MODEL FOR CREW RADIATION ANALYSIS

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The ionizing radiation environment in space pretenses substantial risks to human exploration. It consists primarily of 3 components, Solar Particles Events (SPE), Galactic Cosmic Rays (GCR), and Van Allen Belts (trapped protons) that differ in elemental compositions, energy spectra, and intensities. The extravehicular environment is then modulated by interaction with the shielding provided by the spacecraft design, and the body self-shielding provided differentially to internal organs and tissues. The Orion Multi-Purpose Crew Vehicle (MPCV) is NASA's deep space exploration spacecraft developed for exploration of the solar system. Orion is designed by an industry team lead by Lockheed Martin as the prime contractor. Spacecraft shielding is quantified analytically using Computer Aided Design (CAD) tools to great details. However, NASA is using the Computerized Anatomical Male (CAM) model to quantify the body self-shielding to internal organs and tissues, which is dated back to the 70s and cannot be verified by the modern CAD tools. For this reason, a highly detailed, radiationspecific model, representing the most anatomically correct geometric of the human body, has been developed by Lockheed Martin Space to be used in analyzing radiation dose distribution for human. The model was derived from the BodyParts3D database. BodyParts3D is a threedimensional anatomical structure database for body segments representing the whole-body model for an adult human. The model contains 2234 unique geometric surfaces with no solid regions. A program was developed to convert surface models to solid representation with no loss in geometric quality. The models were then divided into 25 assemblies by organ levels, and organ points were uniformly distributed inside each organ. Multiple analyses were performed with the model. Analyses included tracing rays in CAD through the body geometry, converting results from ray-tracing information to areal density distributions, and creating cross-sectional views. This presentation will discuss the radiation exposure to trapped protons, solar particle events (SPE), and galactic cosmic rays (GCR) at each organ dose point in the body by combining space radiation transport models with the detailed body-shielding mass of BodyParts3D and CAM, respectively, and calculating the dose equivalent to organs and the effective dose per NCRP-132 weighting factors.

“The model was derived from the BodyParts3D database.” “BodyParts3D, © The Database Center for Life Science licensed under CC Attribution-Share Alike 2.1 Japan.”

F2.2-0009-18 IMPACT OF NANOAND MICROMETER SCALES ON RELATIVE BIOLOGICAL EFFECTIVENESS OF ION RADIATION: COMPUTER MODELLING OF DNA DAMAGE AND DICENTRIC INDUCTION

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Detailed understanding of the enhanced relative biological effectiveness (RBE) of ions, in particular at high linear energy transfer (LET) values, is needed to reduce the uncertainty in radiation risk estimations of manned space missions. Track structure based models of radiation effects, such as PARTRAC [1], are suited tools to address this issue. It is generally accepted that the enhanced RBE of high-LET particles results from the spatial clustering of energy depositions around their trajectories. This clustering affects biological material both on nanometer and on micrometer scales. On nanometer scale it leads to multifaceted DNA lesion patterns, in particular DNA double-strand breaks (DSB) of various complexity. Recently, a comprehensive evaluation of DNA damage by light ions over a wide range of LET-values has been undertaken [2]. With increasing LET the damage pattern changes from individual strand breaks towards DSB induction, with highest yields around 100 - 200 keV/µm, and above 300 keV/µm to more complex DSB clusters. On micrometer scale, the energy deposition patterns of high-LET ions are characterized by rather high local doses along the trajectories, decreasing rapidly in radial direction. The preferred localization of DNA lesions along straight lines leads to non-random DNA fragmentation patterns observed experimentally and in computer simulations. However, the role of µm-scale clustering of energy deposition events on biological effects has been largely unclear so far; in conventional radiobiological experiments it could not be frankly separated from local nm-scale effects since both scales are inherently interlinked when radiation quality is changed. To address this issue in an innovative way, experiments at the ion microbeam SNAKE and corresponding track-structure based model calculations of DSB induction and subsequent repair with the biophysical code PARTRAC have been performed [3]. In the experiments, hybrid human-hamster AL cells were irradiated with 55 MeV C ions (LET: 310 keV/µm), 45 MeV (60 keV/µm) Li ions or 20 MeV (2.6 keV/µm) protons; the induction of dicentrics was measured. The particles were either quasi-homogeneously distributed or focused to 0.5 x 1 µm^2

spots on regular matrix patterns of 5.4 µm, 7.6 µm and 10.6 µm grid size, with pre-defined particle numbers per spot so as to deposit a mean dose of about 1.7 Gy for all irradiation patterns. The induction of dicentrics increased with LET after homogeneous irradiation: Li and C ions induced about twoand four-fold higher yields of dicentrics than protons. The induction of dicentrics is, however, affected by µm-scale, too: focusing 20 Li ions or 451 protons per spot on a 10.6 µm grid induced two or three times more dicentrics, respectively, than a quasi-homogenous irradiation [3]. These experimental data provide a unique benchmark for corresponding model calculations. Indeed, first PARTRAC simulations of dicentrics induction with model assumptions and parameters used so far failed to properly match the focusing effect for protons and Li ions as well as the dependence on ion type (or LET) in single-ion irradiation modes [3]. This discrepancy has initiated model and parameter refinements, in particular on DNA end mobility, that enabled the simulations to largely reproduce both the LET-dependence and the focusing effect as well as the usual biphasic rejoining kinetics. The predictive power of the refined model has been successfully benchmarked against measurements of dicentrics after photon irradiation. Ongoing work aims at verifying the model assumptions on the mobility of DNA ends and their processing.

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F2.2-0010-18 AN AB-INITIO APPROACH TO PREDICT DNA DAMAGE FOCI FOLLOWING EXPOSURE TO EARTH AND SPACE RADIATION.

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Albeit its frequent use to quantify radiation-induced DNA insult, the induction of DNA damage foci (e.g. γ-H2AX) is not trivially correlated to the real number of lesions within the nucleus. Moreover, the overall amount of damage and its distribution in space are strongly dependent on the pattern of energy depositions inside the biological matter. This motivated the development of a novel approach to simulate the onset of foci arising from the exposure to different radiation qualities, starting from the initial damage imparted to cells. In the presented study, lowand high-LET radiations adopted in cancer therapy have been used, namely X-rays and Carbon ions. Furthermore, the biological consequences due to neutrons have been investigated exploiting a radiation field mimicking the Hiroshima neutron spectrum at 1.5 km from the device explosion, as reproduced at the RARAF irradiation facility (Columbia University, NY). The proposed strategy consists of different calculation steps, from the characterization of the particle fields involved in the damage induction, to the estimation of initial DNA insult in cells, and finally to the simulation of γ-H2AX foci by applying an ad-hoc clustering algorithm of single damages. Results from calculations have been compared to experimental foci yields scored by a conventional immunocytochemistry protocol: this highlighted the limitations of such detection technique, and a dedicated software optimization has been

carried out to reproduce the artifacts caused by experimental resolution. Preliminary data from confocal microscopy will be shown to offer a better insight on radiation track-structure and on the realistic DNA damage content, and these will be correlated with 3-dimensional simulations. Finally, we address as a pilot study the extension of our modeling approach to radiation fields of interest for space applications, with a particular focus on deep-space travels, also including neutron fields as produced by GCR interactions in the Martian atmosphere or with the walls of an interplanetary spacecraft.

F2.2-0011-18 A NOVEL RADIATION PARTICLE TRAJECTORY ASSESSMENT: IMAGING OF HEAVY ION TRACKS AT CELL LEVEL

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Recently, we developed a radiation detector system to characterize heavy ion particle trajectory at micron resolution (utilizing a 1.67 microns per pixel sensor). The CMOS (Complementary Metal Oxide Semiconductor) sensor used to develop the detector system has an active array of 3664 x 2748 pixels in about 6.1 mm x 4.6 mm dimensions. We also incorporated a holder for chamber slides to be positioned and placed on top of the CMOS sensor. The chamber slide with appropriate biological cell structure, once positioned precisely on the pixel array sensor and exposed to the radiation, the particle trajectory from the sensor data at 1.67 micron resolution can be correlated for the observed particle induced damage at the cell level. Our preliminary studies with heavy ions as part of the NASA Space Radiation Laboratory (NSRL) experiments at Brookhaven National Laboratory (BNL) are very promising with H, He, C, O, Si, and Fe ions. Our preliminary assessment of radiation particle trajectory from the sensor data has been correlated with several biological samples including mCherry 53BP1 mouse hippocampal neuronal cells. We present our preliminary approach in the development of our pixel array radiation detector system and correlate radiation particle induced damage at the cell level. Also, we present our observed radiation track image data of heavy ions at cell dimensions.

F2.2-0012-18 CHALLENGES OF SPACE WEATHER AND SPACE RADIATION PREDICTIONS FOR HUMAN EXPLORATIONS IN DEEP SPACE

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Space agencies such as ESA, NASA, the Chinese space agency and even private sectors have already launched human deep space exploration programs to the Moon and Mars. It requires a very timely and thorough study to better understand the space weather conditions and effects for such human deep space activities in order to further develop mitigation strategies against the associated radiation risks.

In the long-term, there is the omnipresent radiation induced by Galactic Cosmic Rays (GCRs) which are modulated by solar activities. Continuous exposure to the background GCRs may increases the chance of long term health consequences, such as onset of cancer, cardiovascular diseases, skin atrophy, eye cataract, leukemia, anemia, leucopenia and malfunctions of the central nervous system.

In the short-term, intense solar energetic particles (SEPs) can be considered as mightily related to deterministic radiation effects which are of great concern for space exploration. Acute radiation syndrome (ARS) or sickness or poisoning or toxicity is induced after a whole body exposure to high doses of radiation between at the Gy [J/kg] level. Such events, despite of being rather infrequent, could result in severe damage to humans and equipment and lead to failure of the entire mission and therefore should be detected and mitigated as immediately as possible.

Under different shielding environment, the intensity and composition of the GCRs/SEPs may vary due to the interactions of primary particles (of different energies and charges) with the surrounding material (such as the spacecraft and the planetary atmosphere) and the generation of secondaries. Habitable shelters on the Moon and Mars with regolith shielding could provide sufficient protection against such radiations. However the situation of a transit spacecraft in deep space or an astronaut carrying out extra-vehicle or planetary surface activities may be much more severe, especially during the onset of a solar particle event (SPE). This is because an SPE generally have a sudden and sporadic nature and can be very intense, dynamic and vary drastically in time and location. Therefore radiation and particle enhancement measured near Earth (such as the onset time and intensity) may be completely different from of that detected elsewhere in the heliosphere such as on the surface Mars.

Three major factors should be taken into account for evaluating the solar energetic particle radiation environment at different locations in the heliosphere (where the deep space exploration activities may take place): (1) the acceleration process at the Sun which are often related to the flare eruptions and associated shocks, (2) the properties of the accelerated particles injected into the open magnetic field which are connected to the missions (that can be very differently connected compared to Earth), and (3) the atomic and nuclear interaction of particles with the local shielding environment (such as the spacecraft or the Martian atmosphere). Taking into consideration of these 3 factors, we will show our recent study of the September 2017 event which is seen on the surface of both Earth and Mars as well as at STEREO-A (a spacecraft surrounding the Sun at 1 AU). These three locations have a heliospheric longitudinal separation of more than 240 degrees apart and they all saw the SPE with different time profiles, intensities and particle spectra. We highlight the utmost importance of utilizing multi-spacecraft in- situ and remote sensing observations of the Sun and the heliosphere to better understand such dynamic events and their dynamic effects across the heliosphere in particular at locations where human explorations may take place.

F2.2-0013-18 ACTIVE DOSIMETER-BASED ESTIMATE OF ASTRONAUT ACUTE RADIATION RISK FOR REAL-TIME SOLAR ENERGETIC PARTICLE EVENTS

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Radiation exposure from solar energetic particle (SEP) events becomes a much greater concern as human exploration extends beyond low Earth orbit (LEO) and the protective environment of Earth's magnetic field. Free space SEP events have an increased impact on mission planning and operations, as countermeasures may be necessary to avoid exceeding astronaut permissible exposure limits (PELs) and acute radiation syndrome (ARS). Operational analysis tools are needed to assess acute radiation effects during SEP events in order to determine courses of action during the mission. A methodology has been developed to meet this need, which utilizes onboard vehicle dosimeter measurements to estimate dose quantities at astronaut crew locations. The estimated dose quantities provide the necessary inputs to acute biological response models that predict radiation induced performance decrement (RIPD) and other acute radiation effects. The active dosimeter-based crew dose estimate methodology is specifically applied to predicting astronaut organ doses at the storm shelter locations within the Orion spacecraft, which will be tested on the Exploration Mission 1 (or EM-1). The methodology is evaluated and assessed in this presentation, and a simulation of the acute radiation responses in the storm shelter of the Orion spacecraft are shown for the October 1989 SEP event.

F2.2-0014-18 CURRENT APPROACHES TO EVALUATE SPACE RADIATION HEALTH RISKS AND MITIGATION

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Estimating health risks from space radiation exposures during interplanetary travel into deep space currently still involves significant uncertainties. Despite major progress by an international cadre of astrophysicists in characterizing the various radiation types, doses and dose-rates during the 11-year solar cycle, the biological and medical consequences of the multiple combined stressors (including microgravity) to be encountered are not yet fully known. Currently, a diverse array of primarily ground-based but also some in-flight (aboard the International Space Station) laboratory approaches using mainly biological surrogates are ongoing to characterize space radiation health risks from exposure to Solar Particle Events (SPE) and Galactic Cosmic Rays (GCR), with a focus on cancer risk, and effects on the Central Nervous System (CNS). Space radiation effects on the Cardiovascular System (CVS) are also being studied. Astrophysicists and biophysicists are working together to define the relevant set of radiation parameters required to identify key genetic, epigenetic, genomic, and physiological features, and the underlying mechanisms of action attributable to unique particle track structure effects with quantitative and qualitative differences compared to gamma rays, leading to the composite human response to space travel. Physical and pharmaceutical countermeasures are also under development. More basic radiation research is required in order to fill fundamental data gaps, and to allow future theoretical modeling and predictions of outcomes. This presentation will provide a brief overview of current approaches and remaining challenges.

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F2.2-0015-18 SPACE RADIATION MAGNETIC SHIELDING: AN UPDATED ANALYSIS

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Deep-space missions will result in harmful exposure of astronauts to space radiation, eventually leading to late and acute detrimental health effects. Current countermeasures include passive shielding, however, to significantly reduce the effective dose to the crew, large amounts of materials would be necessary and this solution is not compatible with the existing weight restrictions to space missions.

In the last decades, it was commonly believed that the problem of space radiation could be solved by surrounding the spacecraft habitats with large superconducting magnets, even though with considerable technological efforts. At the end of the EU FP7 SR2S Project - Space Radiation Superconducting Shield - we demonstrated however how magnetic shielding is characterized by a number of constraints which restricts its effectiveness, unless properly addressed through an extensive RD.

We present here the results of the project, which attempted for the first time to design an active shielding system, based on superconducting MgB2 magnets. Monte Carlo codes were used throughout all the project to support the multidisciplinary design activities, realistically reproducing the interaction of cosmic rays with the structural materials and with the magnetic field. Comparisons were made between confined and partially confined field configurations and figures of merit were defined, concluding that partially confined field could provide better shielding capability for the same structural mass. The results of this work and the correlated simulations activities are reported, together with a comparison of the performances between active shielding and mass-equivalent passive ones.

In parallel, a description is given of the experimental studies focused on some key technologies, necessary to develop such a shield (superconducting cable, cryogenics, quench protection, heat removal). The results of this study define a new starting point for the technology development and research directions towards active shielding design as a suitable protection tools for deep space exploration.

F2.2-0016-18 PERSONAL RADIATION SHIELDING FOR SPACE EXPLORATION: THE PERSEO EXPERIENCE

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In November 2017, the first phase of the PERSEO (PErsonal Radiation Shielding for intErplanetary missiOns) project, funded by the Italian Space Agency, has come to a successful conclusion with the test on board the International Space Station (ISS) of the first prototype of a water-filled garment for personal radiation protection of astronauts in case exposure to solar particle events.

During the course of the project, a collaboration including academic partners and companies active in space research and technological development designed and manufactured the garment prototype, in compliance with all requirements for use in a space habitat, completing all necessary ground verification tests. The efficacy of the garment as a countermeasure against short-term non-cancer effects was evaluated based on Monte Carlo simulations of achievable dose reduction to sensitive organs of an anthropomorphic phantom, exposed to different reference solar proton spectra in low-shielding conditions, as it could be the case in an emergency scenario during a deep-space mission.

During the test on the ISS, the garment was filled with 21 liters of on-board water and later drained back into the water recovery system, with no water waste. While worn for about 30 minutes,

the garment was judged as comfortable enough, not significantly hindering the astronaut's movements and not posing major problems as a consequence of increased inertial mass.

In this presentation we will revisit the main steps of the project and discuss its achievements, also addressing strategies currently studied for an experimental benchmark of the garment shielding efficacy, and possible future developments for devices of this kind to be used in interplanetary space journeys.

* This presentation will be given also in behalf of the PERSEO collaboration. PERSEO is funded by the Italian Space Agency (ASI), coordinated by the University of Pavia and involve scientists from Thales Alenia Space - Italia, SMAT, AVIOTEC, ALTEC, University of Roma Tor Vergata, Kayser Italia and ARESCOSMO. Full list of contributors is given in the presentation.

F2.2-0017-18 POTENTIAL DIETARY COUNTERMEASURE AGAINST SPACEFLIGHT-INDUCED BONE LOSS

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As humans venture further into space and beyond low Earth orbit, space radiation is one of the main challenges for astronauts health. Radiation-induced bone loss is a potential health problem for long duration habitation in space. We showed that a dietary countermeasure prevents bone loss in mice exposed to total body irradiation (TBI). We used a range of ionizing radiation, gamma (137Cs), proton (1H), iron (56Fe), and a combination of sequential proton and iron beam (1H/56Fe/1H) to evaluate skeletal responses. These TBI cover a range of linear energy transfer (LET), from low-LET such as proton, to high-LET such as 56Fe (HZE: high Zhigh energy) at doses between 1-2 Gy. The countermeasure diet, composed of 25% Dried Plum (DP) was effective at preventing radiation-induced cancellous bone loss in appendicular bone (tibia). Furthermore, exposing mice to HZE radiation, such as 56Fe (1Gy), impaired it ex vivo growth of marrow-derived, bone-forming osteoblasts, which led to reduced mineralization capacity (-77%). In contrast, mice fed the DP diet did not display these deficits, showing the diet's capacity to protect marrow-derived osteoprogenitors. Dietary DP prevented the increase of bone resorbing osteoclast cells, inflammation and oxidative stress, while protecting the osteoprogenitors and mesenchymal stem cells, which few drugs against osteoporosis may achieve. Spaceflight

is a combination of multiple factors including microgravity, in addition to space radiation. Therefore, we conducted additional studies to determine if the DP diet could prevent simulated spaceflight (simulated microgravity and radiation combined) bone loss. Mice were exposed to gamma (TBI, 137Cs, 2 Gy), simulated microgravity (using the hindlimb unloading system, HU) or TBI+HU. While we observed bone loss in mice fed the control diet (CD) due to both treatments (TBI=14%, HU=20%), and a worse effect with combined treatments (TBI+HU=25%), mice fed the DP diet did not sustain significant bone loss relative to untreated controls. The DP diet prevented microarchitectural decrements in both appendicular bone (tibia) and axial bone (vertebrae). In addition, the DP diet mitigated HU-induced deficits in osteoblastogenesis. Interestingly, lower doses of DP diet (5%, 10%) did not appear to prevent cancellous bone loss, which shows the importance of identifying the active component(s) of DP. Finally, we have preliminary data showing the potential of DP to prevent radiationinduced damage at a systematic level. In summary, this novel dietary countermeasure is a promising candidate nutritional countermeasure for spaceflight-induced bone loss and tissue damage. Acknowledgement: This work is supported by a NSBRI grant MA02501 under the NASA Cooperative Agreement NCC 9-58 (RKG); NPP Space Biology fellowships (AS, MT), and a NASA HRP HHC Omnibus Grant (15-15Omni2-0039 (AS)

F2.2-0018-18 CHASING GHOSTS IN SPACE RADIOBIOLOGY RESEARCH: THE LOST FOCUS ON NON-TARGETED EFFECTS

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The doses and dose-rates of astronaut exposures to galactic cosmic rays (GCR) are accurately known, and lead to particle hits per cell nucleus from high charge and energy (HZE) particles of much less than one hit per cell per month. A large number of experiments have shown that additivity of biological effects is a valid assumption for space radiation exposures, while experiments at higher doses and dose-rates than occur in space continue to be a focus of the majority of space radiobiology research. Furthermore HZE particle exposures with mono-energetic particles manifest themselves as a mixed-radiation field due to the contributions of delta-rays and the random impact parameter of a particles track core to DNA and non-DNA targets in cells and tissues. The mixed-field manifestation of mono-energetic HZE particle exposures is well known from theoretical studies of microdosimetry and track structure. Additional mixed-field effects occur for single species experiments due to nuclear fragmentation in particle accelerator beam-lines and biological samples along with energy straggling. In contrast to these well known aspects of space radiobiology there are many open questions on the contribution of non-targeted effects to low dose and dose-rate exposures. Non-targeted effects (NTEs) include cell signaling, bystander effects, tissue microenvironment changes, and genomic instability, and have been shown to be the most important outstanding question for reducing uncertainties in space radiation cancer risk assessment. The dose-rate and radiation quality dependence of NTE's has not been established, while there is an over-arching need to develop 21st century experimental models of human cancer risk. We review possible mechanisms of NTE's and how new experiments to address these issues could be designed

F2.2-0019-18 DYNAMICAL MODELING APPROACH TO RISK ASSESSMENT FOR RADIOGENIC LEUKEMIA AMONG ASTRONAUTS ENGAGED IN INTERPLANETARY SPACE MISSIONS

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A biologically motivated dynamical model, which is capable of predicting the excess relative risk (ERR) for radiogenic leukemia among humans exposed to acute/continuous irradiation in wide ranges of doses and dose rates, is developed (Smirnova, 2017; Smirnova and Cucinotta, 2018). This model is applied to study the dependence of the EER for radiogenic leukemia among astronauts on key parameters of space radiation exposure in interplanetary space missions, namely, the dose equivalent rates of galactic cosmic rays (GCR) and large solar particle events (SPEs), the time interval between SPEs, mission duration, the degree of astronaut's additional shielding, and the total mission dose equivalent. It is necessary to emphasize that the results obtained in the framework of the developed model, practically, coincide with those of the linear model in the range of applicability of the latter. In turn, the developed model is capable of predicting the ERR for radiogenic leukemia among astronauts for the irradiation regimes beyond the applicability range of the linear model, which can occur in some emergency cases. As a supplement to the estimations of cancer incidence and death (REIC and REID), the developed model for the assessment of the ERR for leukemia can be employed in the pre-mission design phase (e.g., for the optimization of the regimes of astronaut's additional shielding in the course of interplanetary space missions), as well as in the phase of the real-time responses during the space mission to make the decisions on the operational application of appropriate countermeasures to minimize the risks of occurrences of leukemia, especially, for emergency cases.

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F2.2-0020-18 SERUM MICRORNAS AS EARLY INDICATORS FOR ESTIMATION OF EXPOSURE DEGREE IN RESPONSE TO IONIZING RADIATION

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Highly energized particles delivered by galactic cosmic rays as well as solar particle events are one of the most severe detrimental factors to the health of crews during long-term space missions. Researches related to the assessment of radiation risk have been carried out with ground-based accelerator facilities all around the world. Serum microRNAs (miRNAs) have the advantages of specificity and stability, which could be used as disease biomarkers and potential bio-dosimeters. Based on this backgroud, serum miRNAs were isolated after Kunming mice were whole-body exposed to 0.5-2 Gy of 300MeV/u carbon ion beam which were generated by the Heavy Ion Research Facility in Lanzhou (HIRFL). The expression levels of 374 miRNAs were detected by miRNA PCR array. It was found that more than one hundred of serum miRNAs were responded to carbon ion irradiation. A specific signature with 12 miRNAs was selected for further validation following 0.1-2 Gy of carbon ion and iron ion exposure. miR-183- 5p, miR-9-3p, miR-200b-5p, miR-342-3p and miR-574-5p showed significant doseand timedependent changes, demonstrating that they were potential biomarkers of radiation and could be used as ideal bio-dosimeters in the early stages after exposure. We also developed a universal model using these 5 miRNAs to predict the exposure degree with high sensitivity and specificity. Those findings indicate that with the properties of high sensitivity of radiosensitive miRNAs and time-saving quantification by standard PCR assay, serum miRNAs may become potential indicators to estimate the exposure degree under some unexpected circumstances during space exploration.

F2.2-0021-18 SPACE RADIATION INDUCED CHROMOSOME INSTABILITY ACTIVATES IMMUNE SIGNALING IN HUMAN CELLS

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Space radiation is known to induce genomic instability and has high potential to cause cancer, however the link between these two events has not been established. Here, we provide a novel evidence that the genomic instability caused by high-charge and -energy (HZE) particles, components of space radiation, triggers immune signaling in response to chromatin fragments in the cytoplasm and that might play a key role in the initiation of cancer. Chromosome missegregation due to defective clustered DNA lesions repair creates a preponderance of LAMINB1 coated micronuclei, genomic instability marker, whose rupture exposes chromatin fragments into the cytosol. This leads to the recruitment of a nuclease MRE11, that process the genomic DNA in the cytosol resulting in the binding of cGAS (cyclic GMP-AMP synthase) and subsequent activation of the STING (stimulator of interferon genes) cytosolic DNA-sensing pathway and downstream interferon signaling. Furthermore, genetic and pharmacological inhibition of nuclease activity of MRE11 markedly blocked the activation immune signaling. Significantly, the extent by which cells trigger immune signaling in response to HZE particle exposure is highly dependent on RAD51, a well-known homologous recombination repair factor. Thus, this study suggests that genomic instability triggered by defective clustered DNA lesions repair provokes cGAS-STING cytosolic DNA sensing pathway mediated immune signaling and that might contribute to the initiation of cancer following space radiation exposure.

F2.2-0022-18 CELLULAR MECHANISMS OF HIGH LET RADIATION EFFECTS

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The increased biological efficacy of modalities of ionizing radiation (IR) with high linear energy transfer (LET) has been described nearly fifty years ago and has been solidly incorporated into all aspects of human radiation protection. Yet, the underlying molecular mechanisms remain speculative to this date and are typically explored in mathematical models formulated on the basis of biological assumptions that are rarely tested experimentally. In an effort to address this void, we developed biological model systems to study the efficacy of clusters of DNA doubles strand breaks (DSBs) at different biological endpoints. There is experimental evidence for the induction of DSB-clusters after exposure of cells to high LET radiation and their pronounced contribution to the adverse biological effects has been repeatedly modeled in a wide range of mathematical formalisms. In the biological model we developed, DSB clusters of pre-designed configuration are generated by the I-SceI meganuclease, in genomicallyintegrated constructs present in the genome at different numbers. This allows the generation of defined combinations and numbers of DSB-clusters in the absence of any other form of DNA lesions, such as base damages or single strand breaks also generated after exposure of cells to IR. The results show a high potential for DSB-clusters, as compared to single-DSBs, to kill cells. Increased killing is mediated by a dramatic increase in the formation of chromosomal translocations and is thought to derive from a chromatin destabilization at the DSB-cluster site. Indeed translocations forming from DSB-clusters utilize Parp1 activity, implicating alt-EJ in their formation. Furthermore, immunofluorescence experiments show that both single-DSBs and DSB-clusters provoke the formation of -H2AX and MDC1 foci with similar efficiency. Notably, however, the late DDR protein, 53BP1 shows in live-cell imaging strikingly stronger recruitment to DSB-clusters as compared to single-DSBs. These observations provide the first direct mechanistic explanation for the long-known increased efficacy of high LET radiation and point to DSB clusters as major contributors. We postulate that DSB-clusters represent a level of DNA damage complexity that adds substantial excess-accident-risk to the processing of DSBs and underpins much of the effects generated by high LET IR. Acknowledgments: Work supported by grants from BMBF (02NUK043B -COLLAR) and the DFG (GRK1739). Conflict of Interest: The authors declare no conflict of interest.

F2.2-0023-18 BIOLOGICAL CHANGES AND HEALTH EFFECTS IN RODENTS EXPOSED TO SPACE RADIATION

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Human health risks that may originate from exposure to low doses/low fluences of ionizing radiation (IR) during long-term interplanetary missions are uncertain and are a major concern. The IR encountered in space is largely protons and high atomic number, high energy (HZE) particles. The linear energy transfer (LET) of protons is low, whereas HZE particles have intermediate and high LET. We have examined oxidative stresses and inflammatory responses in organs of young-adult and middle-aged mice (CBA/CaJ, C57BL/6J) and rats (SpragueDawley) exposed to protons and/or different HZE particles. The radiations were delivered to the whole body or head only at both high and low dose-rates, and the animals were processed for analyses at times ranging from 2 weeks to 15 months after irradiation. The results are compared with those obtained in animals exposed, in parallel, to cesium-137 γγ rays as a reference radiation.

Exposure of the animals to low mean absorbed doses from HZE particles with LET values ranging from 14 to 150 keV/μm, delivered acutely as single bolus or in a fractionated manner, induced structural changes as detected by in vivo imaging several months after irradiation. Moreover, protein oxidation, lipid peroxidation and disruption of redox-modulated physiological functions, such as mitochondrial protein import, were detected in various tissues within days after irradiation and persisted for months thereafter. The changes were observed following wholeand partial body exposures and were associated with effects on antioxidant enzyme activity. Analyses in blood plasma revealed persistent increases in the levels of inflammatory cytokines (e.g., interleukin-6 and interferon-γ). Histological analyses revealed interstitial injury.

At 2 weeks, and 3, 6 and 14 months after irradiation, peripheral blood and bone marrow were also drawn to examine alterations in cell subsets using multicolor flow cytometry. Relative percent change in specific cell populations and absolute cell counts were determined. Increases, up to 10-fold, in circulating neutrophils were detected at two weeks in middle-aged CBA/CaJ mice exposed to 20, 30 or 40 cGy of either of 1 GeV/u Ca, O or Si ions delivered in a fractionated manner ($p<0.001$). The groups also showed an increase in circulating monocytes ($p<0.01$). The mice exposed to a single bolus of 40 cGy of Ca ions did not show significant increases at 2 weeks; however, by 3 months, increases in neutrophils were detected ($p<0.001$). These increases in neutrophils and monocytes in circulating blood were associated with decreases in these cell subsets in bone marrow ($p<0.05$), suggesting mobilization out of this compartment. Common myeloid, as well as granulocyte/macrophage and megakaryocyte-erythroid progenitors were decreased ($p<0.1$) in bone marrow. Notably, decreases ($p<0.01$) in short-term hematopoietic stem cells were detected.

The early response of neutrophils and monocytes in mice exposed to the energetic heavy ions returned to a normal range at 6 months after irradiation, and remained in this normal range at 14 months. However, at the latter time point, the proportion (%) of circulating plasma cells, but not B cells, were increased ($p<0.001$). The effect seems to depend on the radiation dose and delivery manner, and did not occur in rayor proton exposed mice. This indicates the phenotypes may be specific to high LET radiations, and is suggestive of the development of a plasma cell dyscresia.

Analyses of the long-term effects of exposure to isovelocity 1 GeV/u Ca, O or Si ions in a dose range of 20-40 cGy on cancer induction and degenerative conditions in bone and the cardiovascular system are in progress. The effect of a pre-exposure to low LET protons, delivered at low dose rate, on the induced changes is being also evaluated. Together, these ground-based mechanistic studies may contribute to alleviating the uncertainties in predicting health risks to astronauts.

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F2.2-0024-18 THE HURDLES AND PROMISES OF SYSTEMS BIOLOGY APPROACHES IN SPACE RADIATION RESEARCH

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In the era of increasingly more affordable "omics" technologies and impressive advancements in artificial intelligence, big datasets can be easily generated and analyzed through novel and sophisticated approaches, allowing to study in greater details more complex experimental designs. Within this framework, systems (radiation) biology approaches could be applied to pave the way towards a correct integration of different multi-scale and temporal dynamics studies of biological systems. Radiation quality investigations at different low doses and/or dose-rates might take the maximum advantages from these advancements and therefore help in unravelling subtler differences among the biological signature of different radiation exposures, of note in space radiation research. During the presentation, the caveat and pitfalls of identifying in advance key questions to be addressed through a complex experimental setup will be discussed through examples of systems biology approaches applied to radiation biology investigations. The described scenario will serve as basis to highlight the potential advantages and limitations of different experimental designs, encouraging a careful planning in order to avoid biases and maximize the potential outcome of different radiation quality comparisons and dose/dose-rate responses.

F2.2-0025-18 LNC CRYBG3-ACTIN AXIS REGULATES CELLULAR RESPONSE TO SPACE ENVIRONMENT

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Actin cytoskeleton is one of the main cellular sensors for mechanical changes. Previously, we recognized a long non-coding RNA, LNC CRYBG3, directly binding to G-actin to interfere with the assembly of actin cytoskeleton. Ionizing radiation induces its expression and consequently disrupts the assembly of actin cytoskeleton. We further verified that microgravity-induced dissembly of actin cytoskeleton in turn increases the expression of LNC CRYBG3. Therefore, LNC CRYBG3 and actin form a regulatory axis in cells to sense extrogenous stimuli, including ionizing radiation and microgravity. Our current research progress on this axis opens another window that LNC CRYBG3-actin axis also regulates cell metabolism by interacting with lactate dehydrogenase A (LDHA), a vital enzyme of glycolysis. Once LNC CRYBG3-actin axis is activated, LDHA expression is enhanced and consequently promotes the uptaking of glucose and the production of lactate. However, the knockdown of LNC CRYBG3 inhibits radiationinduced glycolysis. These findings indicate that LNC CRYBG3-actin axis play an important role in regulating cellular response to environmental changes, especially in outer space.

F2.2-0026-18 A COMPUTATIONAL AND MATHEMATICAL MODELING APPROACH FOR THE STUDY OF RADIATION-INDUCED HIPPOCAMPAL NEUROGENESIS IMPAIRMENT AND NEURONAL DENDRITIC DAMAGE

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Neurocognitive detriments associated with cranial radiotherapy for cancer treatment and chronic radiation exposure of astronauts for space travel have always been a concern. Neurogenesis impairment and alterations in neuronal morphology are two of the many factors that have been correlated to this cognitive dysfunctions. Computer simulation and mathematical modeling approach provides an effective tool that contributes valuable insights to the role of radiationinduced changes in producing functional deficits in the brain. These computational and mathematical models are also useful for extrapolation to other conditions that are often constrained in experiments. We have developed predictive models to study radiation-induced changes to neurogenesis [1,2] and alterations to dendritic morphology [3]. Using a system of nonlinear ordinary differential equations (ODEs) to represent age, time after exposure and dose-dependent changes to several cell populations participating in neurogenesis as reported in experiments utilizing mouse models, we obtained a description of the age-related dynamics of hippocampal neurogenesis and the effects of a variety of radiation in altering neurogenesis. Predictions of the threshold doses where neurogenesis recovery fails for given radiation types are described in our neurogenesis mathematical model. On the other hand, we investigate radiation-induced changes in neuronal dendritic morphology using a stochastic model that describes time dependent radiation-induced dendritic damage on in silico representations of mouse hippocampal dentate granule cell layer (GCL) and CA1 pyramidal neurons. Our model describes the changes in morphometric parameters, such as total dendritic length, number of branch points and branch number, including the Sholl analysis for single neurons. Our model based predictions for different patterns of morphological changes based on energy deposition in dendritic segments (EDDS) will serve as a useful basis to compare specific patterns of morphological alterations caused by EDDS mechanisms.

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F.A. Cucinotta. Stochastic modeling of radiation-induced dendritic damage on in silico mouse hippocampal neurons (submitted).

F2.2-0027-18 A GENERAL SPACE RADIATION SYNAPTIC SIGNATURE IN HIPPOCAMPUS FOLLOWING PROTON, 56FE, AND 28SI ION IRRADIATION

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Changes in DNA methylation may contribute to the development of cognitive injury after space irradiation. The hippocampus is critical for cognitive function. Hippocampal changes in cytosine methylation, a major epigenetic modification involving the addition of a methyl group to cytosine (5mC), are involved in the regulation of expression of genes required for cognitive performance. A second form of DNA methylation, derived from 5mC by the action of three TET enzymes (TET 1-3), is hydroxymethylcytosine (5hmC). In brain, levels of TET2 are higher than those of TET1 or TET3. Therefore, TET2 is believed most important for brain function. DNA methylation 20 weeks following proton irradiation (150 MeV, 1 Gy) revealed tissue-specific changes in the localizations of 5mC and 5hmC after irradiation when comparing the hippocampus and the left ventricle that reflect perturbations in tissue specific pathways (e.g., vascular development pathways in the ventricle and neuronal specific pathways in the hippocampus), as well as some shared effects (BMC Genomics, 2016, 17:273). As we reported, 56Fe ion (600 MeV/n) (BMC Genomics, 2016, 17:825BMC Genomics) and proton irradiation (150 MeV, 1 Gy) (Scientific Reports, 2017, 7:10227) impaired cognitive function. Impairments in object recognition and spatial memory retention following proton irradiation were observed at the two-week time point and correlated with altered gene expression and 5hmC profiles that mapped to specific gene ontology pathways. Significant overlap was observed between DNA methylation changes at the 2 and 20-week time points demonstrating specificity and retention of changes in response to radiation. Moreover, a novel class of DNA methylation change was observed following an environmental challenge (i.e. space irradiation), characterized by both increased and decreased 5hmC levels along the entire gene body. These changes were mapped to genes encoding neuronal functions including postsynaptic gene ontology categories, indicating that the brain's response to proton irradiation is both specific and prolonged and involves novel remodeling of non-random regions of the epigenome. To determine if different forms of ionizing radiation induce similar types of DNA methylation changes, we compared proton-induced changes in 5mC and 5hmC with those for 56Fe ion-induced changes. Both 0.1 and 0.2 Gy 56Fe gene-associated DHRs (differentially hydroxymethylated regions) and DMRs (differentially methylation regions) showed a highly-significant correlation with proton DHRs and DMRs, demonstrating that many of these changes represent a common response to ionizing radiation exposure regardless of its form, indicating a general space radiation signature. Gene ontology analyses of the overlapping 56Fe and proton DMRs revealed categories linked to cell adhesion, cell junctions, neuronal growth, and synapse function. Following 28Si (600 MeV/n) ion irradiation, mice irradiated with 0.3 Gy were impaired in object recognition, while those at higher doses (0.6 or 0.9 Gy) were not. Consistent with this pattern of the dose-response curve, sham-irradiated mice and those irradiated with 56Fe (600 MeV) at 0.2 Gy showed novel object recognition but mice irradiated with 0.1 Gy were impaired, suggesting that there might be compensatory mechanisms triggered at higher doses that protect against radiation-induced cognitive impairments that might not be present at lower doses. This is especially concerning as the lower doses would be expected to be more pertinent to doses astronauts will be exposed to during space missions than the higher doses. Comparing hippocampal DNA methylation following proton, 56Fe ion, and 28Si ion irradiation revealed a general space radiation synaptic signature with 228 genes that are associated with profound phenotypes, confirming the potential of this approach to identify genes and pathways involved in the CNS radiation response that are critical for CNS function. The most significant category was postsynaptic density. The synapse category was also highly-significant. Thus, the brain's response to space irradiation involves novel postsynaptic remodeling. This study was supported by NASA grant NNJ12ZSA001N.

F2.2-0028-18 STRUCTURE FUNCTION RELATIONSHIPS IN THE IRRADIATED CNS: THE ROLE OF CHARGED PARTICLE LET AND FLUENCE

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Exposure to the space radiation environment poses inherent risk to normal tissue functionality, especially when considering the resultant damage to the intricate cellular structures that define the central nervous system (CNS). The complex radiation response of the CNS is underscored by the surprising sensitivity of mature neuronal populations to structural degradation caused by low dose exposures to individual and/or combinations of charged particle species. As a result, multiple irradiation paradigms have been shown to elicit a wide spectrum of persistent cognitive deficits involving diverse and complex molecular mechanisms.

Despite the challenges of pinpointing the cause and effect relationships of radiation-induced cognitive dysfunction, changes in neurotransmitter availability, the assembly of synaptic machinery and structural plasticity that ultimately results in reduced dendritic arborization and spine density have been implicated to play a significant role in eliciting functional deficits. Analyzing the dose-response relationships that might depend on charged particle LET and/or fluence have revealed some clues, and recent efforts in stochastic modeling have highlighted how differences in microdosimetry might account for observed alterations in neuronal structure at various times after exposure.

The foregoing changes are posited to adversely impact a variety of learning and memory processes dependent on specific regions of the brain, where behavioral decrements in spontaneous exploration tasks, attentional-set shifting, fear conditioning and extinction are accompanied by increased anxietyand depression-like behavior. Importantly, these abnormal behaviors are markedly persistent, and likely reflect the differential sensitivities of mature neuronal populations to radiation-induced structural deterioration. Such findings highlight the multifaceted response of the irradiated CNS, and point to previously uncharacterized properties of neurons that dictate their radioresponse.

Understanding the structure function relationships in the irradiated CNS will provide new insights into the long lasting and adverse effects of cosmic radiation exposure that can compromise neurotransmission. Ultimately, such work will help identify strategies for mitigating the risks of manifesting mission critical performance decrements and/or chronic complications with neurocognitive health that may arise from deep space radiation exposure.

F2.2-0029-18 RADIATION EFFECTS ON BRASSICA SEEDS AND SEEDLINGS

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Space radiation consists of high energy charged particles and affects biological systems, but because of its stochastic, non-directional nature is difficult to replicate on Earth. Radiation damages biological systems acutely at high doses or cumulatively at low doses through progressive changes in DNA organization. These damages lead to death or cause of mutations. While radiation biology typically focuses on mammalian or human systems, little is known as to how radiation affects plants. In addition, energetic ion beams are widely used to gener- ate new mutants in plants considering their high-LET (Linear Energy Transfer) compared to gamma rays and X-rays. Understanding the effect of ionizing radiation on plant provides a basis for studying effects of radiation on biological systems and is the first step to mitigate radiation damage in plants. We exposed dry and imbibed Brassica rapa seeds and seedling roots to proton beams of varying qualities and compared the theoretical penetration range of different energy levels with observable growth response. We used 1, 2 and 3 MeV protons in air at the varying fluences to investigate the effect of direct irradiation on the seeds (10121015ions/cm^2) and seedlings (1013ions/cm^2). The range of protons in the tissue was calculated using M o Carlobased SRIM (Stopping and Range of Ions in Matter) software. The simulation and biological resul response curve showed greater sensitivity of imbibed than dry seeds. In addition, germination rate was strongly dependent on ion beam current, at least for 3 MeV protons. Our data show that weak ionizing particles (low MeV protons) are suitable to study radiation effects and that seeds and seedlings are useful biological systems to study (space) radiation effects. Future experiments will assess the number of transcripts as a function of dose received.

F2.2-0030-18 SPACE RESEARCH AS A MULTIDISCIPLINARY ENDEAVOR

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The natural radiation environment in space consists of a mixed field of high energy protons, heavy ions, electrons and alpha particles. Future missions to Mars and other destinations in the solar system will require crew members to spend much longer periods in space and in area outside of the radioprotective shielding of the Earth's magnetic field. A better understanding of the biological effects of the space environment, including radiation, and of countermeasures to minimize these effects, are topics of interest to many researchers and space agencies. Life support systems need to be explored in order to help support long term habitability and sustainability in space. A multitude of expertise in different disciplines are necessary to provide the required environmental life support systems with constraints on space and power, and isolated from outside support, in order to advance human exploration to space.

F2.2-0031-18 ROUND TABLE DISCUSSION - PART 1: THE FUTURE OF SPACE RADIATION RESEARCH

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Space radiation is the "Number One Health Risk" (Chancellor et al., 2014) for long-term space missions beyond Low Earth Orbit (LEO). During space missions, astronauts are chronically exposed to galactic cosmic radiation (GCR) consisting of energetic protons, helium and heavier nuclei up to iron. This chronic exposure increases the risk for developing cancer and degenerative diseases (cataract of the eye lens, and possibly also decrements of the central nervous system (CNS) and other organ systems). The extents of these risks and the underlying mechanisms have to be further elucidated. In addition to the baseline exposure to GCR, Solar particle events (SPEs) bear the risk of acute high dose exposure, and might even provoke the acute radiation syndrome. Mitigation of the space radiation risks necessitates a multidisciplinary approach, from understanding the nature of the space radiation environment, the development of relevant radiation dosimeter systems, having the relevant tools to model the radiation environment, understanding the influence of shielding to the biological effects of space radiation, and being able to develop relevant countermeasures. The invited speakers of the cross discipline talks of the session F2.5 will discuss the upcoming challenges in the fields of space radiation physics, dosimetry, and modeling, biology and countermeasure development. References: Chancellor JC, Scott GBI,1, Sutton JP (2014) Space Radiation: The Number One Risk to Astronaut Health beyond Low Earth Orbit. Life (Basel). 2014 Sep; 4(3): 491-510.

F2.2-0032-18 ROUND TABLE DISCUSSION - PART 2: THE FUTURE OF SPACE RADIATION RESEARCH

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F2.2-0033-18 FLIGHT SAFETY IMPLICATIONS OF THE EXTREME SOLAR PROTON EVENT OF 23 FEBRUARY 1956

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There is considerable speculation about the effects at aircraft altitudes resulting from extreme solar proton events. The ground level event (GLE) of 23 February 1956 (GLE 5), remains the largest solar proton event of the neutron monitor era in terms of its influence on count rates at monitors near sea level. During this event the count rate was increased by over 5100 percent during one 5-minute period and by as much as 4760 percent (15-minute average) at the Leeds monitor relative to the count rate from galactic cosmic radiation (GCR). Two modern models of the event cumulative solar proton spectrum for this event, a 6-parameter fit in energy and a 4-parameter Band fit in rigidity, are compared with 1-hour of GCR at solar minimum. While effective doses calculated with CARI-7A for both models at low geomagnetic cutoff rigidities are indeed high when compared with GCR and can exceed recommended exposure limits, both GLE spectra exhibit a much stronger dependence on cutoff rigidity than GCR, and a larger fraction of the dose from neutrons. At locations with cutoff rigidities above 4.2 and 6.4 GV, respectively, the GLE effective doses are smaller than the GCR hourly dose. At locations with cutoff rigidities above about 4 GV, GCR was the dominant source of exposure in 10 hours or less at all altitudes examined. This suggests that if a similar event occurs in the future, lowand mid-latitude flights at modern jet flight altitudes could be well-protected by Earth's magnetic field.

F2.2-0034-18 MACHINE LEARNING RISKS CLASSIFICATION AND MICROGRAVITY EXPOSURE RISKS MODEL FOR LONG-TERM MANNED SPACE MISSIONS.

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Astronauts on a long-term mission to Mars or other destinations far from the Earth orbit would be exposed to large amounts of radiation, which is the primary source of morbility and mortality risk. Recent models have added to the fatal cancer risk estimation other risks from circulatory diseases and central nervous system biological effects (1). However, a complete picture of the overall physiological effects and hazards on it from a manned space mission is still not accurate. We report on two additions to these estimations, and the results obtained from adding these models on the existing data on the literature. In the first place, we perform a machine learning classification using Support Vector Machines (SVM) that allows the researcher to classify human subjects depending on their sensitivity to risk of diseases (radiation-induced, cardiovascular, neurological) while exposed to a long-term space mission. Training of the SVM vector machine is based on mordibity and mortality probababilities, coming from available data and simulating different model subjects with a Monte-Carlo method. The method may be useful, for example, to determine likelihood of crew impairement in a given space mission profile of exposure to microgravity and radiation. We correlate some results for a conjunction class and for an opposition class mission to Mars, with existing estimates in the literature, with an average positive 0.93 correlation of disease likelihood (p=0.022). On the other hand, we use results from the implementation of the Numerical Estimation of Long-Term Microgravity Exposure (NELME) developed in our laboratory. This is an electrical-like cardiovascular physiological model that is able to simulate the behaviour and deconditioning of thet human cardiovascular system under altered gravity conditions. The simulator has been validated with parabolic flight experimental data, and is capable to estimate deconditioning of the cardiovascular system for different long-term space missions. Estimations are incorporated to the existing models that take into account other risks such us radiation-induced effects. The results show that the overall risk of exposure induced death (REID) at the upper 95% confidence level of the risk estimate is increased by nearly 1.6% when taking into account deconditioning to the cardiovascular system due to exposure to microgravity; for a typical Mars mission. Results for different mission scenarios, exercise profile countermeasures and thermal stress are also discussed. In conclusion, machine learning and numerical models of the cardiovascular system such as NELME are emerging tools, useful to evaluate the risks to which astronauts are exposed in a long-term manned mission. (1) Cuccinotta F. et al. How safe is safe enough? Radiation Risk for a Human Mission to Mars. PlosOne, (8), 10, e74988 (2013).

F2.2-0035-18 MARSIMULATOR: A DEVICE PROVIDING CONTINUOUS LOW DOSES OF GAMMA-RAYS MIMICKING EXPOSURE TO THE SPACE ENVIRONMENT DURING LONG-DURATION SPACE MISSIONS.

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Space experiments involving biological investigations have generated considerable interest worldwide. Many space experiments have been scheduled for the established experimental area in the International Space Station (ISS), where astronauts and experimental subjects are exposed to both space radiation and microgravity. Both these conditions are difficult to simulate at ground level. Space radiation is comparable to chronic low-dose exposure. It is now well demonstrated that when cells, organs, or entire organisms are exposed to radiation at low doses or at low dose rates, an adaptive response may be observed. We have elaborated an innovative device allowing chronic radiation exposure to be combined with altered gravity. Given the limited access to the

International Space Station, this device could be useful to researchers interested in the field of space biology. The magnitude of the Earth's gravity vector cannot be changed but its effect on biological systems can be modified and microgravity simulators may generate functional near weightlessness of a cell or organism. These kinds of devices are very useful for studying the influence of gravity on biological organisms or to prepare and/or complete a study that has been selected to be performed on the ISS. One of these devices is the "random positioning machine" (RPM), which is characterized by the randomly changing rotational speed and 3D-direction of a platform where biological samples can be placed. Irradiation was provided by thorium nitrate powder, conditioned so as to constitute a sealed source that could be placed in an incubator. Cell plates or plant seedlings could be placed in direct contact with the source or at various distances above it. Moreover, a random positioning machine (RPM) could be positioned on the source to simulate microgravity. Using the RPM placed on the source, we reached a mean absorbed dose of gamma rays of 0.33 ± 0.17 mSv per day.

F2.2-0036-18 SIMULATION OF OPHTHALMIC ALTERATIONS AT THE ARCTIC, ANTARCTICA AND THE INTERNATIONAL SPACE STATION FOR LONG-DURATION SPACEFLIGHT

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Well, we propose a series of long-period medical simulations in scientific bases at the Arctic, at Antarctica and aboard the International Space Station (ISS), involving natural ophthalmic diseases such as radiation and solar retinopathy, induced cataract, etc., and ophthalmic alterations by accidental injuries. These ophthalmic alterations, without a previous diagnosis, are known to appear after 1 month to 1.5 year, in average. Such studies will be valuable for the human deep-space exploration because during long-duration spaceflight, such as staying at the ISS, a Moon base and a manned trip in an astrobiology mission to planet Mars, it requires several months within such environments and during such periods ophthalmic diseases and accidents might eventually occur, which could seriously affect the 'round-the-clock' work schedule of the astronauts and the long-duration spaceight manned program.

F2.2-0037-18 RADIOBIOLOGICAL EFFECTIVENESS OF NEUTRONS IN SPACE

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The space radiation environment consists of a wide variety of ion species in a continuous range of energies. Nevertheless, most accelerator-based experiments to measure the biological consequences of the exposure to radiation qualities of interest in space radiation protection have been performed with single beams at fixed energies.

Efforts are currently being undertaken to implement simulators of mixed-field for radiobiology experiments. However, the neutral component of space radiation is difficult to reproduce in a ground-based measurement: neutrons are not found free in space in significant amount, but they are produced following nuclear reactions in space vehicle or habitat walls (1), in gas components of the planetary atmosphere (2), and in traversed tissues themselves.

Neutrons might be responsible only for a small contribution to the total dose absorbed by astronauts, but their biological effectiveness varies with the energy, and neutron contribution to dose equivalent (or any biologically weighted dose) can be correspondingly higher (with quality factors as high as 20). Neutron data from radiobiological measurements are much varied among different experiments, often available only in the few MeV regions, while space radiation requires dedicated studies also at hundreds of MeV. In this higher energy range, the question of biological effectiveness of neutrons has still to be addressed experimentally.

In this context, a theoretical effort to predict neutron biological effectiveness for different exposure scenario is highly desirable. This can be achieved with a comprehensive modeling approach, bringing together transport calculations of neutrons through

matter, and the predictive power of track structure approaches for secondary charged particles generated by neutron interactions, up to the evaluation of biological damage induction to a sensitive subcellular target as the nuclear DNA.

In this work we discuss and apply possible models for energy dependent neutron RBE (3) (Relative Biological Effectiveness) to neutron spectra of interest in case of astronauts' exposures in space situations, as neutrons inside a space habitat or on the surface of Mars.

References:

(1) L.H. Heilbronn et al., Neutron yields and effective doses produced by Galactic Cosmic Ray interactions in shielded environments in space, Life Sci. Space Res. 7, 90-99 (2015). (2) Jingnan Guo et al., Measurements of the neutral particle spectra on Mars by MSL/RAD from 2015-11-15 to 2016-01-15, Life Sciences in Space Research, 14, 12-17(2017). (3) G. Baiocco et al., The physical origin of neutron biological effectiveness, Sci. Rep. 6, 34033 (2016).

F2.3-0001-18 ADVANCES IN NASA RADIATION TRANSPORT CODES

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The current 3DHZETRN-v2 has a detailed 3D treatment of neutron/light-ion transport based on a quasi-elastic/multiple-production assumption allowing improved agreement of the neutron/lightion fluence compared with results of Monte Carlo codes. The current numerical methods are no longer the main limitation to HZETRN code development and further changes in the nuclear model are required. In a prior study we implemented a Serber model leading to an improved quasi-elastic spectrum based on a solution of the transport approximation to nuclear media effects that showed promise but the remaining multiple-production spectrum remained based on a database derived from the Ranft model using Bertini multiplicities. In the present paper, we will implement a complete Serber first step into the 3DHZETRN-v2 code but we retain the Bertini-Ranft branching ratios and evaporation multiplicities. Improved transistion effects are demonstrated for solar particle events near the aluminum/tissue interface. Results are evaluated to the extent possible using modern Monte Carlo codes (Geant4, FLUKA, and PHITS). Extension of the Serber model to HZE interactions of NUCFRG will be discussed.

F2.3-0002-18 GLOBAL NM NETWORK - A USEFULL TOOL TO ASSESS RADIATION HAZARD AT FLIGHT ALTITUDES

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An important topic in the field of space weather is the assessment of radiation exposure at commercial flight altitudes. A specific interest is related to the contribution of solar energetic particles. For this purpose a precise information about solar energetic particle (SEP) characteristics, namely rigidity spectrum and angular distribution is necessary. Direct measurements with space-borne instruments can provide precise information of SEPs. However, they are constrained in some cases, because the specifics of spacecraft orbits. On the other hand ground based detectors, namely the global neutron monitor network provides a continuous operation. SEP characteristics can be derived using neutron monitor (NM) data during a special class of SEP events - the ground level enhancements (GLEs). A precise analysis of SEP spectral and angular characteristics using NM data requires several steps: detailed computation of assymptotic cones and cut-off rigidity of NMs used for the analysis, modeling of global NM network response using NM yield function and optimization procedure in order to derive spectral and angular characteristics of SEPs. Similar procedure with modifications, namely simplification of the model is applied for sub-GLEs analysis. Subsequently on the basis of the derived spectra and angular characteristics and using recent model based on previously computed yield functions we calculate the effective dose during the GLEs and sub-GLEs at typical commercial flight altitude of 35 kft. Several examples are shown. Hence, we demonstrated that the global NM network is a useful tool to assess the radiation exposure of aircrew due to CR of galactic and solar origin. In addition, we created a new database for assessment of radiation doses in the Earth atmosphere, related to GLE events created under VarSiTi/SCOSTEP support and incorporated to the International GLE database. The upgraded database provides, for each GLE event, where possible, information on the estimated SEP energy/rigidity spectra, the corresponding computed effective doses and bibliography. The effective dose rates were computed for altitude of 35 kft in a polar region, where the exposure is maximal.

F2.3-0003-18 CHARACTERISATION OF THE SPACE RADIATION ENVIRONMENT IN THE NEAR-EARTH REGION BASED ON MEASUREMENTS WITH THE TRITEL THREE DIMENSIONAL SILICON DETECTOR TELESCOPE IN DIFFERENT MISSIONS

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A three-dimensional silicon detector telescope (TRITEL) was developed in the KFKI Atomic Energy Research Institute (the predecessor of the MTA Centre for Energy Research) in order to determine the average radiation quality factor and to estimate the absorbed dose and the the dose equivalent to the astronauts. Since 2011, TRITEL has been operated on different kind of platforms: on board the BEXUS-12 (September 2011) and the BEXUS-14 (September 2012) stratospheric ballons in the frame of space education projects of ESA; on board the European Columbus module of the International Space Station (ISS) in a collaboration with ESA (November 2012 - May 2013); and on board the ISS Zvezda module in collaboration with the Institute of Biomedical Problems, Russian Academy of Sciences (April - July 2013 and October 2017 -). In the present paper, a comparative analysis of all these measurement results will be given. The result of the analysis will be used to characterise the space radiation environment in the stratosphere and in low Earth-orbit based on experimental data from the TRITEL instrument. The ESEO-TRITEL instrument as the scientific payload on board the European Student Earth Orbiter (ESEO) will be also described. The expected launch of the ESEO microsatellite is due in Q2 2019. The expected measurement results will be also compared to TRITEL experimental data already available from the previous missions.

F2.3-0004-18 RELATIVISTIC ELECTRONS ENHANCEMENTS IN AURORAL REGIONS OBSERVED WITH DEPRON DOSIMETER

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Short-term increased fluxes in outer radiation belt were widely observed on polar satellites [1,2], as well as in balloon experiments [3]. The authors of these papers connect these features with the precipitation of energetic electrons into the upper atmosphere, or with the relativistic electrons enhancement events at the outer radiation belt boundary. We selected flux increasing of the charged particles and the dose rate in the region of the outer radiation belt in the period from September 1 to September 3, 2016. 01.09 the radiation conditions are moderately normal. The magnitude of the radiation belt maximum is at the value L = 4 less than 0.001 Gy / h. There are no small in duration features, except for one intersection of the belt in 08: 33: 56UT. Next, from 10:12 September 2 to 16:32 on September 3, we noticed 12 intersections of the belt with short-term features. These features are particle flux and dose rate enhancements and at the time scale up to 20 seconds. We show that such short features can contribute up to 25% of the daily dose in outer radiation belt. The amplitude of the increase exceeds that at the maximum of the radiation belt. Such increases occur on L-shells around 5. In this separate case, 11 increases were found on the night side of the magnetosphere (MLT from 18 to 6) and only one on the morning side of the magnetosphere. We analyze the geomagnetic situation with respect to the search for the preconditions for the formation of flows of energetic particles. According to the geomagnetic index SYM / H, at the beginning of the period under review, a geomagnetic disturbance of -75 nT is observed. The particle flux enhancements occur in the second half of the period, 10 hours after the DST minimum (SYM / H). The deviations of the SYM / H index in the presence of increases are no longer so great, up to -50 nT. Since we observe the increases in auroral zones, we use AE index as the criterion for changing the geomagnetic situation. However, the comparison of the detection time of the flux increases does not reveal the correlation of the AE value with the presence and magnitude of the particle flux increases. Instead, the rise times are in good agreement with the abrupt changes in AE in both directions. We also observe a good correspondence between the magnitude of the flow velocity and the time of observed increases.

F2.3-0005-18 RADIATION MEASUREMENTS WITH A PARTICLE PIXEL DETECTOR (PPD): ON SHINEN-2 SPACECRAFT THROUGH RADIATION BELTS

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Space radiation beyond low-earth orbit is constantly changing due to variations in the radiation particle flux of the Galactic Cosmic Ray (GCR) environment. Prairie View AM University (PVAMU), in collaboration with NASA Johnson Space Center (NASA-JSC), developed a radiation detector system for the Kyushu Institute of Technology (KIT) in Japan and launched the only payload on board their Shinen2 spacecraft in December 2014 as part of the Hayausa2 Mission of JAXA. This newly designed and developed radiation detector (Particle Pixel Detector, PPD) makes use of two CMOS (Complementary Metal Oxide Semiconductor) sensors with custom designed electronic instrumentation capable of identifying radiation particle trajectory and characteristics. Shinen2 spacecraft, designed and built by KIT-Japan, is a hexagonal shaped, 15-kg, 47 x 49 x 49-cm structure built with light-weight and durable Carbon Fiber Reinforced Polymer (CFRP) with dual batteries charged by solar panels on each side of the structure and redundant UHF transmission systems at 437 MHz. Shinen2 proved its success by transmitting radiation data measured by the PPD unit from Moon orbit and up to 30 times distance from Earth to Moon. We present and discuss first data sets received from the Shinen2 spacecraft and assess the measurements with recently obtained calibration data with high energy protons and heavy ions. Our first data through the radiation belts is very promising with additional results from elliptical orbit trajectory around the Sun.

F2.3-0006-18 THE DOSIS 3D PROJECT ONBOARD THE INTERNATIONAL SPACE STATION - STATUS AND SCIENCE OVERVIEW OF 6 YEARS OF MEASUREMENTS (2012 - 2018)

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The radiation environment encountered in space differs in nature from that on Earth, consisting mostly of highly energetic ions from protons up to iron, resulting in radiation levels far exceeding the ones present on Earth for occupational radiation workers. Since the beginning of the space era the radiation exposure during space missions has been monitored with various passive and active radiation instruments. Also on-board the International Space Station (ISS) a number of area monitoring devices provide data related to the spatial and temporal variation of the radiation field in - and outside the ISS. The aim of the DOSIS 3D (2012 - ongoing) experiment is the measurement of the radiation environment within the European Columbus Laboratory of the ISS. These measurements are, on the one hand, performed with passive radiation detectors mounted at eleven locations within Columbus for the determination of the spatial distribution of the radiation field parameters and, on the other hand, with two active radiation detectors (DOSTEL) mounted at a fixed position inside Columbus for the determination of the temporal variation of the radiation field parameters. The talk will give an overview of the current results of the data evaluation performed for the passive and active radiation detectors for DOSIS 3D in the years 2012 to 2018 and further focus on the work in progress for data comparison with other passive and active radiation detector systems measuring on-board the ISS.

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F2.3-0007-18 PROGRESS OF SHIELDING EFFECT CHARACTERISTICS WITH WATERFILLED TOOLS FOR SPACE RADIATION IN 2010-2016

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The shielding effect with water-filled tools, called "Protective curtain", for space radiation was experimentally verified in the Russian Segment of International Space Station (ISS). The Protective curtain consists of a stack board made of the hygienic wipes and towels for ISS crews. The passive dosimeters consisted of a combination of luminescence detectors (TLDs: LiF:Mg,Ti, CaSO4:Dy and Al2O3:C and OSLDs: Al2O3:C) and plastic nuclear track detectors (PNTDs: CR-39 HARZLAS/TD-1). Totally 12 passive dosimeter packages were installed in front of/behind the Protective Curtain with 6 g/cm^2 in mass thickness for measuring the dose reduction rate. The experiment was launched in June 2010 and has been continued by March 2016 through 6 sessions. The dose reduction rate which is the dose ratio with/without

Protective Curtain varies from 53 to 93 % in absorbed doses and from 52 to 97 % in equivalent dose, respectively. The observed dose includes secondary radiations such as neutrons and target fragments as we can see in LET spectra. In this presentation, we

will show the recent progress of shielding effect characteristics of Protective Curtain and long term dose variations related to the ISS orbital parameters and solar activity.

F2.3-0008-18 RADIATION DOSE SIMULATIONS FOR SPHERICAL TISSUE-EQUIVALENT PHANTOM USED IN THE MATROSHKA-R SPACE EXPERIMENT ABOARD ISS

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We present a numeric method for fast calculation of the radiation dose rate during a space flight. We demonstrate its application for the first and the second sessions of MATROSHKA-R space experiment with the spherical tissue-equivalent phantom.

Radiation dose calculations using depth-dose curves consist of two parts. In the first part, real spacecraft geometry is processed into shielding distribution function. This function is calculated for each point of interest using ray-tracing method. In the second part, shielding distribution function is convoluted with the depth-dose curves. Depth-dose curve is a dependence of the radiation dose in a very small tissue volume on the shield thickness and composition. Depthdose curves for this work were calculated using GEANT4 Monte-Carlo code combined with GCR and AP8/AE8 trapped radiation models. Both absorbed and equivalent doses were calculated. Equivalent dose was calculated using quality factors dependent on LET.

The first main feature of the work is that the depth-dose curves were calculated for a doublelayer aluminum-water shield and shielding distribution function is replaced with shielding and composition distribution function. Aluminum-water shield is a good simplification of the real geometry, as water is good equivalent for biological tissues and aluminum is the major material for a spacecraft wall. We demonstrate that this ratio has influence on the depth-dose curves in the thickness rage over ~10 g/cm^2.

The second main feature is that we calculated contribution of primary and secondary radiation. Secondary radiation was additionally separated according to particle type (gammas, protons, neutrons, nucleus, leptons, mesons and baryons).

F2.3-0009-18 MEASUREMENTS WITH THE TRITEL SYSTEM ON THE RUSSIAN SERVICE MODULE OF THE ISS IN THE PERIOD BETWEEN APRIL-JULY 2013 AND AFTER OCTOBER 2017

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After 4 years of intermission, operation of the TRITEL 3D silicon detector dosimeter system, developed in the Centre for Energy Research, Hungarian Academy of Sciences in cooperation with BL-Electronics Ltd., continued on board the Russian Segment of the International Space Station (ISS). The TRITEL instrument has been used aboard the ISS in the framework of the Russian (IBMP and RSC ENERGIA) space experiment MATROSHKA-R to study radiation dose distribution, dynamics, and anisotropy in the space station compartments. The TRITEL instrument, including three silicon detector telescopes with axes mutually orthogonal to each other, thus having almost uniform sensitivity in 4, is capable of determining the energy deposition spectrum in 300-μm-thin silicon detectors and the LET spectrum of the radiation in three mutually orthogonal directions, from which the absorbed dose rate and the dose equivalent rate can be estimated. The scientific objectives, a brief description of the experiment as well as the calibration of the system will be given in the paper. Results of the measurement from the period between April-July 2013 and after October 2017 will be presented, interpreted and compared.

F2.3-0010-18 COMPARISONS OF HIGH-LINEAR ENERGY TRANSFER PARTICLE SPECTRA ON THE ISS AND IN DEEP SPACE

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In deep space, personnel and equipment are exposed to the space radiation environment in the form of energetic particles, specifically Galactic Cosmic Rays and sporadic Solar Energetic Particle events. Radiation fields resulting from these particles are modified by shielding, but most radiation measurements in deep space have been made with detectors that were unshielded or very lightly shielded. In contrast, the space radiation environment on the International Space Station is more complicated, with time-dependent modification of the incident flux by the geomagnetic field and complex bulk shielding distributions; measured particle spectra inside the ISS are affected by both types of shielding. Here, our primary aim is to compare charged particle spectra at high linear energy transfer (LET) obtained by the ALTEA detector on ISS during high-latitude portions of the orbit to similar data acquired by the CRaTER and RAD instruments, both in deep space. The CRaTER instrument is on the LRO spacecraft in lunar orbit, and RAD is part of the Curiosity rover science payload. RAD operated for most of its cruise to Mars aboard the MSL spacecraft, during a period in 2012 when ALTEA was in regular operation on the ISS in the USLab. Later in 2012, ALTEA was moved to the Columbus module, while RAD was acquiring data on the surface of Mars. CRaTER operated continuously during both periods. All three instruments report the energy deposition in silicon from charged particles. These energy depositions are used in ground analysis to determine LET spectra in water, which in turn are used to calculate the dosimetric quantities of interest. The results have implications for radiation biology; the ISS radiation environment - at least at high latitudes - may offer a superior platform for radiation biology experiments compared to accelerator laboratories, where even the lowest dose rates are orders of magnitude higher than those in space, though the challenges of performing radiation biology experiments in space would be formidable.

We find that the GCR environments measured by ALTEA when ISS is at high latitudes have many features in common with the environment as measured in shielded environments outside the geomagnetosphere. In the first period studied, ALTEA was in the USLab module of the ISS and under heavy shielding; the LET spectrum it measured is quite similar to that obtained by RAD on Mars in the later period, under similar heliospheric conditions. The spectra obtained by RAD during its cruise to Mars are very similar to the spectrum seen in the most-shielded CRaTER detectors, and the ALTEA spectrum obtained in the second period (while in Columbus) are very similar to these spectra. We conclude that the radiation environment inside the ISS at high geomagnetic latitudes can, in the more-shielded areas, serve as a reasonable proxy for the Martian surface environment, and in less-shielded areas, as a proxy for interplanetary space.

F2.3-0011-18 ESA ACTIVE DOSIMETER A TECHNOLGY DEMONSTRATION FOR ISS AND BEYOND

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Human presence in space has increased significantly over the last decade. Extended space flights supported by various international crews that lasted half a year and longer became a reality. Challenges to human health and well-being proofed to remain significant and increasing with mission-length and workload. Ongoing strong efforts did enable for such mission scenarios and shall do so for the future, the human journey to deep space that is intended. Several of the risks arising seem to have the potential to be mitigated and finally covered sufficiently. Despite health risks from ionizing radiation during extended exploratory deep space missions remain to be of significance and may strongly limit human presence and mission goals beyond Low Earth Orbit. The ESA Active Dosimeter [EAD] hardware enables for advanced personal dosimetry capabilities in real time. The system consists of several small portable Personal Active Dosimeters (MU = Mobile Unit's) as well as a surface attached docking station, called "Personal Storage Device (PSD)". The PSD provides data read-out data and advanced display capabilities as well as data storage and telemetry. The PSD contains a Tissue Equivalent Proportional Counter (TEPC) and an internal MU (iMU) for advanced analysis of the complex radiation environment in the space station and to ensure means of cross calibrations. The MU is applied for personal dosimetry as well as used for area monitoring purposes throughout the station. Verification of the system capabilities have been successfully executed in flight on ISS. Further utilization has been recommend by the ISS partner agencies. System developments and testing, including operations during a future flight of NASA's Orion program, is en-route. This presentation will give an overview of the relevant data from the first year of operations on ISS.

F2.3-0012-18 COMPARATIVE STUDIES OF TWO SIMILAR SPES AS MEASURED IN LEO AND OUTSIDE EARTH MAGNETOSPHERE

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The effects on humans of Solar Particle Events (SPEs) inside a space habitat, are key knowledge for a proper risk assessment. Beside information from the radiobiological standpoint it is important to know how the SPEs will propagate to the habitat, in the habitat and how soon the warning concerning the SPE arrival can be issued. Validation of the related transport models, provision of SPE parameters - as inputs for optimizing the now-casting capabilities - are therefore of paramount importance (now-casting: ability to predict the risk associated to an SPEs from the very first radiation precursors as measured on the vessel itself). Here we focus on two SPEs (August 9th 2011 March 13th 2012) as measured by ALTEA, an active silicon detector system orbiting in Low Earth Orbit (LEO) in the International Space Station (ISS). The SPEs observed by ALTEA are quite different from those detected outside Earth's magnetic field by e.g., GOES, the Geostationary Operational Environmental Satellite, as they are modulated by the geomagnetic shielding The shown measurements provide: i) experimental results of actual SPEs detected within a space habitat; ii) means to extrapolate these results to deep space; iii) information to better understand the interaction between the geomagnetic field and the radiation field from the sun. Results from the the two SPEs will be shown correlating the ALTEA data with data coming from other in-

situ detectors, such as GOES and EPHIN taking into account the geomagnetic field cutoffs. Data from RAD instrument (in transit to Mars) will also be used for the comparison. Other publicly available data from detectors in LEO (such as PAMELA) will be used for the comparisons if available. We will also investigate the reasons of different ALTEA responses to similar SPEs.

F2.3-0013-18 THE DOSIS 3D PROJECT ONBOARD THE INTERNATIONAL SPACE STATION - ANALYSIS OF THE SOLAR PARTICLE EVENT IN SEPTEMBER 2017

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Besides the effects of the microgravity environment, and the psychological and psychosocial problems encountered in confined spaces, radiation is the main health detriment for long duration human space missions. The radiation environment encountered in space differs in nature from that on earth, consisting mostly of high energetic ions from protons up to iron, resulting in radiation levels far exceeding the ones encountered on earth for occupational radiation workers. Accurate knowledge of the physical characteristics of the space radiation field in dependence on the solar activity, the orbital parameters and the different shielding configurations of the International Space Station ISS is therefore needed. As a follow up to the DOSIS experiment (2009 - 2011) DOSIS 3D measures since May 2012 the spatial and temporal variations of the radiation field in Columbus. The active part the DOSIS MAIN BOX thereby consist of two active radiation detectors (Dosimetry Telescopes = DOSTELs) with a DDPU (DOSTEL Data and Power Unit) is mounted in a Nomex pouch at a fixed location in the bottom area of the European Physiology Module rack (EPM). The temporal variation in dependence of ISS altitude and solar cycle has been measured with the DOSTEL instruments since May 2012 covering thereby already 6 years of continuous measurements in the frame of DOSIS 3D. Of special interest was the first Solar Particle Event (SPE) (GLE 72) measured inside the Space Station within the DOSIS 3D project in September 2017. This was the first event measured since 2012 inside the ISS and in terms of exploration missions extremely important, since it was also measured in Moon orbit and at the surface of Mars. The presentation will focus on the timeline of the event observed inside Columbus and provide data for dose and relevant energy deposition spectra and also show first comparisons with GEANT4 simulations. It will also provide comparison with events observed with DOSTEL like instruments on space station MIR (1997) and on ISS (2001). The CAU contributions to DOSIS and DOSIS 3D are financially supported by BMWi under Grants 50WB0826, 50WB1026, 50WB1232 and 50WB1533.

F2.3-0014-18 THE SEPTEMBER 2017 SOLAR ENERGETIC PARTICLE EVENT OBSERVED BY MSL/ RAD ON THE SURFACE OF MARS

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The Radiation Assessment Detector (RAD) has been continuously monitoring the Martian surface radiation environment in Gale crater as part of NASA's Mars Science Laboratory (MSL) mission since August 2012. On September 11 2017, RAD detected the strongest SEP event on the Martian surface to date. This event lead to the highest radiation levels since the beginning of the RAD operations in Gale crater. The SEPs associated with this solar storm increased the surface radiation dose by a factor of 3 over the course of a few hours, and the peak radiation dose was more than 50% higher than the previous maximum measured in October 2013.

Here, we give an overview of the heliospheric conditions during the September 2017 solar storm, and present measurements of charged particle spectra during and before the event. RAD saw significant increases in the surface proton and helium fluxes, as well as in the neutral particles (neutrons and gamma-rays) created by interactions of the SEPs with the atmosphere and soil.

F2.3-0015-18 A GENERALIZED APPROACH TO MODEL THE SEP/GCR SPECTRA AND RADIATION DOSE RATE ON THE SURFACE OF MARS

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For future human missions to Mars, it is important to study the surface radiation environment during extreme and elevated radiation conditions. In the long term, it is mainly Galactic Cosmic Rays (GCRs) modulated by solar activity that contribute to the radiation on the surface of Mars, but intense solar energetic particle (SEP) events may induce acute health effects due to their high dose rate. Such events may enhance the radiation level significantly and should be detected as immediately as possible to prevent severe damage to humans and equipment. However, the energetic particle environment on the Martian surface is significantly different from that in deep space due to the influence of the Martian atmosphere. Depending on the intensity and shape of the original solar particle spectra as well as particle types, the surface spectra may induce entirely different radiation effects. In order to give immediate and accurate alerts while avoiding unnecessary ones, it is important to model and well understand the atmospheric effect on the incoming SEPs including both protons and helium ions.

In this study, we have developed a generalized approach to quickly model the surface response of any given incoming proton/helium ion spectra and have applied it to a set of historical large solar events thus providing insights into the possible variety of surface radiation environments that may be induced during SEP events. Based on the statistical study of more than 30 significant solar events, we have obtained some empirical correlations for estimating the surface dose rate directly from any given power-law shaped SEP spectra.

We have also found a pivot energy (300 MeV) at which the intensity alone can be used to determine the surface dose rate induced by a power-law SEP event. Such quantified correlations can be used (1) to make instant predictions of the radiation environment on the surface of Mars upon the onset of SEP events and (2) to retrieve the particle spectra properties (intensity and spectral index) at Mars based on the most recent measurements of dose rate by the Radiation Assessment Detector on the Curiosity rover.

F2.3-0016-18 IMPLICATIONS OF THE SEPTEMBER 2017 SOLAR PARTICLE EVENT FOR HUMAN EXPLORATION OF MARS

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Although the Sun is approaching solar minimum, a series of large solar particle events (SPEs) occurred in September 2017 that impacted both Earth and Mars. In particular, the event of 10 September 2017 was the largest event that RAD has seen on the surface of Mars since it landed in 2012. Due to the modulating effect of the Martian atmosphere, the shape and intensity of these SEP spectra will differ significantly between interplanetary space and the Martian surface. Understanding how these SEP events influence the surface radiation field is crucial to assessing associated health risks for potential human missions to Mars. We will discuss in this talk the dosimetric quantities measured by MSL RAD before, during and after the Sept. 10 event, and their implications for potential human missions to Mars.

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F2.3-0017-18 MARS NEUTRON RADIATION ENVIRONMENT: SURFACE AND ORBITAL DATA

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The charged particles of the Galactic Cosmic Rays (GCR) penetrate through the thin martian atmosphere and collide with the nuclei of basic rock-forming elements in the subsurface layer producing high energy neutrons. This process forms the neutron radiation environment of Mars which present significant problems/hazard for the future robotic and human exploration. Currently some of orbital and surface missions exploring Mars are equipped with neutron spectrometers to monitor martian neutron flux in different energy ranges. In this study we have used neutron spectroscopy data gathered by HEND/Odyssey, DAN/MSL Curiosity and FREND/ExoMars/TGO experiments for the time period starting from 2002 till now. This analysis includes search for long and short-term variations of neutron flux/GCR during quiet and active Sun, comparison between orbital and surface measurements and comparison with dosimetry data.

F2.3-0018-18 LIDAL (LIGHT ION DETECTOR FOR ALTEA) DETECTOR: A COMPACT SYSTEM FOR TIME OF FLIGHT MEASUREMENT ONBOARD THE INTERNATIONAL SPACE STATION

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LIDAL (Light Ion Detector for ALTEA) is a detector based on scintillators for fast time applications, designed to work paired with three ALTEA Silicon Detector Units (SDUs). It performs Time Of Flight (TOF) measurements and allows also to extend the ALTEA (Anomalous Long Term Effects on Astronauts) detection capability for the lower-Z cosmic ions on-board the International Space Station (ISS). Moreover, by merging particle velocity measured by LIDAL with the deposited energy measured by ALTEA, the Particle Identification capability is enhanced. This paper consists of three main parts. The first one is an overview of the different tasks and timing performances required for LIDAL detector: starting from simulations results, we will show how it is possible to fulfill timing requirements using the on-the-edge available technology. The second part is dedicated to the LIDAL prototype-0 developed at University of

Tor Vergata: the different realization steps, like the scintillator assembly, wrapping and light tight procedures, are briefly shown and discussed. The last part is dedicated to the prototype characterization performed at TIFPA proton beam line at Trento (Italy). The results are presented and discussed. Development status, foreseen schedules, flight opportunities and possible collaborations will be also presented.

F2.3-0019-18 HIGH ENERGY PARTICLE ENVIRONMENT IN THE MARTIAN ORBIT: PROPOSED MEASUREMENTS USING ENERGETIC ION SPECTROMETER

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Energetic particles of the interplanetary and solar origin are continuously bombarding the Martian ionosphere and plays an important role in the atmospheric loss. These particles can change the state of the Martian ionosphere significantly. In order to quantify and evaluate these changes in the Martian ionosphere due to the arrival of energetic particles generated close to the Sun during flare or due to the passage of interplanetary coronal mass ejection (ICME) and co-rotating interaction region (CIR), it is important to identify the arrival of these energetic particles at the Martian orbit relatively accurately. By measuring the H++ - He++ ratio in the Solar Energetic Particles (SEP), the precise time of arrival of these particles at the Martian orbit can be determined. The measurements of these proton and alpha fluxes at the Martian orbit can also further help to understand the energetic particle environment around the Martian orbit. Keeping these objectives in mind, the Energetic Ion Spectrometer (EIS) is planned for future Indian Mars Orbiter Mission. The prime objective of the EIS is to make the in-situ measurements of the high-energy charged particles (H+ and He++) in the energy range of 20 keV/n to 20 MeV/n from the Martian orbit. EIS uses customized Si-PIN detectors in the E-E configuration mode for the energy measurement and identification of the H+ and He++ particles. It uses a stack of 20 µm thick and 1.5 mm thick Si-PIN detectors to cover the energy range of 20 keV/n to 20 MeV/n. Third detector is placed behind

the 1.5 mm Si-PIN detector to work in the flag mode. This detector and the Anti-Coincidence Shield (ACS) are designed using plastic scintillator and Silicon Photomultiplier (SiPM) readout. Electrons measurements up to the energy of 400 keV are avoided by using the permanent magnetic assembly designed using SmCo magnets and Mu metal shielding. In this talk, overall configuration of the EIS, its salient features will be discussed. Developmental status of the bread-board model with preliminary results will also be presented.

F2.3-0020-18 INTERNATIONAL SCIENCE ABOARD ORION EM-1: THE MATROSHKA ASTRORAD RADIATION EXPERIMENT (MARE) PAYLOAD

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Lockheed Martin, Houston, Texas, United States Matroshka AstroRad Radiation Experiment (MARE)

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The natural ionizing radiation environment present in space poses risks to human exploration that require mitigation. Space ionizing radiation consists primarily of highly energetic charged particles including protons and heavy ions. Solar energetic particles (SEP) originate from the Sun and are emitted during transient events referred to as Solar Particle Events (SPEs). Galactic Cosmic Rays (GCR) originate outside the solar system and form a slowly varying background modulated by the solar cycle. Spacecraft designed for Exploration beyond Earth orbit (BEO) do not benefit from the Earth's magnetosphere protection and are subject to stricter radiation design requirements than their low Earth orbit (LEO) counterparts. Spacecraft flying beyond Earth orbit may also be exposed to the Van Allen (trapped radiation) belts environment depending upon their trajectories. Orion is NASA's next generation crewed spacecraft, developed specifically for Exploration missions. Orion's first test flight Exploration Flight Test 1 (EFT-1) was successfully completed in December 2014, along a trajectory traversing the peak flux region of the Van Allen proton belt. The upcoming Orion mission referred to as Exploration Mission 1 (EM-1) is a test flight scheduled for 2019. The EM-1 trajectory will reach cis-lunar space for a total mission duration of 21-42 days. The Van Allen proton exposure during EM-1 is expected to be lower than EFT-1 primarily due to faster transit through the belts, but significantly higher than that experienced by the International Space Station (ISS) during South Atlantic Anomaly (SAA) passes. Characterization of the space radiation environment and development of mitigation strategies are complex problems. The environmental components (GCR, SPE, Van Allen radiation) differ in elemental compositions, energy spectra, and intensities. The intra-vehicular environment is modified as a result of interaction of the extra-vehicular environment with the spacecraft materials. This occurs due to both the primary particles being slowed down by electronic interactions with the shielding material, and secondary particles being generated by nuclear interactions. Knowledge of exposure specific to organ points of interest is

important for biological effects quantification. Human body self-shielding differs among organs and tissues. The measuring efficiency of detectors varies across the wide range of particle species and energies of interest. Tissue equivalent phantoms have been used to perform space radiation measurements relevant to biomedical effects. The MATROSHKA series of international collaboration experiments using the anthropomorphic Alderson Rando phantom as measurement platform has been conducted starting from 2004, both intraand extravehicular on ISS. Lockheed Martin is the NASA prime contractor responsible for the Orion vehicle. Radiation protection has been incorporated in the Orion spacecraft as a design driving requirement and consistent with the ALARA principle. Feedback invited by Lockheed Martin as part of ongoing efforts to optimize radiation protection of the Orion crew attracted interest in an incremental improvement of previous MATROSHKA experiments. In coordination with Lockheed Martin Advanced Programs, an ionizing radiation science payload referred to as MARE (Matroshka AstroRad Radiation Experiment) was proposed by the German Aerospace Center DLR and the Israel Space Agency ISA. In May 2017, MARE was approved by NASA and manifested aboard the Orion EM-1 flight. MARE consists of two CIRS ATOM® 702 Adult Female radiotherapy phantoms flown inside the Orion cabin at seat positions 3 and 4. The phantoms are fitted with ionizing radiation detectors placed both internal for organ point-, and external for skin exposure measurements. In an improvement over the ISS MATROSHKA, the science objectives are expanded to include characterization of a novel personal protection equipment item deployed on one of the phantoms, the AstroRad individual radiation protection shield. AstroRad is the product of an international collaboration between StemRad Ltd., Israel and Lockheed Martin. AstroRad provides customizable radiation protection for astronauts, focused on radiation-sensitive stem-cell rich organs and tissues. The MARE suite of radiation detectors includes over 5,000 passive detectors for dose depth profile and organ point measurements, consisting of Thermoluminescenceand Optically Stimulated Luminescence dosimeters, and Plastic Nuclear Track Detectors. For purposes of dosimetry intercomparison and detector cross-characterization, assemblies of dosimeters provided by the international research community will be included in MARE, with heritage participation in the DOSIS-3D experiment. MARE also features active detectors - the DLR M-42, the NASA CPAD (Crew Personal Active Dosimeter) and the ESA Active Dosimeter Monitor Unit - Orion (EAD MU-O). Time-resolved measurements provided by the active detectors will allow separate characterization of mission-phase-specific environments. Preliminary environment assessments were performed for the EM-1 mission, including on a family of expected trajectories through the Van Allen belts to confirm sensitivity requirements for the MARE detectors. This presentation will include background on the Orion vehicle, BEO vs. LEO radiation environments, heritage space dosimetry efforts relevant to MARE, and focus on the current MARE status including active radiation detector development, testing and characterization. In conjunction with other radiation detectors aboard the vehicle, the Matroshka AstroRad Radiation Experiment is designed to provide a comprehensive picture of the radiation environment beyond Earth orbit specific to the Orion vehicle and internal to human body analogs. This data set will inform about expected exposures, enable better planning by validating the operational toolsets used to predict crew radiation exposure risk on future Orion missions, and evaluate a potential countermeasure. MARE epitomizes the spirit of international collaboration toward human space exploration. The experiment is co-managed by DLR and ISA, with NASA participation as a co-PI. StemRad and Lockheed Martin contribute to the development of AstroRad science objectives. Numerous research groups on three continents participate as co-Is, including ESA. Lockheed Martin personnel facilitate payload integration in the spacecraft. As one of the first science payloads to fly aboard Orion, MARE demonstrates the research opportunities aboard NASA's next generation space exploration vehicle.

F2.3-0021-18 TIME-DEPENDENT RADIATION DOSE SIMULATIONS DURING INTERPLANETARY SPACE FLIGHTS

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Space radiation is one of the main concerns in planning long-term interplanetary human space missions. There are two main types of hazardous radiation - Solar Energetic Particles (SEP) and Galactic Cosmic Rays (GCR). Their intensities and evolution depend on the solar activity. GCR activity is most enhanced during solar minimum, while the most intense SEPs usually occur during the solar maximum. SEPs are better shielded with thick shields, while GCR dose is less behind think shields. The overall dose from SEP and GCR depends on the time of the mission and thickness of the spacecraft shield. In order to minimize the radiation intensity and dose from SEP and GCR it is encourage to the search of the optimal launch date. In this study, we combine state-of-the-art space environment models with GEANT4 simulations to determine the optimal shielding of the spacecraft, and launch time with respect to the phase of the solar cycle. The radiation environment was described by the time-dependent GCR model, and the SEP spectra that were measured during the period from 1990 to 2010. We included gamma rays, electrons, neutrons and 28 fully ionized elements from hydrogen to nickel.

We calculated the astronaut's radiation doses during interplanetary flights using the MonteCarlo code that accounts for the primary, secondary and albedo radiation. Secondary and albedo radiation dose was additionally classified according to particle type (gammas, protons, neutrons, nucleus, leptons, mesons and baryons). We also calculated dose distribution inside the astronaut's phantom, to estimate radiation dose for different organs.

In conclusion, we present the dependences of the radiation dose as a function of launch date from 1990 to 2010, for flight durations of up to 6 years.

F2.3-0022-18 FEASIBILITY OF A USAGE OF SMALL-SIZED P-TERPHENYL SCINTILLATORS WITH ORIENTED CRYSTALLINE AXES IN SPACE MEASUREMENTS OF HIGH ENERGY CHARGE RADIATION

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Detector head of the Background Particle Monitor (BPM) is a constituent part of the solar soft X-ray spectrophotometer ChemiX for interplanetary space mission "Interhelioprobe". The BPM measurements of particle fluxes will assist to determine level of X-ray spectra contamination due to high-energy ambient interplanetary particles. BPM's head comprises organic scintillator, which is built on the base of p-terphenyl single crystal, optically coupled with semiconductor multi pixel photon counter - silicon photomultiplier (Si-PM). As far as lightweight organic scintillators typically have moderate technical light yields as compared with "massive" inorganic scintillators such as CsI(Tl), NaI(Tl), we have studied the possibility obtaining highest luminescence intensity from small-sized p-terphenyl single crystals for particle detection.

In this research we present results of laboratory measurements of dependence of technical light yield for small-sized p-terphenyl detectors in relation with the direction of their crystalline axes. The research was performed for a crystal sample with dimensions that are very close to geometric parameters of BPM's anti-coincidence detector. A cubic sample of the scintillator with dimensions 6 x 6 x 6 mm3 has been manufactured with this purpose to match an active area of Si-PM. We have measured its spectrometric characteristics in the energy range from 482 1048 keV along specific crystalline axes using betha-particles from isotopes bismuth-207 and cesium-137.

We demonstrate that scintillation detector made from lightweight organic scintillator and 57,600

pixel' Si-PM photomultiplier is capable to respond to low energy gamma-quanta and electron fluxes in a wide energy range from E = 32 keV up to E = 1048 keV on conditions when the temperature

of photodetector is constant. The greatest technical light yield of such type scintillator is seen when light splashes propagates along axis b of sample crystalline array. Taking into account small values of effective charge and density of this type of organic single crystal scintillator the probability for registration of bremsstrahlung in space is almost negligible, that allow us to detect, to count and even to register energy spectra of primary electrons, protons and other nucleons in magnetosphere and interplanetary space with high efficiency.

F2.3-0023-18 ENERGETIC PARTICLES' FLUXES AND DOSE IN THE RADIATION GENE BOX MEASURED BY SPACE RADIATION DETECTOR ONBOARD SJ-10 SATELLITE

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The space is a total different environment to the surface of the earth, it is essentially without atmosphere, without gravity, without protection form radiation. While radiation in space will hazard the astronauts' health, many experiment about animals and cells abnormal in space have been done to investigate the effect of space radiation on human being. As different types of radiation have different effects on biological tissues, it is important to know exactly fluxes of different radiation particles. The Radiation Gene Box (RGB) was designed to evaluate the effects of space environment on the mESCs and drosophila. While the Space Radiation Detector (SRD) was designed to derive the fluxes of electron, proton, hellion and gamma ray inside the RGB. In this paper, we presented the data obtained during 13 days of instrument operation on low earth orbit. The derived results showed that the total dose of particles inside the RGB would have no obviously biological effect on the mESCs and the fruit fly Drosophila.

F2.3-0024-18 A PROTON IRRADIATION TEST FACILITY FOR SPACE RESEARCH IN ANKARA, TURKEY

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Space radiation often aects the electronic components' performance during the mission duration. In order to ensure reliable performance, the components must be tested to at least the expected dose that will be received in space, before the mission. Accelerator facilities are widely used for such irradiation tests around the world. Turkish Atomic Energy Authority (TAEA) has a 15MeV to 30MeV variable proton cyclotron in Ankara and the facility's main purpose is to produce radioisotopes in three dierent rooms for dierent target systems. There is also an RD room which can be used for research purposes. This paper will detail the design and current state of the construction of a beamline to perform Single Event Eect (SEE) tests in Ankara for the rst time.

ESA ESCC No.25100 Standard Single Event Eect Test Method and Guidelines is being considered for these SEE tests. The proton beam kinetic energy must be between 20MeV and 200MeV according to the standard. While the proton energy is suitable for SEE tests, the beam size must be 15.40cm x 21.55cm and the ux must be between 105p/cm^2/s to at least 108p/cm^2/s according to the standard. The beam size at the entrance of the RD room is mm-sized and the current is variable between 10µA and 1.2mA. Therefore, a defocusing beam line has been designed to enlarge the beam size and reduce the ux value. The beam line has quadrupole magnets to enlarge the beam size and the collimators and scattering foils are used for ux reduction. This facility will provide proton uxes between 107p/cm^2/s and 1010p/cm^2/s for the area dened in the standard when completed. Also for testing solar cells developed for space, the proton beam energy will be lowered below 10MeV. This project has been funded by Ministry of Development in Turkey and the beam line construction will nish in about one year and SEE tests will be performed for the rst time in Turkey.

F2.3-0025-18 SIMULATION OF RADIATION MONITORING TELESCOPES PARAMETERS AND FEATURES OF THEIR OPERATION IN THE DETECTION OF ELECTRONS

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This work presents the technique and results of computer simulation of the interaction of cosmic radiation with telescopic detectors. The program code based on Geant4 libraries is designed, to simulate the operation of the detector of ionizing radiation, consisting of several sequentially located semiconductor and scintillation detectors. Using the Geant4 toolkit, we simulate signals from electrons and protons of various energies in the detecting regions of the device, taking into account the generation of secondary particles. Separation of signals from primary particles passing through the entrance window of the telescope and through the walls of the housing is carried out. The obtained data are used to simulate the necessary throughput of the device electronics. The characteristics of the sensitivity and accuracy of the spectrum determination are performed using an original algorithm. This algorithm realizes quantile regression to obtain information on the spectra of cosmic radiation, based on the energy losses of particles in the detectors of the instrument. We can definitely separate signals from electrons and protons but there are some problems with determination of electron energy when using such detectors. The combination of discussed software packages allows optimizing the parameters of the geometry and logic circuits of the device. Application of the results obtained using the presented software codes at the design and production stages of detectors will significantly increase the reliability of received data. The source files of the program codes are available in the public domain.

F2.3-0026-18 AN IMPROVED METHOD TO CORRECT THE THERMAL EFFECTS OF RADFETS FOR SENSITIVE MEASUREMENT OF TOTAL RADIATION DOSE

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"FengYun-4" satellite, which was launch into orbit on December 11, 2016, is the China second generation of geostationary meteorological satellite. The radiation dosimeter on this satellite was designed with the use of 8 radiation sensitive field effect transistors(RADFETs), and it could measurement the total space radiation dose under different shielding thicknesses and directions up to 2000krad(Si) with a sensitivity better than 150rad(Si). RADFETs are specially designed p-MOSFETs to measure the total radiation dose. When the RADFET is irradiated by ionized radiation, electron-hole pairs in the gate oxide of the MOSFET are produced. Then, the holes are trapped in the oxide and the gate threshold voltage is shifted. This shift in the gate threshold voltage is proportional to the total radiation dose. However, the gate threshold voltage could also be shifted as the temperature varies and this is known as the thermal effect. Temperatures inside the "FengYun-4" satellite on the geostationary orbit could varied up to 20C within one day and its effect on the threshold voltages of the p-MOSFETs need to be corrected. An improved method is developed for the correction of the thermal effect. The temperature coefficients are fitted for each RADFET based on the data obtained on-orbit. Then the contributions of temperature fluctuations are subtracted. After thermal effect correction, the total radiation dose of each RADFET is achieved. The results are about 15 35rad(Si)/day with 0.87mm equivalent aluminum shielding thickness and about 0.7rad(Si)/day with 3.87mm shielding thickness. Doses in the Y direction of the satellite are less than those in X and Z directions.

F2.4-0001-18 TRANSCRIPTOME OF ARABIDOPSIS LEAVES UNDER MICROGRAVITY ON BOARD THE CHINESE SPACE LAB TG-2

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Plant leaves, which can capture sunlight and fixed CO2, are main sources of food on earth, thus, growth and development of leaves are directly related to the production of crops in agriculture as well as in plant basis space life support system. Leaf development and its physiological activity are regulated by microgravity in space, but how the growth and development of leaves are affected by microgravity at molecular level is still unknown. To delineate the transcriptional response mechanisms, we carried out whole-genome microarray analysis of Arabidopsis leaves of plants grown on board the Chinese space lab Tian gong-2. We identified a novel set of microgravity response genes, recognized mainly by quantitative differences. These included a transcriptome signature of more pronounced proline transport, respiratory burst, protein refolding and jasmonic acid biosynthetic process in developing leaves. This study provides developmental stage specific molecular resolution of different age leaves and demonstrates that a new molecular plasticity in Arabidopsis leaves to adaptation to microgravity by adjusted genome status during development in space.

Key words: Arabidopsis thaliana, leaves, gene expression, microgravity, Chinese space lab

F2.4-0002-18 ROS PROFILING AND PROTEOMIC ANALYSIS OF ORYZA SATIVA AFTER SJ10 SPACE RADIATION

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During spaceflight biological samples are exposed to a variety of radiations, including galactic cosmic rays composed of high energy protons and high-energy charged (HZE) nuclei, and solar particle events containing lowto medium-energy protons. On-ground simulated studies have found that HZE exposures can induce early reactive oxygen species (ROS) in seconds which can last for days to months and cause persistent oxidative stresses. In order to investigate the ROS-caused chronic biological effects exposed to actual complex space radiations, Oryza Sativa (Nipponbare) seeds were irradiated by"Shijian-10" (SJ10) spacecraft and the ROS level, antioxidant ability during plant growth and functional protein expression profiles were studied in present research. The results showed that SJ10 space radiations could induce persistent oxidative damage by ROS in rice cells. The H2O2 content and activity of ROS scavenging system were significantly enhanced in 2 or 3-day-old rice seedlings and still existed in 7-day-old plants. Proteome alterations of 21-day-old plants showed that space radiation had significant impacts on the expression of proteins involved in cell redox homeostasis, anti-stress signaling pathway, electron transport chain, removal of superoxide radicals, protein translation and carbohydrate metabolic process. Results indicated that space radiations broke down the homeostasis of rice cells, reduced the synthesis of protein and stored energy metabolism of starch for adapting to oxidative stress induced by chronic ROS. Significant up-regulation of Cytochrome b6f complex proteins involved in photosynthetic electron transport explained that they might be one of the electron sources leading to chronic oxidative stresses in rice.

F2.4-0003-18 GLOBAL RNA-SEQ ANALYSES REVEAL A DRAMATIC LACK OF CONCORDANCE BETWEEN BACILLUS SUBTILIS TRANSCRIPTOMES FROM SPACEFLIGHTVS. CLINOSTAT-GROWN CULTURES

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Performing microbiological experiments in space is constrained by a number factors, including high launch costs, intense competition for limited payload volume and mass, infrequency of rocket launches, and limitations on crew time. These factors nearly preclude opportunities for performing replicate experiments in space, the hallmark of high-quality science. The above constraints have driven experimenters to search for microgravity analogues such as drop towers or parabolic flights. Although cheaper and more convenient, drop towers and parabolic flights provide free-fall conditions for a few seconds at most, which is inadequate for the majority of microbiological experiments that occur over much longer time frames. In an attempt to address this issue, microbiologists have increasingly turned to ground-based clinorotation instruments, which are purported to simulate microgravity by randomizing the gravity vector and minimizing fluid shear within the sample chamber. Clinostats have thus become widely used for testing spaceflight hypotheses prior to spaceflight missions. However, to date few experiments have actually measured the correlation between clinostat and spaceflight results. We recently were afforded a unique opportunity to perform two separate spaceflight experiments (called BRIC21 and BRIC-23), each containing multiple replicates, with matched flight (FL) and ground control (GC) samples using the same medium, hardware, and growth conditions. Comparison of the RNA-seq datasets from the BRIC-21 (n = 3) vs. the BRIC-23 (n = 9) experiments revealed a 32% and 35% concordance in significantly in upand down-regulated transcripts, respectively. These results show that even replicated spaceflight experiments can exhibit substantial experiment-to-experiment variability, highlighting the need for multiple repetitions to increase confidence. Next, to determine whether clinostats are a reliable model for simulating spaceflight effects, we performed RNA-seq analysis on the same B. subtilis strain cultivated in the same medium and temperature as the spaceflight experiments, but in High Aspect Rotating Vessels (HARVs, Synthecon; n = 4), and compared its transcriptome with those from the

BRIC-21 and BRIC-23 spaceflight experiments. Preliminary results of our analysis show essentially no concordance between the transcriptomes from the two spaceflight experiments vs. the samples grown in the HARVs. The results suggest that, at least for B. subtilis, clinostats may not be a reliable analogue for spaceflight missions. Supported by NASA grants NNX14AT38G and NNX17AD51G.

F2.4-0004-18 THE WHOLE GENOME SEQUENCING OF RICE SEEDS SURVIVING 12.5- DAY EXPOSURE TO SPACE ENVIRONMENT

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Space radiation was the most important stressor which can induce biological damage and genetic variation in spaceflight. A great deal is known about the kinds of damage produced in the DNA by ultraviolet radiation, to a lesser extent, by ionizing radiation. On the molecular level these effects to the organism are caused mainly by the damage induced by the ionizing radiation to the DNA of the living cell. The SNP, InDel and SV were often found in DNA by radiation after spaceflight. In this study, sequencing research on whole genome of rice seeds surviving 12.5 days exposure to space environment by HiSeqPE150. Taken the genome sequence ofjapanica rice Nipponbare completed the whole genome determination as a control, samtools and breakdancncer and cnvnator were used to study SNP, InDel, SV and CNV of seeds induced by spaceflight and wild-type rice materials. The mapping rate was 82.54%.The analysis showed that the mutagenic effects by space factors evenly distributed and had positive correlation with sizes of each chromosomes. We found 12,775 SNPs, 4,161 InDel, 1,290 SV and 422 CNV. The mutation type occurred in mutant is that SNPs, InDel, SV and CNV, that showed that the space factors changed the single nucleotide of the rice genome was the main factor. This study laid the foundation for exploring the molecular biological mechanism of the real actual spatial environment.

F2.4-0005-18 LONG-TERM SPACE FLIGHT MEDIATED CHANGES IN TRANSCRIPTION INITIATION LANDSCAPE IN ZEBRAFISH (DANIO RERIO) TISSUES

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Animal models are important to understanding influence of different factors of long-term space flights on living organisms and can be helpful for forecasting and prevention negative effects of space flights on humans. Teleost fishes, as Japanese medaka (Oryzias latipes) and Zebrafish (Danio rerio), are one of the most popular model organisms in molecular genetics studies, including space biology, primarily by sequenced and well-annotated genome, rapid external development, small size and relatively simple maintenance procedures aboard space-labs. Some previous experiments, which were performed on fish models using simulated microgravity and exposure aboard International Space Station (ISS), showed significant changes in fish behavior, physiology and whole genome gene expression. In this study we focused on several features of transcription initiation landscape and their changes during long-term exposure in space environment in different Zebrafish tissues. To define impact of space flight to tanscriptional activity on promoter level, experiments using cap-analysis gene expression (CAGE) approach were performed. Usage of CAGE, instead more traditional RNA-seq analysis, allows not only perform precise differential expression analysis, but directly map each transcription start site (TSS) with a single nucleotide resolution to access core promoter shape and location. Two groups of Zebrafish individuals were used as experimental and control groups. The individuals from experimental group were launched to international Space Station (ISS). Part of them were fixated in RNA stabilization reagent immediately after arriving, others transfered to Aquatic Habitat (AQH) and fixated after 36 days of staying aboard. Remaining part of experimental group animals were returned alive from ISS to investigate recovery processes. RNA preservation treatment was carried out with this animals in two time-points: 2 and 33 days after return. The animals from control group were maintained in the same Aquatic Habitat system on the Ground with fully identical physical environment conditions and were fixated at the same time-points. First results of CAGE showed the absence of significant changes on promoter shape level. Width of promoter area and dominant TSS position were not demonstrated any differences between pairs of “space” and “ground” samples. However, we have found significant impact of space flight conditions on promoter activity. More than 600

genes changed their expression in eye samples, after arriving aboard ISS. Notably, the number of differentially expressed genes decreased to 154 after 36 days in space, thereby it can be supposed a successful adaptation to space flight conditions after initial stress. Gene Ontology analysis of genes, which were overexpressed after arriving on ISS, showed significant over-representation of functional categories associated with circadian clock system, so it can be supposed an influence of microgravitation to regulation of rhythmic processes in animals. Additionally, from GO categories, enriched in up-regulated genes in all spaceflight time-points, were found several closely related GO terms associated with regulation of transcription. Among genes, characterized by this GO terms, four genes, which are members of Activation protein 1 (AP-1): fosb, fos, jdp2, junbb, showed significant overexpression during spaceflight. The same time analysis of presence of regulatory motifs in promoter surroundings demonstrated over-representation of AP-1-like binding sites in differentially expressed promoters. This facts suggest deeply involvement of AP-1 family members in organismal response to microgravity. The performed transcriptional analysis demonstrated both the considerable gene expression changes in zebrafish eye during long-term spaceflight and the successful adaptation to new environment.

F2.4-0006-18 GUT MICROBES IN CORRELATION WITH MOOD: A STUDY IN "LUNAR PALACE 365"

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Human gut microbiota, sometimes called the second genome or the second brain, may influence our mood through an imaginary microbiota-gut-brain axis. Numerous studies have demonstrated that the gut microbiome and their metabolites are extensively involved in the communication between brain and gut. Understanding the gut-brain correlationship is important for maintenance of mental health and prevention of mental illnesses. However, different from the study on people with mental illnesses, it could be more difficult to study the gut/brain relationship with healthy people whose emotional fluctuation is within a relatively narrow range. Varying physiological, nutritional and environmental conditions would affect the host's gut microbial community, and these factors could also directly affect the mood. Fortunately, the closed experimental bioregenerative life support system (BLSS, Lunar Palace 1) provided an ideal experimental condition under to minimize other possible interferences when we look into the gut/mood correlationship, because it keep the crewmembers living under a relatively stable environment (include environmental microbes), keep a regular dietary and living habit, and maintain a steady activity and health level. In 2014, a 105-day closed experiment with three crewmembers was conducted in the Lunar Palace 1. Previous study by our team has found that 15 genera in the three healthy crewmembers were strongly correlated with mood states. Among which, Faecalibacterium spp. had the highest abundance, and showed a significant negative correlation with mood. Now, a new study on the correlation between gut microbial alternation and mood swings of eight healthy crewmembers was conducted during "Lunar Palace 365" experiment. This study examined the whole metagenome of crewmembers' gut microbes at both speciesand gene-level resolution every week during the 365-day experiment. The mood swings of the crewmembers were investigated by self-rating scale (i.e., POMS, SCL-90), his rating scale (i.e., HAMA, HAMD) and behavioral analysis weekly. The Changes of metabolic, immune, protein were also analyzed. The association analysis between gut microbes and mood were identified with several analytical platforms and various bioinformatics methods (-omics). Our results indicated that the composition of microbial community could play an important role in emotional change in mentally-physically healthy adults. Keywords: Lunar Palace 1,

Microbiota-gut-brain axis, Metagenome, Gut microbes, Mood swing.

F2.4-0007-18 THE SYNERGISTIC EFFECT OF SIMULATED MICROGRAVITY AND CHARGED PARTICLE RADIATION ON GENE EXPRESSION IN HUMAN FIBROBLASTS

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Outer space is a unique environment that includes mixed microgravity (μG) and space radiation having a broad range of energy and ions. Currently, there are numerous unclear aspects of various biological responses (ex. gene expression profile change, bystander effect, etc.) induced by exposure to low-fluence heavy-ions under μG for the assessment of human health risks in space. In this study, we focus on comprehensive gene expression analysis for the combined effects using a newly developed 3D clinostat irradiation system with carbon-ion (C-ion) at ground level. Human fibroblasts 1BR-hTERT were maintained in standing or μG condition for 3 h or 24 h after synchronized C-ion irradiation (1 Gy, 290 MeV/nucleon, average linear energy transfer = 50 keV/μm at the center of the 6 cm-spread-out Bragg peak) as part of a total culture time for 2 days. The upor down-regulation change of gene expression profile was listed according to ratios of the expression value using the EDGE (Empirical analysis of Digital Gene Expression) ($p<0.05$, fold change with absolute value>1.5) with CLC Main Workbench software (Qiagen Bioinformatics, CA, USA). After exposure to only C-ions, we found downstream of p53, CDKN1A was enhanced 3 h after irradiation while CCND1 was not significantly changed at either 3 h or 24 h after treatment. On the other hand, in the case of combined treatment,

CDKN1A was suppressed 3 h after treatment and CCND1 was enhanced 24 h after irradiation. Therefore, these results suggest G1 arrest does not occur, and cells may pass through the G1/S check point with DNA damage due to changes in p53 signaling pathway related genes after combined treatment. Further studies are needed to determine whether the changes in gene expressions affect the DNA damage repair of treated cells and could affect bystander cells in simulated space flight environment.
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F2.4-0008-18 LONG-TERM EVOLUTION STUDIES OF E. COLI UNDER COMBINED EFFECTS OF SIMULATED MICROGRAVITY AND ANTIBIOTIC.

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Organisms exposed to the space environment for extended periods of time may evolve in unanticipated ways thereby negatively impacting long duration space missions. We report here, an experimental study of microbial evolution in which the effect of long-term exposure to LSMMG on microbial gene expression and physiology in it Escherichia coli (it E. coli) was examined using functional genomics, and molecular techniques with and with-out simultaneous exposure to broad spectrum antibiotic chloramphenicol. it E. coli MG1655 was grown under simulated microgravity for 1000 generations in High Aspect Ratio Vessels (HARVs) that were either heatsterilized (115 deg C, 15 min) or by using/rinsing the HARVs with a saturated solution of the broad-spectrum antibiotic chloramphenicol. Gene expression patterns and cellular physiology were analyzed in comparison with short-term exposure. In the case of the cells evolved using the antibiotic sterilized HARVs, the expression levels of 357 genes were significantly changed. In particular, fimbriae encoding genes were significantly up-regulated whereas genes encoding the flagellar motor complex were down-regulated. Resequencing of the genome revealed that a number of the flagellar genes were actually deleted. The antibiotic resistance levels of the evolved strains were analyzed using VITEK analyzer. The evolved strain was consistently resistant to the antibiotics used, even after 11 cycles of ‘erasure’ of the ‘adaptation memory’ this ‘erasure’ was accomplished by re-growing the evolved cells under shaker flask conditions and 1 cycle equals 10 generations. In the case of the cells evolved using heat sterilized HARVs, no resistance was observed to any of the antibiotics used, even after 1000 generations of growth under LSMMG. Competition experiments using an isogenic pair revealed that the adaptive advantage of the 1000G strain (in both cases) over an unexposed strain was rapidly eliminated. While this obviously implies that the adaptation was both environmental and genomic, the levels of antibiotic resistance observed to be consistently maintained, raises the concern of persistent resistance conferred to bacterial communities through exposure to antibiotics on space missions.

F2.4-0009-18 EFFECT OF MICROGRAVITY ON THE NUCLEUS

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The shape of the nucleus and its position is found to be altered in various pathological conditions, such as cancer, laminopathy and muscular dystrophy. Cells sense the external mechanical cues and these cues alter the cytoskeletal forces, which in turn are sensed by the nucleus due to the mechanical coupling between the nucleus and the cytoskeleton. The shape of the cell and shape of the nucleus are closely related and any changes to the morphology of the cell results in changes in nuclear shape and gene expression. Interestingly, several cell types cultured in microgravity have altered morphology and their cytoskeleton is reorganized. To understand what kind of changes morphology of the nucleus undergoes in cells exposed to microgravity, we analyzed 3-dimensional parameters of the nuclei in human fibroblast cells cultured on International Space Station (ISS) for 3 days and 14 days. The cells were in confluent status before being launched to ISS. Due to contact inhibition, more than 90% of the cells were in G1 phase. The confocal images acquired from the fixed samples were used to reconstruct the 3-D structures of the nucleus, which revealed neither the vertical height of the nucleus and nor the aspect ratio (length/width) changed significantly in cells exposed to microgravity for 3 days or for 14 days compared to the 1 g control cells. Taking together the lack of changes in cell and nuclear morphology and also in gene and miRNA expression levels, it is possible that the exposure to microgravity for longer durations (3 days and 14 days) is giving the cells enough time to adapt to the mechanical effects of microgravity, especially for confluent cell cycle arrested fibroblasts.

F2.4-0010-18 CELLULAR RESPONSES AND GENE EXPRESSION PROFILE CHANGES DUE TO BLEOMYCIN-INDUCED DNA DAMAGE IN HUMAN FIBROBLASTS IN SPACE

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Living organisms in space are constantly exposed to radiation, toxic chemicals or reactive oxygen species generated due to increased levels of environmental and psychological stresses. Understanding the impact of spaceflight factors, microgravity in particular, on cellular responses to DNA damage is essential for assessing the radiation risk for astronauts and the mutation rate in microorganisms. In a study conducted on the International Space Station, confluent human fibroblasts in culture were treated with bleomycin for three hours in the true microgravity environment. The degree of DNA damage was quantified by immunofluorescence staining for

-H2AX, which is manifested in three types of staining patterns. Although similar percentages of these types of patters were found between flight and ground cells, there was a slight shift in the distribution of foci counts in the flown cells with countable numbers of -H2AX foci. Comparison of the cells in confluent and in exponential growth conditions indicated that the proliferation rate between flight and the ground may be responsible for such a shift. We also performed a microarray analysis of gene expressions in response to bleomycin treatment. A qualitative comparison of the responsive pathways between the flown and ground cells showed similar responses with the p53 network being the top

upstream regulator. The microarray data was confirmed with a PCR array analysis containing a set of genes involved in DNA damage signaling; with BBC3, CDKN1A, PCNA and PPM1D being significantly upregulated in both flight and ground cells after bleomycin treatment. Our results suggest that whether microgravity affects DNA damage response in space can be dependent on the cell type and cell growth condition.

F2.4-0011-18 THE CANDIDA ALBICANS ADAPTATION RESPONSES TO MICROGRAVITY

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Candida albicans is an opportunistic fungal pathogen that maintains phenotypic plasticity and is capable of responding to a variety of environmental stimuli. Studies have demonstrated that this normally commensal yeast responds to conditions of low-fluid shear in modeled microgravity studies by displaying phenotypes consistent with pathogenicity. C. albicans responds to low-fluid shear with increased antifungal resistance, increased filamentation, and differential expression of genes in several biosynthetic pathways. We propose that low-fluid shear induces alterations to the chemical environment to which C. albicans is responding. Indeed, C. albicans gene expression studies indicate that there are increased levels of carbon dioxide when the yeast is cultured in conditions of low shear. Extrapolating from our prior findings that low-fluid shear conditions contribute to Amphotericin B resistance in C. albicans, we found that increased carbon dioxide levels result in altered expression of several genes involved in ergosterol biosynthesis. Interestingly, C. albicans cultured in the presence of elevated carbon dioxide plus a sterol sequestering agent assume a highly filamentous cell morphology and hyper irregular wrinkle colony morphology, similar to the response observed following growth in low shear conditions. Taken together, these data indicate that the physiological and morphological responses of C. albicans to low-fluid shear are induced, in part, by increased levels of carbon dioxide.

F2.4-0012-18 TRANSIENT GENE AND MICRORNA EXPRESSION PROFILE CHANGES OF CONFLUENT HUMAN FIBROBLAST CELLS IN SPACE

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Microgravity, or an altered gravity environment from the Earth 1g, has been shown to influence global gene expression patterns and protein levels in cultured cells. However, most of the reported studies conducted in space or using simulated microgravity on the ground have focused on the growth or differentiation of these cells. Whether non-proliferating cultured cells will sense the presence of microgravity in space has not been specifically addressed. In an experiment conducted onboard the International Space Station (ISS), confluent human fibroblast cells were fixed after being cultured in space for 3 and 14 days, respectively, for investigations of gene and miRNA expression profile changes in these cells. Results of the experiment showed that on Day 3, both the flown and ground cells were still proliferating slowly, as measured by the percentage of Ki-67 positive cells. Gene and miRNA expression data indicated activation of NFB and other growth related pathways involving HGF and Vegf along with down regulation of the Let-7 miRNA family. On Day 14 when the cells were mostly non-proliferating, the gene and miRNA expression profiles between the flight and ground samples were indistinguishable. Comparison of gene and miRNA expressions in the Day 3 samples with respect to Day 14

revealed that most of the changes observed on Day 3 were related to cell growth for both the flown and ground cells. Analysis of cytoskeletal changes via immunohistochemistry staining of the cells with antibodies for -tubulin and fibronectin showed no difference between flown and ground samples. Taken together, our study suggests that in true non-dividing human fibroblast cells in culture, microgravity experienced in space has little effect on the gene and miRNA expression profiles.

F2.4-0013-18 "OMICS" DATA SYSTEMS FOR SPACEFLIGHT AND SIMULATED SPACEFLIGHT ENVIRONMENT

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NASA's GeneLab Data System is a repository that hosts multi-omics datasets generated by biological experiments flown onboard the International Space Station. Strategies regarding how GeneLab envisions the involvement of the scientific community and the public at large will be discussed, and current and future capabilities of the system will be described. Information describing how scientists can participate in analyzing the current datasets on plants, microbes, invertebrates or mammals will be provided, and initial findings from the current datasets will be discussed during this presentation. Anyone interested in genomics, transcriptomics, epigenomics and proteomics, and systems biology, or who is curious to understand how space modifies living organisms should attend.

F2.4-0014-18 A NEW MODEL FOR EVALUATING THE DEPENDENCE OF BIODOSIMETRY ON DOSE-RATES BASED ON GENE EXPRESSION PROFILES

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Health risks from space radiation are an important barrier for long-term manned spaceflight, in particular towards missions to the Moon and Mars. However, high uncertainties have always existed in estimating space radiation risks for manned interplanetary missions by the conventional method of risk assessment. One of the major uncertainties is related to the dependence of risk on low dose-rates, which can increase or decrease the risk of radiation damage compared to the acute exposures. Several promising approaches to radiation biodosimetry have been proposed in the past few years, while current biodosimetry methods have not yet been developed to distinguish low dose-rate and acute exposures for the risk assessment of potential radiological damage. Because of the diversity of gene expression responses to ionizing radiation, it may be possible to develop a new model of biodosimetry to investigate the dependence of gene expression profiles on dose-rates for providing rapid individual dose estimates and/or space radiation risk assessments. In this study, a combined algorithm, which integrates the feature selection techniques, was used to deal with the microarray datasets of the male C57BL/6 mice irradiated with a range of X-rays doses under low dose-rate (3.09 mGy/min) and acute (1.03 Gy/min) exposures. Compared with controls, a large number of genes were found to be differentially expressed ($p<0.05$) both in low dose-rate and acute exposures. Gene Ontology annotation and functional enrichment analyses showed that distinct patterns of the biological function responses were impacted by low dose-rate and acute exposures. Furthermore, the back propagation algorithm based on artificial neural network was conducted to learn the datasets of the differentially gene expressions and to train the network weights. After training, the estimations of the multi-layer network were agreement with the experimental doses, which indicated that this method could be used to distinguish the low dose-rate and acute exposures and predict the absorbed dose for biodosimetry.

F2.4-0015-18 MICROGRAVITY BIOLOGICAL MECHANISM STUDY OF MUSCLE MOVEMENT IN CAENORHABDITIS ELEGANS AFTER SJ-10 SPACEFLIGHT

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The mechanism of muscle atrophy caused by microgravity has been a key medical issue in the study of space biology. For comparing the muscle movement through life cycle and expression levels of proteins especially participate in regulating muscle contract pathway between N2 wild-type Caenorhabditis elegans (C.elegans) and gravity-sensing defect mutant (dystrophy gene mutation, dys-1)the dauer larva were onboard Chinese SJ-10 satellite for a 303-hour spaceflight. The aim of this study was to in-depth discuss of the mechanisms and regulatory pathways of space microgravity on generation, transmission and regulation of C.elegans locomotion ability. The results showed that space microgravity slowed the rate of decline of C.elegans movement ability as growth. The phenomenon of over-bending in dys-1 mutant disappeared after space flight and returned to the same level as the wild type. Space microgravity significantly affected the locomotion of C.elegans. Proteomic Gene Ontology analysis and differential protein clustering showed that, compared with N2 wild-type, less proteins of dys-1 mutant were significantly changed, especially lacking of proteins involved in muscle contraction-related pathways. Thus, Dystrophy plays a key role in muscle response to microgravity. The effect of the disappearance of gravity signals on dys-1 mutant movement led to the decrease of mechanical signal transduction into the muscle cells, the process of muscle contraction and the structural protein expression level of cytoskeleton. Comparative analysis of differentially expressed proteins of movement pathways revealed that Ca2+ transduction and binding were key pathways for Dystrophy to respond to space microgravity. This finding provides an important basis for revealing the changes in muscle function under space microgravity.

F2.4-0016-18 INVESTIGATION OF CHANGE IN THE GROWTH, MORPHOLOGY, CELL MEMBRANE USING FTIR TECHNIQUE, AND CELL SURFACE HYDROPHOBOCITY OF STAPHYLOCOCCUS AUREUS IN SIMULATED MICROGRAVITY CONDITION.

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Micro-organisms have various sensors and receptors which enable them to sense the changes in their environment and adapt to their surroundings. Several studies indicate that microgravity alters the microbial metabolism and physiology, which signifies that microbes sense the change in the mechanical forces that occur in microgravity and it can be speculated that bacterial cells might sense these changes in mechanical forces at their surface. In current project, the effect of simulated microgravity on the growth, morphology, cell surface hydrophobicity using microbial adhesion to solvents (MATS) test, and Fourier transform infrared spectroscopy (FTIR) analysis of the cell membrane extract of S.aureus was investigated. Accelerated growth rate in simulated microgravity was observed in S.aureus, however no significant change in the scanning electron microscope (SEM) imaging of S.aureus bacteria grown in simulated microgravity as compared to normal gravity was observed. FTIR analysis of the cell membrane extract of S.aureus revealed that microgravity could change the conformation of compounds present in the cell membrane of S.aureus. Changes in the cell surface hydrophobicity of S.aureus grown in simulated microgravity conditions compared to normal gravity were also observed. More studies are planned to further scrutinize the mechanisms or processes manoeuvred by the bacterial cells to sense and adapt to the changes in mechanical forces introduced due to microgravity.

F2.4-0017-18 EPIGENETICS RESEARCH ON THE INTERNATIONAL SPACE STATION

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The International Space Station (ISS) is a state-of-the orbiting laboratory focused on advancing science and technology research. Experiments being conducted on the ISS include investigations in the emerging field of Epigenetics. Epigenetics refers to stably heritable changes in gene expression or cellular phenotype (the transcriptional potential of a cell) resulting from changes in a chromosome without alterations to the underlying DNA nucleotide sequence (the genetic code), which are caused by external or environmental factors, such as spaceflight microgravity. Molecular mechanisms associated with epigenetic alterations regulating gene expression patterns include covalent chemical modifications of DNA (e.g., methylation) or histone proteins (e.g., acetylation, phorphorylation, or ubiquitination). For example, Epigenetics ("Epigenetics in Spaceflown C. elegans") is a recent JAXA investigation examining whether adaptations to microgravity transmit from one cell generation to another without changing the basic DNA of the organism. Mouse Epigenetics ("Transcriptome Analysis and Germ-Cell Development Analysis of Mice in Space") investigates molecular alterations in organ-specific gene expression patterns and epigenetic modifications, and analyzes murine germ cell development during long term spaceflight, as well as assessing changes in offspring DNA. NASA's first foray into human Omics research, the Twins Study ("Differential effects of homozygous twin astronauts associated with differences in exposure to spaceflight factors"), includes investigations evaluating differential epigenetic effects via comprehensive whole genome analysis, the landscape of DNA and RNA methylation, and biomolecular changes by means of longitudinal integrated multi-omics research. And the inaugural Genes in Space student challenge experiment (Genes in Space-1) is aimed at understanding how epigenetics plays a role in immune system dysregulation by assaying DNA methylation in immune cells directly in space using miniPCR technology. In addition, NASA's geneLAB campaign covers the epigenome as part of the "expressome", by employing an innovative open source science platform for multi-investigator high throughput utilization of the ISS. Earth benefits of Epigenetics research onboard the ISS range from contributions to the fundamental understanding of epigenetic phenomena with applications in countermeasure development for biomedical conditions, to the generation of integrated strategies for personalized medicine based on unique physiological responses.

F2.4-0018-18 INDUCTION OF GENOTOXICITY BY ACCELERATED HEAVY IRON PARTICLES IN THE HEMATOPOIETIC SYSTEM IN MICE

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Purpose: The genotoxicity induced by high LET iron particles was studied and compared to that by low LET X-rays in the ground-based experiments carried out at NIRS using total body irradiation (TBI) of mice with the Heavy Ion Medical Accelerator in Chiba (HIMAC) and an Xray generator (Pantak 320S, Shimadzu). Materials and Methods: C57BL/6J Jms strain female mice of 8 weeks old were used. TBI was performed at a dose ranging from 0.1 to 3.0 Gy for iron particles (500 MeV/nucleon, 200 keV/m), or from 0.1 to 5.0 Gy for X-rays (200 kVp, 0.5 mm Al

+ 0.5 mm Cu filter). The RBE of iron particles to X-rays for induction of acute genotoxicity and late residual damage in the hematopoietic system was determined respectively at one and two months after TBI using the frequency of micronuclei in bone marrow erythrocytes as the endpoint. The health condition (body weight gain and the hemogram of the peripheral blood) was also investigated. Animals were treated in accordance with the Guidelines for the Care and Use of Laboratory Animals established by NIRS. Results and Conclusions: Reduction of body weight gain after TBI was in a similar way observed in the groups exposed to high doses from iron particles or X-rays. X-rays caused more efficiently hematological abnormality than iron particles. Iron particles and X-rays reduced the ratio of polychromatic erythrocytes (PCEs) to PCEs plus normochromatic erythrocytes (NCEs), an indicator for bone marrow proliferation, in a similar way, while iron particles resulted in more efficiently micronucleated PCEs and NCEs at low doses than X-rays. The relative effectiveness of iron particles to X-rays for induction of genotoxicity in bone marrow erythrocytes was higher at a low dose (0.5 Gy) than that at a high dose (3.0 Gy).
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F2.4-0019-18 EFFECTS OF SIMULATED MICROGRAVITY AND/OR LOW-DOSE RADIATION ON NEUROVASCULAR REMODELING IN THE MOUSE BRAIN AND EYE

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Microgravity and increased radiation are environmental stresses unique to the spaceflight environment. These stressors can have an impact on the central nervous system (CNS) including brains and eyes, potentially leading to significant risks to astronaut health both acutely, during the course of a mission, or chronically, leading to long-term, post-mission decrements in the quality of life. In an ongoing study, a mouse model was used to simulate these two critical components of the spaceflight environment for 21 days and examine their effects on the brain. To simulate the radiation component, 57Co plates were used to deliver low-dose/low-dose-rate (LD/LDR) whole-body -irradiation of 0.04Gy at 0.01 cGy/h to mature, 6-month old female C57BL/6 mice. A subset of these mice simultaneously underwent anti-orthostatic tail suspension for 21 days to model the unloading, fluid shift, and physiological/psychological stress aspects of the microgravity component. To date, we have characterized tissues from mice on 7 days, 3 and 9 months post-exposure. Brains were isolated for characterization of various oxidative stress markers and vascular topology. Long-term behavioral effects were also evaluated following chronic exposure of radiation + unloading. Our data demonstrated that exposure to simulated microgravity and LD/LDR radiation leads to increased oxidative stress-associated biomarkers and reduced antioxidant defense which may increase the likelihood of brain injury and functional/behavioral changes. In parallel studies, we have focused on the retina in animal models of the space environment. The retina and the retinal vasculature play important roles in vision. Changes in microvascular topology and function are common causes of vision loss in aging individuals and patients with diabetes, as well as after exposure to X-rays. Nonetheless, the retina and the retinal vasculature have not been studied extensively in relation to space travel and space radiation. We have shown that combined exposure to proton radiation of 0.5Gy and hindlimb unloading cause oxidative damage and vascular endothelial cell apoptosis in the retina. Understanding how environmental insults and radiation impact on the neurovasculature will help development toward more effective countermeasures during human spaceflight and planetary exploration. Mechanistic studies may also lead to new efficacious therapies that can prevent, reverse or stop the progression of neurovascular-related diseases and retinal degeneration.

F2.4-0020-18 HUMAN OIGODENDROCYTES IN SIM-0G BUT NOT IN 1G SECRETE NUMEROUS LIPIDS IN JUST THREE DAYS

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The primary energy sources of mammalian cells are proteins, fats and sugars that are processed by well-known biochemical mechanisms that have been discovered and studied in 1G (terrestrial gravity). Here we sought to determine how simulated microgravity (sim-0G) impacts in oligodendrocytes (OLs), the myelin forming cells in the central nervous system (CNS). In humans CNS myelination starts perinatally, continues during early postnatal development and it continues into early adulthood (Miller et al., 2012; Young et al., 2013). The myelin membrane has a highly unique protein and lipid composition. Myelin is very rich in lipids (70% of myelin dry weight). Once at the plasma membrane, these myelin elements assemble to form the myelin sheath. Astronauts' health during and after space travel is of vital importance and it has been reported that microgravity induces intracranial hypertension, representing a risk factor and a potential limitation to long-duration space missions.Here we report increased mitochondrial respiration and increased glycolysis 24 hours after of oligodendrocyte progenitors (OLPs) were exposed to sim-0G. Examination OLPs secretome after three days exposure of OLPs to sim-μG revealed a significant increase in the synthesis of fatty acids and complex lipids such as, 1,2-dipalmitoyl-GPC (5.67) and sphingolipids. Longer chain lipids were not observed in this study, it is possible that at longer time points OLs would have continued moving forward toward the synthesis of lipids that constitute myelin. These "surprising findings" indicate that sim-0G preserves, and enhances in just three days, metabolic reactions that are required for membrane synthesis as the first step in myelinogenesis. Because intracranial hypertension does not go away when astronauts come back to earth, we had previously postulated that microgravity associated intracranial hypertension with or without visual impairment and altered ophthalmic anatomy might be at least in part due to increased cell proliferation in the brain based on our data published in our first paper. With the enormous increase of lipids found in the secretome of OLs kept in 0G but not in 1G, we now hypothesize that not only there may be more cells in the CNS of astronauts but perhaps an increased number of molecules secreted by OLs while in space that are contributing to the symptoms mentioned above. A better understanding on how to modulate secretion of lipids in the CNS is very important, in order to maintain a normal intracranial tension in astronauts while in space and upon return to earth. Moreover, for centuries, basic biology research has been the pillar to an array of discoveries that have led to clinical applications for mankind on earth; we believe that studies using microgravity will open new avenues to our understanding of the brain in health and disease, in particular, to the discovery of new molecules and mechanisms impossible to unveil while in 1G.

F2.4-0021-18 EFFECTS OF ACANTHOPANAX SENTICOSUS ON BRAIN INJURY INDUCED BY SIMULATED SPATIAL RADIATION

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Abstract: The active compounds in Acanthopanax senticosus (AS) have different pharmacokinetic characteristics in mouse models. Cmax and AUC of Acanthopanax senticosus polysaccharides (ASPS) were significantly reduced in simulated spatial radiation-injured mice, suggesting that the blood flow of mouse was blocked or slowed, due to the pathological state of ischemia and hypoxia, which are caused by simulated spatial radiation. In contrast, the ability of various metabolizing enzymes to inactivate, capacity of biofilm transport decrease, and lessening of renal blood flow accounts for simulated spatial radiation, resulting in the accumulation of syringin and eleutheroside E in the irradiated mouse. Therefore, there were higher pharmacokinetic parameters-AUC, MRT, and t1/2 of the two compounds in simulated spatial radiation-injured mouse, when compared with normal mouse. In order to investigate the intrinsic mechanism of AS on radiation injury, AS extract's protective effects on brain, the main part of mouse that suffered from simulated spatial radiation, were explored. The function of AS extract in repressing expression changes of radiation response proteins in prefrontal cortex (PFC) of mouse brain included tubulin protein family (α -,β-tubulin subunits), dihydropyrimidinase-related protein 2 (CRMP2),γ-actin, 14-3-3 protein family (14-3-3ζ,ε), heat shock protein 90(HSP90β), and enolase 2.The results demonstrated the AS extract had positive effects on nerve cells' structure, adhesion, locomotion, fission, and phagocytosis, through regulating various action pathways, such as Hippo, phagosome, PI3K/Akt (phosphatidylinositol 3 kinase/ protein kinase B), Neurotrophin, Rap1 (Ras-related protein RAP-1A),gap junction glycolysis/gluconeogenesis,and HIF-1(Hypoxia-inducible factor 1) signaling pathways to maintain normal mouse neurological activity. All of the results indicated that AS may be a promising alternative medicine for the treatment of simulated spatial radiation injury in mouse brain. It would be tested that whether the bioactive ingredients of AS could be effective through the blood-brain barrier in the future.

F2.4-0022-18 FISH ANALYSIS OF CHROMOSOMAL ABERRATIONS INDUCED BY ACCELERATED HEAVY IRON PARTICLES IN MOUSE SPLENOCYTES.

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Purpose: High atomic number and energy (HZE) particles such as iron-56 (Fe) ions are a major contributor to health risks in long-term manned space exploration. To understand radiationinduced differential genotoxic effects between high linear energy transfer (LET) HZE particles and low LET photons, ground-based experiments were carried out at the National Institute of Radiological Sciences (NIRS) using total body irradiation (TBI) of mice with accelerated Fe particles generated by the Heavy Ion Medical Accelerator in Chiba (HIMAC). Materials and Methods: C57BL/6J Jms strain female mice of 8 weeks old were treated in accordance with the Guidelines for the Care and Use of Laboratory Animals established by NIRS. TBI was performed at a dose ranging from 0.1 to 3.0 Gy for Fe particles (500 MeV/nucleon, 200 keV/m), or from 0.1 to 5.0 Gy for X-rays (200 kVp, 0.50 mm Al+0.50 mm Cu filter). At one or two months after TBI, splenocytes were isolated and cultured in the presence of mitogens for 24 h. Colcemid was added to the last 2 h of the culture. Metaphase chromosome spreads prepared from splenocytes were painted with the fluorescence in situ hybridization (FISH) probes for chromosomes 1 (green), 2 (red) and 3 (yellow). Chromosomal aberrations (CAs) visualized by FISH were classified as translocations, insertions, dicentrics, and acentric fragments. Results and Conclusions: The present study is still in progress and observation of CAs is ongoing. Induction of CAs was detected at 0.5 Gy and higher doses of both X-rays and Fe particles. For each mouse, among all types of CAs translocations were around 90%. Fe particles didn't induce CAs as frequently as X-rays. X-rays were 5 times more effective to induce translocations than Fe particles as compared at 3 Gy. The frequencies of unstable-type CAs didn't show dose dependency at high dose and decreased with time. It is probable that DNA double-strand breaks induced by Fe particles are hardly rejoined and cause cell cycle arrest or cell death rather than lead to induction of CAs. Funding:

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F2.4-0023-18 SPACEFLIGHT ALTERS THE MUTATION FREQUENCY AND MUTAGENIC SPECTRUM IN BACTERIA

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In contrast to the classical view that mutations are random, a growing body of evidence indicates that exposure to environmental stresses in microbes can alter both the mutation rate and the mutagenic spectrum, a phenomenon known as Stress-Induced Mutagenesis (SIM). It is thought that SIM supplies an environment-specific variety of mutational outputs for selection to operate on, thus shaping the evolutionary trajectory of organisms. To test whether SIM might be induced in cells exposed to the spaceflight environment, we sent two Gram-positive bacteria to the International Space Station (ISS). On two separate spaceflight experiments (BRIC-18 and BRIC-21), Bacillus subtilis and Staphylococcus epidermidis cells were cultivated in the same medium, temperature, hardware, and duration in matched Flight (FL) and Ground Control (GC) samples. Upon return, we plated the cultures for total viable cells, and selected for mutants that had become resistant to the antibiotic rifampicin (RifR mutants), to calculate the frequency of mutation. We observed that the frequency of mutation to RifR was significantly increased 24-fold in FL samples of S. epidermidis, but was not significantly different between FL and GC samples in B. subtilis.

RifR arises from mutations in the rpoB gene, which encodes the β-subunit of RNA polymerase. To examine mutagenic spectrum in rpoB, we amplified by PCR and sequenced the relevant portions of the rpoB genes from all RifR mutants obtained in FL and GC samples of both S. epidermidis (n = 124) and B. subtilis (n = 181). In both cases we found dramatic differences in the spectrum of mutations between flight (FL) and ground control (GC) samples, including three newly discovered rpoB alleles in FL samples of B. subtilis (Q137R, A478V, and L489S). These results strengthen the idea that exposure to the human spaceflight environment causes unique stresses on bacteria, leading to alterations in their mutagenic potential.

Because RNA polymerase is a single enzyme that interacts with all the promoters in the genome, mutations in its subunits can have far-reaching effects on the global transcriptome, hence the phenotype, of mutants. Future experiments are directed towards understanding how novel rpoB mutations induced by exposure to

spaceflight conditions could alter the evolutionary fitness of the resulting mutants in the spaceflight environment. Supported by NASA grants NNX12AN70G and NNX14AT38G.

F2.4-0024-18 COMBINED EFFECTS OF SIMULATED MICROGRAVITY AND RADIATION EXPOSURE ON OSTEOCLAST CELL FUSION

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The loss of bone mass and alteration in bone physiology during space flight are one of the major health risks for astronauts. Although the lack of weight bearing in microgravity is considered a risk factor for bone loss and possible osteoporosis, organisms living in space are also exposed to cosmic radiation and other environmental stress factors. As such, it is still unclear as to whether and by how much radiation exposure contributes to bone loss during space travel, and whether the effects of microgravity and radiation exposure are additive or synergistic. Bone is continuously renewed through the resorption of old bone by osteoclast cells and the formation of new bone by osteoblast cells. In this study, we investigated the combined effects of microgravity and radiation by evaluating the maturation of a hematopoietic cell line to mature osteoclasts. RAW 264.7 monocyte/macrophage cells were cultured in rotating wall vessels that simulate microgravity on the ground. Cells under static 1g or simulated microgravity were exposed to rays of varying doses, and then cultured in receptor activator of nuclear factor-B ligand (RANKL) for the formation of osteoclast giant multinucleated cells (GMCs) and for gene expression analysis. Results of the study showed that radiation alone at doses as low as 0.1 Gy may stimulate osteoclast cell fusion as assessed by GMCs and the expression of signature genes such as tartrate resistant acid phosphatase (Trap) and dendritic cell-specific transmembrane protein (Dcstamp). However, osteoclast cell fusion decreased for doses greater than 0.5 Gy. In comparison to radiation exposure, simulated microgravity induced higher

levels of cell fusion, and the effects of these two environmental factors appeared additive. Interestingly, the microgravity effect on osteoclast stimulatory transmembrane protein (Ocstamp) and Dcstamp expressions was significantly higher than the radiation effect, suggesting that radiation may not increase the synthesis of adhesion molecules as much as microgravity.

F2.4-0025-18 SIMULATED MICROGRAVITY IMPACTS THE LIPID RAFTS IN PLANT CELLS

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Currently it has been shown the presence of functional microdomains with the specific content of lipids and proteins in the plasmalemma of plant cells, that became known as “lipid rafts”. It is supposed that rafts enriched on cholesterol and sphingolipids modulate the protein interrelation and in this way they include in many vitally important cell processes. Therefore, we studied the composition and content of fatty acids and sterols in lipid rafts isolated from the root plasmalemma of Pisum sativum seedlings grown during 6 days under slow horizontal clinorotation. The raft fraction was controlled by the electron-microscopic method with a transmission electron microscope JEM 1230 (Jeol, Japan). Fatty acids and sterols were determined by the method of gas chromatography with a chromatograph HRGC 5300 (Carlo Erba Instruments, Italy). It was shown that lipid rafts from the root plasmalemma of pea seedlings grown in the stationary conditions and under clinorotation have the appearance of thin tapes of 80-100 nm in length, they were similar to those in other plant species on the structure and size, and also were enriched on cholesterol and saturated fatty acids. Under clinorotation, the percentage of cholesterol in lipid rafts increased 7 times in comparison with control, that may indicate an increase in their density. It is of interest that a significant increase in content of cholesterol and some saturated fatty acids under clinorotation was determined in the plasmalemma microdomains, while the plasmalemma fluidity reached the control level. Based on these firstly obtained data, it is proposed to increase attention to study the impact of microgravity on the behavior of rafts as they contain the protein complexes responsible for perception and transmission of external signals, vesicular transport, protection from stress. Further understanding the gravisensitivity of basic cell processes and mechanisms of plant adaptation to microgravity is necessary for working out the technologies of the autotrophic chain in the Bioregenerative

Life Support Systems and its reliability.

F2.4-0026-18 STUDY ON ANTI-RADIATION MECHANISM OF DIOSMIN

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Diosmin (Diosmetin 7-O-rutinoside) is a natural flavonoid compound extracted from Galium verum L. (Rubiaceae) and has significant effects on the treatment of chronic venous insufficiency, postoperative edema and hemorrhoids. Our research group found that Diosmin also has anti-radiation effect, and the anti-radiation mechanism of Diosmin was studied through in vitro cell experiments, animal experiments and differential protein spots of mouse liver radiation-damaged proteins to obtain the following results: (1) Cell experiment: The splenic lymphocytes of Rattus norvegicus (SD rats) and PC12 cells were cultured in vitro and irradiated by 60Co-γ ray. It has been experimentally demonstrated that the addition of Diosmin to the cells before irradiation to the final concentration of 80μg/ml, can promote cell proliferation and improve cell survival. Meanwhile, at this dose, the activities of superoxide dismutase (SOD) Glutathione peroxidase (GSH-px) increased and the content of intracellular malondialdehyde (MDA) decreased. By measuring the cell cycle and apoptosis in PC12 cells, it was found that Diosmin can promote cell differentiation and reduce the damage brought about by irradiation of cells. (2) Animal experiments: By establishing 60Co-γray irradiation model, the indices of Kunming mice given Diosmin continually for 14 days were measured. It was noted that Diosmin can play a protective role in white blood cells and immune organs such as liver and spleen. The activities of SOD and GSH-px in mouse tissues were improved and the content of MDA, the rate of chromosome aberration and micronuclei in bone marrow decreased. The experimental results above suggested that Diosmin can enhance the antioxidant activity by increasing endogenous antioxidant enzyme activity, decrease DNA damage and protect mice from radiation damage. (3) Through the 2D-PAGE analysis of the liver protein of mice in radiation protection experiment, 10 protein spots with significant difference were selected for MALDI-TOF-MS analysis and proved to be acetylcholinesterase A-acylase 2, peptidyl-proline cis-transisomerase A, 3-hydroxybenzoate 3, 4 double oxidase, three-dimensional structure - myosin-V, heterogeneous nuclear ribonucleoprotein A2 / B1, (TPI), fructose-bisphosphate aldolase B, protein disulfide isomerase, hemoglobin β subunit, and mitochondrial ATP synthase β subunit.

F2.4-0027-18 PROTECTIVE EFFECT OF ULVA PERTUSA POLYSACCHARIDE-FE COMPLEX ON RADIATION

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Radiation protection effect of Ulva pertusa polysaccharide with different molecular weights (100kDa, 30-100kDa and 30kDa) were investigated through mice model. According to the micronucleus, organ index, SOD and MDA contents, the fraction of 30kDa was selected as the best active component. Besides, the effect of radiation protection of active polysaccharide chelating with Fe was also studied. Results indicated that the complex, which nucleus was -FeOOH, has significant anti-radiation effect as well. Proteomics research of spleens from mice treated by active polysaccharide and its Fe complex revealed that 3502, 4705, 5402, 5803 and 6801 were five different protein spots. According to MS, they were 78kD glucose regulatory protein, hydroxylase-5 subunit calcium network protein precursor, tubulin-5 and vimentin respectively, which were all related to immune injury. Therefore, the radiation protection mechanism of polysaccharides and its ion complex may be through repairing these different proteins to improve the immunity and reduce the radiation damage.

F2.4-0028-18 THE DNA DAMAGE REPAIR GENES EXPRESSION OF ARABIDOPSIS THALIANA SEEDS SURVIVING 12.5-DAY EXPOSURE TO SPACE ENVIRONMENT

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The microgravity and space radiation were the two important stressors which can induce biological damage and genetic variation in spaceflight. It is emphasized that we must pay high attention to the DNA damage repair pathway. But so far, the molecular biological mechanism of DDR induced by radiation and microgravity were still not clear. In this study, the biological effects of spaceflight were investigated in Arabidopsis thaliana from the levels of phenotypes, cell and molecular. In addition, the expression of Ku70, Rad51, XPD and OGG1 genes, as the important biomarkers, were used to assess the effects of spaceflight on the pathway of DDR. The dry seeds of Arabidopsis of wild type and gravity insensitive mutants (pin2 and pgm-1) were brought to space by SJ10 recoverable satellite for 12.5 days. The results shown that the normal growth of Arabidopsis was influenced after spaceflight for a long time. The genes expressions of DDR pathway was promoted varied by microgravity at different development stages in the wild-type and mutants of Arabidopsis after spaceflight. In summary, this study revealed the combined biological effects and mechanisms induced by space radiation and microgravity in the wild-type and mutants of Arabidopsis after spaceflight. It is of great significance to study the biological effects of the real actual spatial environment.

F2.4-0028-18 EFFECT OF SPACE ENVERIMENT ON ARABIDOPSIS SEED GERMINATION AND GROWTH AFTER A LONG RECOVERY

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Space flights expose plant seeds to various risks. Space radiation and microgravity are two of the main factors among them. But how long the effects of space envirement will last after flights on seeds germination and plants growth is still uncertain. Arabidopsis (it Arabidopsis thaliana) seeds were tiled on a stacking device with a CR39 radiation detector which were put into the Biological Radiation BOX A and B. The seeds were emplyed in Shijian-10 recoverable satellite (SJ-10) and suffered the space flight of 302.85h at an altitude of 252 km. 420 days after the space flight, the seeds in both of BOX A (group SA) and B (group SB) as well as their controls in ground (group C) were planted. From the detecting results of CR39, the seeds used in this study did not be hit directly by space heavy ions. And there were some differences in radiation dose between BOX A and B. The parameters of growth and early development were determined. There was no significant difference in both of germination potential and germination rate among groups of C, SA and SB. But the root length in 7d of SA group significantly lower than that in other groups. After 4 weeks growth, however, both of space flight groups appeared increase in growth compared to group C. For instance, the averge wet weight of SA and SB were increased 48.95% and 103.22% than that of group C, respectively. The number of leaves (NL) were counted during the nutritional growth period (14-28d). The NL value in SB was prominent higher than that of SA and C groups (it $p < 0.05$). And after 17d growth, the NL value of SA was higher than that in group C although there was no sinificant difference. Besides, the earing rate of SB was higher than that of other groups. The Fv/Fm, which is presented the photosynthetic efficacy of plants, was also affected by space flight. Both SA and SB increased their maximum photosynthetic efficiency significantly (it $p < 0.05$), which maybe one of the reasons of their rapid growth. In summary, after the space flight, the plant seeds presented the stimulatory effect during nutritional growth period although experienced a long term of recovery.

F2.4-0030-18 A NEW MODEL TO STUDY REAL AND SIMULATED MICROGRAVITY INFLUENCE ON PLANT CELL GRAVISENSITIVITY

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A new model "Rhizogenesis in vitro" is proposed to study the biological effects of microgravity. Rhizogenesis from the leaf explant petiole and callus culture of Arabidopsis thaliana wild type, scr mutant and transgenic plants has been investigated. It was shown that roots emerged de novo in two ways: 1) from callus dedifferentiated cells (morphogenic loci) and 2) directly from leaf explant petiole cambium cells. Since roots formed in vitro on callus surface had some structural abnormalities, rhizogenesis in vitro from leaf explants is considered as more convenient. Anatomical and ultrastrucrural analyses demonstrated the absence of significant differences in root cell differentiation in vitro under clinorotation. At the same time, sensitivity to clinorotation was revealed in the cells of the distal elongation zone (DEZ). An increase in the percentage ratio of vacuoles and ER-bodies as well as the presence of numerous smaller mitochondria were found in these cells. Also, cortical microtubules' orientation in DEZ of A. thaliana GFP-MAP4 roots formed de novo was also changed under clinorotation similarly that in embryonic roots. Using A. thaliana DR5rev::GFP transgenic plants allowed to reveal that clinorotation changes auxin distribution in roots formed de novo. We proposed such model for the experiments on board the ISS to study morphogenesis and cell differentiation in vitro in microgravity.

F2.4-0031-18 F2.4-0030-18 RESEARCH OF MICROGRAVITY EFFECTS ON PLANTS ON BOARD THE CHINESE SPACECRAFTS

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We focus on the molecular mechanism of the interaction between plants and microgravity environment, try to understand the effects of microgravity environment in the space on plant growth and the molecular mechanisms underlying. The transcriptome of Oryza sativa calli on regular and on hormone free medium was analyzed on board the Chinese spaceship "Shenzhou 8" which was launched at 1 November, 2011 to study the effects of microgravity on plant signal transduction and secondary metabolism. The calli on hormone free medium were precultured for 4 days on ground and fixed by RNAlater after grew 324 h under microgravity and returned to Earth after 17 days. After comparing1 g-inflight controls with 1 g-ground controls, 157 probe sets with different expression levels (fold change 2, $p < 0.05$) were identified. When comparing spaceflight controls to 1 g-ground controls and to 1 g-inflight controls, 678 probe sets with different expression levels (fold change 2, $p < 0.05$) were identified. The fact that the same 678 probe sets were identified in these two comparisons suggests that transcription was affected under microgravity conditions. MapMan analysis was used to classify 627 microgravity responsive (MR) transcripts. The MR transcripts were mainly involved in cell wall structure, the TCA cycle, primary metabolism, transcription, protein modification and degradation, hormone metabolism, calcium regulation, receptor like kinase activity and transport. The calli grown on regular medium under microgravity were also analyzed. The relationship between the cell wall modification and alteration of cell growth under microgravity was discussed. We also carried out epigenetic studies associated with microgravity conditions using Arabidopsis thaliana on board the Chinese recoverable science satellite "SJ-10" which was launched at 6 April, 2016. Interestingly, we found the variation of DNA modification in Arabidopsis seedlings exposed to microgravity. These results are important to understand the mechanism of plant adaptation to the microgravity environment.

F2.4-0032-18 SWATH-BASED PROTEOMICS ANALYSIS OF HIPPOCAMPUS IN MEMORY DEFICIENCY RATS INDUCED BY PROLONGED SIMULATED SPACE ENVIRONMENT

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It has been found that spaceflight may lead to impairments in cognitive functions performed by CNS. However, the underlying mechanism of effects of space environment on the learning and memory function in animal nervous system is not elucidated yet. In present study, a simulated spaceflight complex environment rats model (SSCE) was successfully built and assessed. We employed the tail suspension model with noise (65 db), circadian rhythms (1.5 h) and limited space to simulate spaceflight complex environment. Morris water maze test was applied to determine the learning and memory function in SSCE animals. Compared with the control groups, SSCE groups showed significant decrease in memory function. Using SWATH-based proteomics analysis, a total of 4250 proteins were quantified in hippocampus. Of these identified proteins, 425 proteins were found differentially expressed under SSCE. Based on the results of DAVID analysis, we observed transportation of synaptic vesicle and synaptic transmission may play key role in learning and memory function. Moreover, through multiple reaction monitoring(MRM), we found that the concentration of Glu was 154.38 g/mg wet tissue in the rat hippocampus under simulated spaceflight complex environment, compared to 85.68 g/mg in the control, indicating remarkable enhancement, while the concentration of GABA was 15.42 g/mg wet tissue in the rat hippocampus under simulated spaceflight complex environment, compared to 36.44 g/mg in the control, a dramatic drop. These changes all indicated simulated spaceflight complex environment may cause degrading of the learning and memory function and the possible mechanisms might be related with glutamate excitotoxicity and imbalances in specific neurotransmitters.

LIFE SCIENCES AS RELATED TO SPACE (F)

ASTROBIOLOGY - EXPERIMENTS FROM MARS ANALOGUE SITES, EARTH ORBIT, AND BEYOND (F3.1)

F3.1-0001-18 FIST YEAR RESULTS OF TANPOPO: CAPTURE AND EXPOSURE EXPERIMENT OF MICROMETEORITE AND MICROBES ON EXPOSURE FACILITY OF INTERNATIONAL SPACE STATION

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Tanpopo, a dandelion in Japanese, is a plant species whose seeds with floss are spread by wind. We proposed this mission to examine possible interplanetary migration of microbes, and organic compounds at the Exposure Facility of Japan Experimental Module (JEM: KIBO) of the International Space Station (ISS) [1-4]. The Tanpopo mission consists of six subthemes: Capture of microbes in space (Subtheme 1), exposure of microbes in space (Subtheme 2), analysis of organic compounds in interplanetary dust (Subtheme 3), exposure of organic compounds in space (Subtheme 4), measurement of space debris at the ISS orbit (Subtheme 5), and evaluation of ultra low-density aerogel developed for the Tanpopo mission (Subtheme 6). Exposure Panels for exposure of microbes and organic materials and Capture Panels for aerogel were launched on April 2015. The Panels were placed on the Exposed Experiment Handrail Attachment Mechanism (ExHAM) in the ISS. The ExHAM with Panels were placed on the Exposure

Facility of KIBO (JEM) with the Japanese robotic arms through the airlock of KIBO. The trays and panels were exposed for more than one year. The first set of Capture Panels and a Exposure Panel were retrieved on June 2016, returned to the ground and passed over to Tanpopo team for the analyses in September. Aerogel blocks in Capture Panels are inspected by the automated micro-image detector CLOXS. Tracks and particles identified will be used for organic and inorganic compounds, as well as microscopic analyses [3]. An Exposure Panel consists of 20 Exposure Units. The returned Exposure Panel was disassembled to the units, each was handed over to the researchers for organic compound and microbiological analyses [4]. First year results will be presented. 1) Yamagishi, A. et al.: Tanpopo: Astrobiology exposure and micrometeoroid capture experiments - Proposed experiments at the Exposure Facility of ISS-JEM. ISTS29 Special Issue Publication 2013-k-49, (2014) 2) Kawaguchi Y, et al.: Investigation of the interplanetary transfer of microbes in the Tanpopo mission at the Exposed Facility of the International Space Station. Astrobiolgy, 16, 1-14 (2016) 3) Kawaguchi Y, et. al.: Fluorescence imaging of microbecontaining particles that had been shot from a two-stage light-gas gun into an ultra-low density silica aerogel. Origins of Life and Evolution of Biospheres, 44, 43-60 (2014) 4) Kawaguchi Y, et. al.: The possible interplanetary transfer of microbes: Assessing the viability of Deinococcus spp. under the ISS environmental conditions for performing exposure experiment of microbes in the Tanpopo mission. Origins of Life and Evolution of Biospheres 43, 411-428 (2013.) 5) Arrhenius, S. A.: Worlds in the making: The evolution of th Universe, Harper and Brothers, New York, 1908 6) Horneck, G., Klaus, D. M. and Mancinelli, R. L.: Space microbiology. Microbiol. Mol. Biol. Rev., 74, 121-156 (2010)

F3.1-0002-18 ASTROBIOLOGY EXPERIMENTS IN EARTH ORBIT TO EXAMINE FORMATION, ALTERATION AND DELIVERY OF ORGANIC COMPOUNDS: RESULTS OF THE TANPOPO MISSION AND FUTURE PROSPECTS

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In prior to the generation of the first life on the Earth, organic compounds such as amino acids should have been supplied to the primitive Earth. If primitive Earth atmosphere was strongly reducing (e.g., containing large mixing ratios of methane and/or ammonia), production of amino acids and other bioorganic compounds is not difficult by conventional energies such as spark discharges. In these days, however, the primitive Earth atmosphere was regarded as only slightly reducing [1]. In such a case the production of amino acids and other N-containing organics by conventional energies was difficult.

Since a wide variety of organic compounds have been detected in extraterrestrial bodies such as carbonaceous chondrites and comets, it is safe to say that extraterrestrial organic compounds were important sources for the first life on the Earth. Chyba and

Sagan [2] suggested that cosmic dusts delivered much more organics to the primitive Earth than meteorites and comets. It is difficult, however, to detect bioorganics in cosmic dusts if they are collected in the terrestrial biosphere.

We started an astrobiology experiments in Earth orbit named the Tanpopo mission [3] in May 2015. In the mission, cosmic dusts are collected by using aerogel, and amino acid-related compounds are exposed to space environments. The mission is carried out by utilizing an ExHAM (Exposed Experiment Handrail Attachment Mechanism) on the Exposed Facility of Japanese Experimental Module (JEM-EF) in the International Space Station (ISS). We have already recovered the samples exposed for one year in 2016, and those for two years in 2017. The mission will be concluded in 2019. Preliminary results of the organic exposure experiments will be reported.

After the completion of the Tanpopo mission, same spaces for space exposure on the ExHAM facilities would be available. Other facilities for space exposure experiments on JEM-EF, including i-SEEP (IVA-replaceable Small Exposed Experimental Platform), are now available or under discussion. We are also discussing possible astrobiology exposure/capture experiments in the next generation by using Free Flyers. One of possible themes is direct space exposure experiment without optical windows to utilize full spectrum of solar light. Not only organic alteration experiments, but also organic formation experiments are quite interesting. We could examine possible formation of bioorganic compounds in upper planetary atmosphere: Cosmic rays are promising energy sources to synthesize amino acids and other bioorganics in slightly reducing atmosphere [4], but the present flux or cosmic rays is limited. Solar UV flux is quite high, but is singly not a good energy source to synthesize N-containing organics from the slightly reducing gas mixture. We expect, however, that it would enhance amino acid formation by synergistic effect with cosmic rays.

We are also discussing other possible space experiments of the new generation, including an experiment to examine space weathering of meteoritic organics, and that to test abiotic formation of biological molecules in a primordial ocean before the formation of the ozone layer.

The present work was carried out in collaboration with Ms. Saaya Minematsu (Fukuoka Institute of Technology), Ms. Izumi Endo (University of Tokyo), Mr. Tomohito Sato (Yokohama National University), Takuya Yokoo (Yokohama National University) and Dr. Eiichi Imai (Nagaoka University of Technology). This work was partly supported by Grants-in-Aid of MEXT, Japan (17H02991 and 16H04823), and by that of NINS Astrobiology Center Satellite program (AB292002).

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F3.1-0003-18 SPACE EXPOSURE EXPERIMENT OF LABORATORY-SYNTHESIZED CARBONACEOUS SOLIDS USING ISS/KIBO/EXHAM; PROJECT OVERVIEW

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We have carried out the space exposure experiment of various kinds of carbonaceous solids using International Space Station (ISS)/KIBO/ExHAM. The major goal of this project is to understand how the carbonaceous dust particles synthesized in the stellar ejecta from evolved stars are chemically and physically altered in nature in the circumstellar environment until it becomes a member of the interstellar medium. In particular, we aim to investigate the properties of 'astronomical' polycyclic aromatic hydrocarbons (PAHs), the carrier of the unidentified infrared (UIR) bands, which have been observed ubiquitously in various astrophysical environments. So far, we have brought three experiment samples to the ISS. Each experiment sample has a 10cm x 10cm exposure surface and has 64 slots for exposure experiment materials. In total, more than 40 kinds of materials including quenched carbonaceous composites (QCCs), deuterated quenched carbonaceous composites (deut-QCCs), nitrogen-included carbonaceous composites (NCCs), anthracite, graphite, and silicates are installed in the experiment samples. Among the three samples, two of them (EE64-I and EE64-II) were attached on ExHAM-1 and were exposed in the space exposure environment for 384 days from 26 May 2015 to 13 June 2016. The final sample (EE64-III) was attached on ExHAM-1 and was exposed for 386 days from 29 June 2016 to 19 July 2017. All the samples are now collected back on earth and the difference in properties of our exposure experiment materials between before and after the experiment is investigated based on infrared micro-spectroscopy. In this presentation, I will present the overview of this space exposure experiment project and introduce some of the initial results.

F3.1-0004-18 INTACT CAPTURE SAMPLE RETURN AND INITIAL SAMPLE ANALYSES OF METEOROIDS AND EARTH ORBITING MICROPARTICLES FROM LEO BY THE TANPOPO MISSION

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The Tanpopo mission has been operational onboard the International Space Station JEMExposed Facility since 2015 to expose terrestrial microbes and astronomical organic analogs to space and to intact capture organic-bearing micrometeoroids and Earth-orbiting microparticles including orbital debris and potential terrestrial aerosols which may contain colonies of terrestrial microbes.

As of the writing, more than two dozen of 100x 100x 20 mm sized silica aerogel capture panels were returned from the low Earth orbit to ground laboratories in 2016 and 2017, after being exposed in space for 1 year or so. The first-year samples counted 119 hypervelocity impact signatures larger than 100 microns and the second-year samples are now investigated in the initial sample analysis phase with the CLOXS (Captured particle Locating, Observation and Extraction System) at ISAS.

By calibrating with hypervelocity impact experiments on ground, each impact signatures are estimated their impactor sizes and three-dimensional directionality of impacting trajectories. After identifying and correcting local shielding and secondary impact ejecta effects, the microparticle impact flux onto the ISS orbit is calculated and compared with previous spacecraft data.

In this paper, we summarize the in-orbit operation, initial sample analysis results, flux estimate and other findings from this experiment, in the context of panspermia and chemical evolution hypothesis.

F3.1-0005-18 SURVIVAL AND DNA DAMAGE OF CELL-AGGREGATE OF DEINOCOCCUS SPP. EXPOSED TO SPACE FOR TWO-YEARS IN TANPOPO MISSION

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The concept of panspermia hypothesis proposes the interplanetary transfer of life propelled by solar radiation-pressure (Arrhenius, 1903). Japanese space mission named Tanpopo, which means dandelion in Japanese, has performed capture and exposure experiments of microbes using outside of International Space Station (ISS) (Yamagishi et al., 2007; Kawaguchi et al., 2016). Previous exposure experiment of microbes in space revealed that microbes inside shielding (e.g. small fragments of rock, mixture of sugar or clay) with efficient thickness to protect from UV irradiation survive in space for a long period. On the other hand, we proposed the possible interplanetary transfer of cell-aggregate in sub-millimeter to survive in harsh space environment (Kawaguchi et al., 2013). We named the hypothesis massapanspermia. For the investigation of microbial survival and DNA damage induced in space, dried cells of radioresistant bacteria, Deinococcus radiodurans, Deinococcus aerius and Deinococcus aetherius, as well as D. radiodurans DNA repair-deficient mutants, were put in wells of aluminum plates in Exposure Panels (EPs) and exposed in space at the outside of Exposure Facility, Japanese Experimental Module of ISS since May 2015. After one-year exposure, the first set of EPs were retrieved into the ISS pressurized area in June 2016, and returned to the ground laboratory in September 2016. Cell-aggregate of dried-deinococcal cells with 100 m-thickness irradiated with sunlight corresponding to 3.4 × 103 kJ/m2 (110-315 nm) UV dose were dead. Quantitative-PCR analysis revealed that intact DNA (%) in the 100 m-thick sample was less than 1%. On the other hand, cell-aggregates with over 500 m-thickness were alive. We tested the survival of DNA repairdeficient mutants, D. radiodurans KH311, rec30 and UVS78. From comparison of their surviving fractions between ground control and space samples, we found that DNA damage such as singleand double-strand breaks as well as base damage were induced by space factors. Intriguingly, base damage was only detected from cell-aggregate exposed to space. We concluded that the cell-aggregates with 100 m-thickness were dead by UV-irradiation, while the 500 m-thick cell layer is sufficient to protect subsurface cells from UV-radiation in space. In addition, UV-induced pyrimidine dimers and ionizing radiationand space vacuum-induced double-strand breaks were also detected in space exposed samples. These results highlight the importance of microbial cell-aggregates as an ark for interplanetary transfer of microbes as we hypothesized in massapanspermia (Kawaguchi et al., 2013). We also report survival and DNA damage detected from cell-aggregates exposed to space for two-years exposure.

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F3.1-0006-18 IMPACT OF SIMULATED MARTIAN CONDITIONS ON BACTERIAL STRAINS FROM MARS ANALOGUE SITES

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During the project "Mars Analogues for Space Exploration" (MASE) several microbial isolates were obtained from extreme terrestrial environments. Some of these strains were subjected to Mars relevant environmental stress factors in the laboratory under controlled conditions;

e.g. radiation, low water activity, high salt concentrations, or oxidizing compounds. All sampling, isolation, and cultivation steps, as well as the stress tests were performed under anoxic conditions.

So far, five only distantly related microorganisms are under detailed investigation: Buttiauxella sp. MASE-IM-9, Clostridium sp. MASE-IM-4, Halanaerobium sp. MASE-BB-1, Trichococcus sp. MASE-IM-5, and Yersinia intermedia MASE-LG-1. It was shown that tolerance to desiccation and to ionizing radiation, applied separately, was not correlated as it is known for example for deinococcal representatives. If desiccation and exposure to radiation were applied together typical additive effects as well as an enhanced radiation tolerance could be observed. Additionally, the survivability after exposure to oxidizing compounds applied as single stress was tested. The survival after addition of hydrogen peroxide / perchlorate for dedicated time points (15 minutes; 24 hours) was very divers. The comparison of the five microorganisms revealed that Trichococcus sp. MASE-IM-5 was the most sensitive strain and survived only 20 mM hydrogen peroxide for 15 minutes and 24 hours, respectively. The most tolerant organism was Buttiauxella sp. MASE-IM-9 which was able to survive 230 mM hydrogen peroxide for both tested time points. In between, the other Bacteria were arranged with different tolerances against hydrogen peroxide (Buttiauxella sp. MASE-IM-9 > Yersinia intermedia MASE-LG-1

> Halanaerobium sp. BB-1 > Clostridium sp. MASE-IM-4 > Trichococcus sp. MASE-IM-5). Comparable strain specific results were obtained after the addition of different perchlorates.

In general, the strategy of the MASE project has proven to be useful to gain new model organisms. The isolated and characterized MASE strains have so far unknown high tolerances against cell damaging treatments and may serve as model organisms for future space exposure experiments.

F3.1-0007-18 VIABILITY OF THE SOIL AND PERMAFROST MICROBIAL COMMUNITIES AFTER IRRADIATION WITH ACCELERATED ELECTRONS UNDER SIMULATED MARTIAN AND OPEN SPACE CONDITIONS

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It was assumed that the putative biosphere of Mars could be viably cryopreserved and had been stored for billions of years in anabiotic state like microbial communities of Arctic and Antarctic permafrost deposits have been preserved till now for millions of years. In this case the main factor causing cell's death should be ionizing radiation.

We irradiated arid soil ancient Arctic permafrost microbial communities with up to 1 MGy doses of accelerated electrons (1 MeV) in conditions of low pressure (0.01 Torr) and low temperature (-130°C) which are the key factors of subsurface layers of Martian regolith to assess possible duration of survival of putative Martian biota in anabiotic state in subsurface of the planet. Results of culturing, epifluorescence microscopy, multisubstrate testing, GC-MS of lipids and Illumina sequencing of 16S rRNA genes of control and irradiated samples will be discussed. In general it was found that living cells and microbial biomarkers could be reliably detected in irradiated soil samples. Among the bacteria cultured from irradiated samples the representatives of Advenella, Arthrobacter, Brevundimonas, Chryseobacterium, Clavibacter, Dyadobacter, Massilia, Microbacterium, Micrococcus, Microvirga, Planococcus, Planomicrobium, Pontibacter, Rufibacter and Spirosoma genera were detected.

Taking into account the ionizing radiation intensity on the Mars' surface the resistance to 1 MGy dose of irradiation in simulated conditions proves that if there was an Earth-like biosphere on the early Mars microorganisms could survive in the shallow subsurface layer of the Martian regolith for not less than 13 million years after climate change. With increasing depth and decreasing radiation intensity, the possible duration of viable cryoconservation of the microorganisms could be assessed as 33 million years at 2 m depth (estimated depth of sampling by the ExoMars 2020 mission) and at least 200 million years at 5 m depth (the horizon below which the only background radiation is presented). Moreover, the results of the study could be applied for estimation of possible survival duration of microorganisms in small space bodies like meteorites, asteroids, comets to assess the probability of the panspermia. The obtained data point out that the radioresistance of native microbial communities being entrapped into the complex natural substrates is significantly underestimated.

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F3.1-0008-18 ADAPTATION STRATEGIES OF HALOPHILIC BACTERIA TO CHLORATES AND PERCHLORATES IDENTIFIED ON MARS' SURFACE

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The search for life beyond Earth is mainly focused on finding a planet or satellite that could potentially sustain life, it means by having physical and/or geochemical factors where life as we know it, can be preserved. These factors can be summarized as the availability of liquid water, of chemical elements to synthesize biomolecules, and the presence of an energy source to sustain a metabolism [1]. On the other hand, the study of extremophiles, organisms that require at least one extreme condition to subsist, has a great impact in Astrobiology because they allow to understand the limits of life. Among the extreme conditions where extremophiles have been identified we find high or low temperatures, absence of oxygen or light, highly acidic or alkaline locations, or salty environments [2]. Geological evidence shows that there were floods on Mars. According to the Phoenix Mars Lander Mission these floods can only be found in Martian slopes where liquid water is enriched with chlorates and perchlorates which can allegedly lower water's freezing point to 80 K. As these chemical compounds are highly hygroscopic they allow water to remain liquid over Mars' surface for short periods of time [3]. We explore the possibility offered by this scenario to determine if Bacillus pumilus, a halotolerant bacterium, Cobetia marina, a moderate halophilic bacterium, and Psycrobacter cryohalolentis a psycrohalophilic bacterium, can survive to modified environments added with $Mg(ClO_4)_2$, $NaClO_4$, $KClO_3$, and $NaClO_3$ that mimic the salty conditions of Mars floods.

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F3.1-0009-18 RESISTANCE OF THE ANTARCTIC BLACK FUNGUS CRYOMYCES ANTARCTICUS FROM ANTARCTIC DRY VALLEYS TO HIGH-ENERGY CHARGED PARTICLE RADIATION

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Cryomyces antarcticus, isolated from the McMurdo Dry Valleys in Antarctica, a Mars analogue on Earth, has already been chosen as one of the best eukaryotic models for astrobiological investigations for its stunning resistance to temperature cycles (-20°C/+20°C) and high temperature(+90°C), saline concentration (up to 25% NaCl), UV exposure (up to 5x105kJ/m2) and ionizing radiation (60 Co, up to 55.81 kGy). The fungus survived and recovered the metabolic activity even after 1.5 years of real space exposure (10−4Pa vacuum, -20°C/+47°C, 439 MJ/m2UV ir-radiation) and simulated Martian conditions (Mars-like CO_2 atmosphere, 980 Pa). STARLIFE is an international consortium which aims to investigate the responses of astrobiological model systems to different types of ionizing radiation, simulating the galactic cosmic rays, to deepen knowledge on the biological effects and risks in space. Here, we report the preliminary data on the resistance in terms of survival and ultrastructural and DNA integrity of a cryptoendolithic black fungus Cryomyces antarcticus after the irradiation with high-energy charged particles (He, Ar and Fe), as part of the cosmic rays spectrum. The irradiation experiments have been performed at the HIMAC facility (Heavy Ion Medical Accelerator) at the National Institute of Radiological Sciences (NIRS) in Chiba, Japan; doses ranged from 0 up to 1000 Gy. The resistance of this eukaryotic model to cosmic rays as the high-energy charged particles here tested gives insights of astrobiological relevance, including search for life on Mars, Lithopanspermia Theory, planetary protection and for a safer design of manned space missions.

F3.1-0010-18 EVOLUTION OF ORGANIC MOLECULES UNDER MARS SURFACE-LIKE UV RADIATION CONDITIONS SIMULATED IN SPACE AND LABORATORY

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The detection and identification of organic molecules at Mars are of primary importance for astrobiology, as some of these molecules are life precursors and components. While in situ exploration missions are searching for them at the surface of the planet, it is essential to understand how organic molecules evolve and are preserved at the surface of Mars. Indeed the harsh conditions of the environment of Mars, such as ultraviolet (UV) radiation or oxidative processes, due for example to iron-bearing minerals and perchlorate ions, could explain the low abundance and diversity of organic molecules detected so far [1][2]. In order to get a better understanding of the evolution of organic matter at the surface of Mars, we exposed organic molecules under Mars-like UV radiation and oxidative environments. Similar organic samples were exposed in two experiments: directly to the Sun radiation, outside the International Space Station (ISS) on the EXPOSE R2 facility; and under the flux of a wide range UV lamp in the laboratory with the MOMIE experiment. The EXPOSE R2 facility was placed in low Earth orbit (LEO), outside the International Space Station (ISS) in 2014, to be exposed to the Solar radiation. One of the EXPOSE R2 experiment, called PSS (Photochemistry on the Space Station), was dedicated to astrobiologyand astrochemistry-related studies. Several of the PSS samples were prepared for the study of the evolution of organic molecules under Mars-like surface radiation conditions. Organic samples have been exposed directly to the Sun under KBr filters (UV transmission >200 nm) from November 2014 to February 2016, mimicking the UV radiation conditions of the surface of Mars. Four types of samples were exposed in the form of thin layers of solid molecules: pure deposits of adenine, adenine mixed with nontronite (a clay mineral detected on Mars), pure deposits of chrysene and glycine mixed with nontronite. The MOMIE (Mars Organic Matter Irradiation and Evolution) experiment has been set up to study the evolution of organic matter under simulated martian UV radiation within the laboratory [3][4]. Organic samples are in this case exposed under a UV lamp (200-400 nm) as thin homogenous films (a fraction of µm thick). Adenine, chrysene and glycine were studied in this experiment as well, allowing us to compare their evolution with the results in LEO. Uracil was also studied. Perchlorate salts effect on organic evolution was investigated. To characterize the evolution of our samples, analyses by infrared spectroscopy (IRTF) were performed: before and after exposure in LEO, for the PSS samples, and continuously along the experiment for the MOMIE samples. These analyses allowed determining whether each molecule is preserved or photodegraded, and if so, its photolysis rate. Most of the studied molecules were rapidly degraded under Mars-like UV radiation. On the other hand, uracil seems to form new bigger compounds in Mars-like UV radiation conditions. The effect of nontronite and perchlorates on organic molecules preservation has been investigated as well. We also compared results from LEO with laboratory data.

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F3.1-0011-18 THE BIOMEX EXPERIMENT ON-BOARD THE INTERNATIONAL SPACE STATION: BIOMOLECULARAND BIO-GEOCHEMICAL CHANGES OF LICHENS EXPOSED TO SPACEAND TO MARS-LIKE CONDITIONS

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Exploration of the solar system is a priority research area of the AstRoMap European Astrobiology Roadmap (Horneck et al., 2015) [1], focusing on several research topics, such as “Life and Habitability” andan other one is “Biomarkers for easy the detection of life”. Therefore, “space platforms and laboratories”, as the EXPOSE setup installed outside the ISS, are essential to gain more knowledge of spaceand planetary environments, which might be an essential basis for improvement of the robotic and human interplanetary exploration (Space, Moon, Mars, Encedalus, Titan, Europa). At the exposure platform EXPOSE-R2 on the ISS (2014-2016), samples of the astrobiological model lichen Circinaria gyrosa [3,4,5,6], a specie which was exposed 18 months to space and simulated Mars-like conditions during the BIOMEX experiment

[2] (Biology and Mars Experiment, ESA), was investigated, to study Mars’ habitability and resistance to space conditions. The data obtained by this biomarker-study after being exposed to Mars-like conditions will support the analysis of data obtained during future instrumental detection operations in future space missions on Mars (i.e. ExoMars or Mars 2020). After the return of the samples in June 2016, the first preliminary analysis showed a quick and complete recovery of metabolic activity of the control samples exposed to space vacuum and Mars-like atmosphere. In contrast, the samples directly exposed to solar UV radiation showed slow recovery, in reference to their observed original activity. Recent results will be presented that show biomolecular changes of the DNA analysed by PCR-based [7, 8] and complementary sequencing techniques, in correlation with the previous results showing changes in metabolic activity and changes in viability (Electron and fluorescence microscopy techniques), as well as in morphology/ultrastructure - a potential effext due to space vacuum and Mars atmosphere. In addition, the biogeochemical variations have been examined with spectroscopic analyses (Raman) to look for possible degradation of cell surfaces and pigments which were in contact with terrestrial rocks, and Martian analogue regolith. Moreover, differences were observed between samples irradiated directly with solar UV radiation and samples positioned in the shielded area as darkcontrol. These experiments will contribute to answer questions of the habitability of Mars, on the likelihood of the Lithopanspermia Hypothesis, on the capability to detect biomolecules by life-detection instruments exposed to an extraterrestrial environment and will be of relevance for planetary protection issues.

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F3.1-0012-18 GENE EXPRESSION MEASUREMENT MODULE (GEMM)- THE DOOR TO HIGH-THROUGHPUT IN-SITU ANALYSES OF BIOLOGICAL SYSTEMS

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A central, long-standing goal of the astrobiology program that holds promise for both major scientific discoveries and exciting the general public is to understand life in outer space and on other celestial bodies. One strategy towards achieving this goal is to determine the potential for terrestrial microbial life to adapt and evolve in space environments. Identifying the limits of terrestrial life in space and the accompanying molecular adaptations is a prerequisite for developing predictions and hypotheses about life on other worlds. The ability of microorganisms to survive in a wide range of conditions encountered in space would support the hypothesis that terrestrial life might not be a local planetary phenomenon, but instead could expand its evolutionary trajectory beyond its planet of origin. This would, in turn, support the notion that terrestrial life may not be unique and similar life forms might exist elsewhere in the Universe. In order to facilitate studies on the impact of the space environment on biological systems, we have developed GEMM (Gene Expression Measurement Module) - an automated, miniaturized, integrated fluidic system for in-situ measurements of gene expressions in bacterial samples. The project has been funded through the ASTID program. The GEMM instrument is capable of (1) lysing bacterial cell walls, (2) extracting and purifying RNA released from cells, (3) hybridizing it to probes attached to a microarray and (4) providing electrochemical readout, all in a microfluidics cartridge. Its first application on a nanosatellite platform is to cultivate and measure gene expression of the photosynthetic bacterium Synechococcus elongatus, a cyanobacterium known for its metabolic diversity and resilience to adverse conditions, under light and dark cycles exposed to polar orbit for a period of 6 months. The integration and end-to-end technology validation of this instrument will be discussed. In particular, results demonstrating that the instrument properly measures gene expression after cellular lysis, nucleic acid extraction, its purification, and hybridization to an electrochemical array will be presented and compared to commercial microarray

analysis. Finally, a proposed version of GEMM that is capable of handling both microbial and tissue samples on the International Space Station will be briefly reviewed.

F3.1-0013-18 PREPARING FOR ROBOTIC ASTROBIOLOGY MISSIONS TO LAVA CAVES ON MARS: THE BRAILLE PROJECT AT LAVA BEDS NATIONAL MONUMENT (N. CA, USA)

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Planetary caves offer direct access to the subsurface, have stable thermal environments, and are protected from harsh surface conditions such as cosmic radiation and small-scale bombardments. These features may enhance preservation of biosignatures over long periods of time and make caves an attractive astrobiology target in the search for evidence of life beyond Earth. BRAILLE (Biologic and Resource Analog Investigations in Low Light Environments) is a NASA analog research project focusing on lava caves. The BRAILLE team is using the NASA Ames CaveR rover to deploy a scientific payload (cameras and spectrometers) and execute astrobiology science and mapping activities, robotically, in a lava cave. Our field site is Lava Beds National Monument, in Northern California, USA; 3 caves selected for our initial work (Valentine, Hopkins-Chocolate, and L300) have a range of human visitation and lava flow ages. CaveR is shephered by engineers inside the cave, but operations are planned and directed from a surface science and engineering team, located in a mission control center a few minutes away. In tandem, we are conducting an integrated field and laboratory study at the same locale to characterize the microbial life and associated secondary minerals or biominerals, explore the mineral-microbe continuum, and assess resources (water, nutrients, energy sources) that can limit and/or sustain microbial life there. We will present initial results from our first field campaign at Lava Beds and our concept of mission operations to simulate planetary cave exploration. This work was supported by the NASA PSTAR program NNH16ZDA001N.

F3.1-0014-18 BACTERIAL GROWTH AND SURVIVAL UNDER THE EXTREME CHEMICAL AND PHYSICAL CONDITIONS OF MARS AND THE ICY WORLDS

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On Mars and the icy worlds, the liquid water required for life may be cold, salty, and under pressure. High solute concentrations depress the freezing point of water, broadening the range of potentially habitable regions. Sulfate salts, along with chlorides, are important in Mars regolith with Ca, Fe, Mg, and Na counterions. Hygroscopic sulfate and (per)chlorate salts may form deliquescent brines with low eutectic points on Mars. While the bulk ocean of Europa may not be highly saline, pockets or layers of liquid water intercalated with ice may have high salinities, as might be the case for Callisto and Ganymede. Enceladus may have pockets of alkaline soda brines, while the frigid waters of Pluto may be rich in ammonia. We have been examining bacterial responses to high solute concentrations using heavy salt brines and sugars. Our organisms were isolated from natural environments rich in NaCl (Great Salt Plains, OK) or MgSO4 (Hot Lake, WA; Basque Lake, BC), oligosaline common soils, and spacecraft assembly facilities (NASA JPL). The collections include Halomonas, Marinococcus, Nesterenkonia, and Virgibacillus isolates that grow at 10% NaCl (1.7 M) or 2 M (50%) MgSO4. We have examined the anions chloride, nitrate, (per) chlorate, phosphate, and sulfate coupled in every combination with the cations Ca, Fe, Mg, K, and Na. Salts of borate, Cs, and Li also have been tested. Strong growth was commonly observed in salts at 1 M, including LiCl, MgCl2, MgSO4, KNO3, K2SO4, and NaCl. such as Cs and borate, seemed toxic. Comparisons between salts and among other solutes (sugars) suggest that water activity or chaotropicity alone were not dictating cellular responses to specific solutes. Growth at >2M Mg or >25% chlorate was unexpected. However, we observed strong growth at the MgSO4 saturation point (67% at 25 °C). Furthermore, we observed slow growth at the eutectic points for MgSO4 (43% at -4 °C) and K chlorate (3% at -4 °C), the first demonstration of microbial growth in eutectic brines with astrobiological relevance. We continue to examine microbial survival and recovery from non-permissive conditions, where salinities or temperatures stop growth. Salty cold water on the icy satellites may be under considerable hydrostatic pressure. We are currently investigating the interplay of pressure, salinity, and temperature with microbial survival. Measuring the toxicity of solutes at extremely high concentrations and low temperatures helps to define extraterrestrial habitable regions and informs us about the types of microbes on spacecraft that pose greater risks for forward planetary contamination. Supported by awards from NASA, Research Opportunities in Space and Earth Science (ROSES), Planetary Protection Research (09-PPR09-0004 and 14-PPR14-2-0002) and Kansas INBRE NIGMS NIH (P20 GM103418).

F3.1-0015-18 VENUS' SPECTRAL SIGNATURES AND THE POTENTIAL FOR LIFE IN THE CLOUDS

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The lower cloud layer of Venus (47.5-50.5 km) is an exceptional target for exploration due to the favorable conditions for microbial life, including moderate temperatures and pressures (60 C and 1 atm), and the presence of micron-sized sulfuric acid aerosols. Nearly a century after the ultraviolet contrasts of Venus' cloud layer were discovered using Earth-based photographs, the substances and mechanisms responsible for the changes in Venus' contrasts and albedo are still unknown. While current models include sulfur dioxide and iron chloride as the ultraviolet absorbers, the temporal and spatial changes in contrasts, and albedo between 330-500 nm, remain to be fully explained. In this presentation, therefore, we will discuss the potential for microorganisms to survive within Venus' lower clouds and contribute to the observed bulk spectra. In summary, we will provide an overview of Venus spectroscopy, compare the spectral and physical properties of Venus' clouds to terrestrial biological materials, discuss the potential for a coupled iron and sulfur metabolism in the clouds, and review conceivable mechanisms of transport from the surface towards a more habitable zone in the clouds. Together, our lines of reasoning suggest that particles in Venus' lower clouds contain sufficient mass balance to harbor microorganisms, water, and solutes, and potentially sufficient biomass to be detected by optical methods. Looking ahead, these comparisons warrant further investigations into the prospect of biosignatures in Venus' clouds.

F3.1-0016-18 SURVIVAL RATE OF SPORES UNDER NEAR-SURFACE CONDITIONS OF ICY WORLDS

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Icy-Ocean worlds like Europa or Enceladus likely represent our best targets for finding nonEarth life in our Solar System, owing to the presence of an ocean under their ice shell. Microorganisms formed there can potentially migrate to the surface via plumes, ice shell tectonics, or in chaos regions, and be accessible to an eventual landed mission. While a detection on the surface is unlikely due to the harsh UV and energetic particle irradiation to which these moons are subject, the near-surface (mm-cm) provides slightly more hospitable conditions and is accessible without the need for deep drilling.

The goal of our work is to investigate micro-organism survival under the temperature, radiation, and chemical conditions found near the surface of icy worlds. To accomplish this, we chose bacterial spores, a dormant bacterial state, as our model micro-organism because of their known resilience under extended and extreme conditions. In our laboratory, spores can be irradiated by UV photons using an Ar arc lamp lamp or an electron gun under high vacuum to simulate Europa-like conditions. They can be cooled cryogenically in the 10 - 300 K range, and molecular films are deposited by introducing gaseous mixtures that condense on the cooled spore samples.

Here we present survival fractions of Bacillus Subtilis spores irradiated by UV photons (and keV electrons) under a range of temperature and in different chemical environments. We discuss the origin for the observed variations with temperature and the

impact of shielding versus that of chemical reactions by different ice compositions and discuss the expected survival time of Bacillus Subtilis spores under Europa-like conditions with respect to latitude.

F3.1-0019-18 BIOSPHERE SUBSTRATE AND ITS PARAMETERS RANGE

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For providing the maximal carrying capacity and expansive potential of a planetary system (PS), optimal utilization of the orbital material is required. It raises the question of suitability of various objects in a planetary system for the purpose of terraforming and developing full-scale open biospheres. The term “Biosphere Substrate” (BS) is introduced for celestial bodies, like terrestrial planets or big gas giant moons, suitable to sustain a full-scale open biosphere after terraforming. The purpose of the work is to examine the range of parameters for a biosphere substrate. Most importantly, to be a BS, a celestial body gravity should sustain a full-scale open breathable atmosphere dense enough after terraforming in astrophysical time scale comparable to the lifecycle of a planetary system. Extremely high gravity is also the limit for complex life forms. The gravity is the main parameter that is the most difficult to be influenced, thus the range of object sizes fitting the BS definition is examined. The capability of a celestial body to retain breathable atmosphere during a time interval comparable to the planetary system life cycle depends on its magnetic field strength. The lower boundary of the objects sizes fitting the BS definition is studied on the basis of their capability to hold hot convecting interiors for strong enough magnetic fields during a PS life cycle. As the chemical composition of a BS’s surface, hydrosphere and atmosphere can be drastically adjusted in most cases by importing asteroid and cometary material, this factor in most cases does not determine whether a celestial body can become a BS. But for water worlds where any solid material to build biological bodies and industrial structures can be more than thousand kilometers deep, chemical composition can become an issue, while this problem can be solved to some extent by importing solid materials (asteroids). Also, concentrations of some chemical elements and compounds in extremely toxic quantities in crust might be an obstacle to develop a full-scale open biosphere. Thus, the range of chemical compositions for celestial bodies of suitable sizes is also reviewed. The temperature is another important parameter, as a molten celestial body cannot become a BS in near term, but can become a BS when it cools enough. The temperature factor and capabilities to adjust it are also estimated. For a full-scale open biosphere development, there must be a source of energy. A BS orbit can go inside the circumstellar habitable zone, or can be partially inside and partially outside it for highly elliptical orbits. Possibilities to extend a circumstellar habitable zone with large orbital light diffusers and light concentrators are researched. For planets with solid crusts, their rotation can be adjusted by hitting asteroids and comets strictly tangentially with high velocities to gain required spin. But for water worlds and tidally locked satellites, rotation can be an

issue. The rotation factor is also examined. The work attempts to introduce a new concept and the term that can be used for further terraforming research, developing a mathematical model of its limits. Our estimations are required to be discussed with a wide range of relevant specialists in the linked fields of studies, such as astrophysics, especially exoplanets characterization professionals; astrochemistry; astrobiology; planetary science, etc. To provide the basis for this discussion, the article suggests preliminary estimations of the parameters crucial for selection of BS candidates.

LIFE SCIENCES AS RELATED TO SPACE (F)

THE EVOLVING CHEMICAL UNIVERSE: FROM PROTO-STARS TO THE ORIGIN OF LIFE: PART 1 (F3.2)

F3.2-0001-18 INTRODUCTION TO THE EVOLVING CHEMICAL UNIVERSE

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The formation of stars and planets in dense, cold regions of the interstellar medium is a complex process with a number of intermediate and overlapping evolutionary stages, such as dense prestellar cores, hot cores, protostars, and protoplanetary discs. A significant portion of our knowledge of these stages comes from the spectroscopic study of molecules in the gas and on dust particles, as detected at assorted wavelength regions, mainly via rotational and vibrational transitions. During the formation of stars and planets, molecular complexity is built up via both gas-phase and solid-state reactions, contributing to the inventory of organic molecules in new exo-planets. Still larger organic molecules, including PAHs and fullerenes, are not as directly connected with star formation. In this Event, sessions are organized to include the formation and observation of complex organic molecules in diverse sources including the atmospheres of new planets, as well as assorted ideas concerning the origins of life from the organic molecules produced both in external sources such as comets and protoplanetary discs as well as in the atmospheres of young planets.

F3.2-0002-18 COMPLEX ORGANIC MOLECULES IN COLD CORES

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As likely precursors of prebiotic molecules in space, complex organic molecules have been the subject of intensive investigation. Long thought to be characteristic of the hot cores of star forming regions, they are now found in a wide range of regions with various physical conditions, including prestellar dense cores, i.e. at a stage even prior to the formation of protostars. The unexpected detections of terrestrial-like complex organic molecules in these cold (10 K) sources questioned our understanding of their formation mechanism, since these species were first thought to originate from warm chemistry. In this contribution, recent observational results of complex organic molecules in prestellar cores will be presented, addressing their inventory, spatial distribution and what we can learn about their formation mechanisms. I will then highlight the remaining challenges and future progress we can expect in the coming years.

F3.2-0003-18 DETECTION AND MODELING OF COMPLEX ORGANIC MOLECULES IN GALACTIC-CENTER HOT CORES

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The interstellar medium (ISM) is replete with molecules, and high-mass star-formation regions in particular are host to some of the most complex organic molecules yet detected outside of our solar system. Millimeter/sub-millimeter wavelength spectral data from the ALMA telescope allows us to explore the chemistry of such regions in much greater detail than ever before. The ALMA 3mm line survey EMoCA ("Exploring Molecular Complexity with ALMA") of the chemically-rich Galactic Center source Sagittarius B2(N) has not only identified several new molecules in that source, but has led to the identification of new hot cores - a total of five are now known to exist.

I will give a brief overview of the molecular detections made toward Sag B2(N). I will also present chemical kinetics models of the coupled gas-phase and grain-surface/ice-mantle chemistry occurring in Sag B2(N) related to these molecules, with an emphasis on the treatment of the recently-detected branched carbon-chain molecule iso-propyl cyanide (i-C3H7CN). I will also assess the possibilities for the presence and detectability of other branched carbon-chain molecules in the ISM.

F3.2-0004-18 FIRST DETECTION OF CYANAMIDE (NH2CN) TOWARDS SOLAR-TYPE PROTOSTARS

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Cyanamide (NH2CN) is thought to be an important pre-biotic molecule, as it is converted to urea in liquid water (Kilpatrick 1947). Despite being detected in external galaxies (Martín et al. 2006; Aladro et al. 2011), NH2CN has only previously been detected twice in the Milky Way, in Sgr B2 (Turner et al. 1975) and Orion KL (White et al. 2003). Here we report the first detection of NH2CN surrounding two solar-type protostars, using data from the Atacama Large Millimeter/submillimeter Array Protostellar Interferometric Line Survey (PILS) of IRAS 16293-2422 B and observations of NGC1333 IRAS2A taken with the IRAM Plateau de Bure Interferometer. Towards IRAS 16293B, we also detect the deuterated and 13C isotopologues of NH2CN, constituting the first interstellar detection of NHDCN.

LTE analysis shows that the deuteration of cyanamide (1.7%) is similar to that of formamide (NH2CHO), perhaps suggesting a common molecular precursor to both. The NH2CN/NH2CHO abundance ratio varies between the sources, being 0.2 for IRAS 16293-2422B and 0.02 for IRAS2A. These values are comparable to observed values for Sgr B2. We use the threephase chemical kinetics model MAGICKAL to investigate the formation and destruction of this molecule. Production of NH2CN on the surface of grains through the combination of NH2 and CN radicals was added to our network, and it is demonstrated that our model can reproduce observed gas-phase abundances of NH2CN, depending on the choice of the gas-phase density. The NH2CN/NH2CHO abundance ratio is still too low however, which is perhaps related to overproduction of NH2CHO.

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F3.2-0005-18 JWST CAPABILITIES FOR COMPLEX MOLECULES

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Knowledge of the molecular content of dense clouds, embedded protostars and protoplanetary disks is fundamental to our understanding of the chemical trail leading to the formation of life. Millimeter-wave spectroscopy, in particular using the powerful Atacama Large Millimeter Array (ALMA) interferometer, is able to image molecules with permanent dipole moments down to scales of 10 AU in the closest star forming regions. Infrared spectroscopy enables observations of species without permanent dipole moments (e.g., CO2, CH4, C2H2, .) as well and also of the vibrational modes of dust and ices. It traces molecules down to spatial scales (tenths of AU) smaller than ALMA because the transitions can be observed in absorption against the continuum emission from stellar photospheres or hot dust. The James Webb Space Telescope (JWST), to be launched in Spring of 2019, will offer unprecedented sensitivity, spatial resolution, and spectral coverage at a spectral resolution suited for detailed observations of gas and solid state molecules in the infrared. JWST will enable observations of the vibrational modes of ices in environments and for sample sizes not possible before. Ices are a key location of molecule formation and studying their composition and structure directly is important (as opposed to after sublimation). The need for spectra of analogs of interstellar ices produced in laboratories is highlighted. I will also present which ice observations are planned at the beginning of the JWST mission as part of the Early Release Science program "Ice Age".

F3.2-0006-18 TWO DIMENSIONAL CARBON CHEMISTRY IN THE ISM: LABORATORY AND OBSERVATIONAL INVESTIGATIONS OF AROMATIC MOLECULES

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In the last 50 years of astrochemical research, the realm of one-dimensional carbon chemistry (i.e. carbon chain molecules) has been well explored. Life, however, relies on two and three-dimensional carbon - branches, rings, bridges, and so forth. Here, we present the first rotational detection of a six-membered ring molecule in the ISM, benzonitrile, using deep GBT observations of TMC-1 combined with high-precision laboratory spectroscopy. We then explore the formation chemistry of this two-dimensional carbon molecule using a combined laboratory, quantum chemical, and modeling approach. We demonstrate the synthesis of cyclic species (benzene and benzonitrile) from simple, acyclic precursors, providing definitive evidence for facile bottom-up generation of two-dimensional carbon chemistry in the ISM.

F3.2-0007-18 INTERSTELLAR FULLERENES

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Cosmic Fullerenes in Planetary Nebulae

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In recent years, fullerenes (and in particular C60) have been detected in a variety of astrophysical environments – from the circumstellar carbon-rich surroundings of evolved stars to interstellar reflection nebulae and young stellar objects. Understanding how these species form, evolve and respond to their environment yields important insights into astrochemistry and the characteristics of large aromatics in space, thought to be the main reservoir of organic material in space.

In this talk, I will present an overview of what we have learned about cosmic fullerenes from multi-wavelength astronomical observations, theoretical calculations and recent laboratory experiments, and show how fullerenes have significantly changed our understanding of interstellar chemistry. I will discuss the conditions that appear to be conducive to the formation and/or detection of fullerenes, and highlight some of the difficulties we still face in understanding the formation of fullerenes, especially in planetary nebulae.

F3.2-0008-18 SPACE FULLERENES, PAHS & DIFFUSE INTERSTELLAR BANDS

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C60 was discovered in 1985 from a mass spectrometer peak by Kroto, Curl, Smalley al, for which they got the Nobel Prize in Chemistry in 1996. It was then produced in macroscopic quantities by Kratschmer et al in 1990, that allowed to confirm the structure of soccer ball geometry, and started a revolution in research and application, to the delight of chemists, physicists, astronomers, architects and UEFA-FIFA fans. In 1994 Foing Ehrenfreund reported the discovery of two near IR diffuse bands coincident with C60+ bands, with abundance of up to 0.5 % of cosmic carbon .The interstellar bands detected at OHP observatory at 9577 and 9632 A were consistent with C60+ spectra in frozen matrix lab measured in 1992 by D'Hendecourt, Fostiropoulos and Léger and other groups. The DIBs assignment as C60+, largest (and most beautiful) interstellar molecule was celebrated by H. Kroto, and confirmed in subsequent observations (ESO, CFHT, etc. and recently by latest near gas phase laboratory experiments. The quest for fullerenes, PAHs and large organics in space and Diffuse Interstellar Bands (DIBs) research has advanced since 20 years. DIB observational surveys, DIB families, correlations and environment dependences, resolved substructures indicative of rotational contours by large molecules. DIBs carriers have been linked with large organic molecules observed in the interstellar medium such as IR bands (assigned to PAHs, with some new bands detected by Spitzer assigned to fullerenes, Cami et al 2010), Extended Red Emission or recently detected Anomalous Microwave Emission (AME). Fullerenes and PAHs have been proposed to explain some DIBs and specific molecules were searched. These could be present in various dehydrogenation and ionisation conditions, for example fully dehydrogenated (Vuong, Foing 2000), in a form similar to graphenes (Nobel prize Physics 2010). Infrared measurements confirm the presence of vibrational bands of fullerene compounds in circumstellar environments. Ground based astronomical surveys confirmed the C60+ band detection, and allow to use fullerenes as probes of interstellar processes and environments. Experiments in the laboratory and in space (on FOTON BIOPAN, ISS EXPOSE, OREO Cubes) allow to measure the survival and by-products of these molecules.

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F3.2-0009-18 COMETARY CHEMISTRY: COMPLEX MOLECULES

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I will summarize what is currently known of the chemistry of comets. Sublimation of nuclear ices near perihelion generates the coma - a multi fluid plasma whose understanding requires consideration of a variety of chemical processes. Compositional studies, from ground and space, especially of organic molecules, isotopologues, and ortho-para ratios can provide important clues as to their origins, and to their possible role in providing water and biomolecules to the early Earth.

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F3.2-0010-18 PRIMORDIAL ORGANIC MATTER IN COMETS AND ASTEROIDS

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Laboratory studies of meteorites and cosmic dust from asteroids and comets reveal a multitude of organic compounds of astrobiological and astrochemical interest. Isotopic, structural, and chemical studies suggest some of these materials have interstellar origins. Yet there are also signatures of subsequent chemical synthesis and alteration within the solar nebula and the interiors of planetesimals.

Among meteorites thought to derive from asteroids, organic compounds are most abundant in carbonaceous chondrites that have undergone hydrothermal alteration. Some meteoritic organics have elevated D/H and 15N/14N ratios that resulted from isotopic fractionation during low-T ion-molecule and grain-surface chemistry in cold molecular clouds and the outer protoplanetary disk [1]. These signatures were obscured by aqueously mediated chemistry and thermal processing in asteroid parent bodies, forming amino acids and other prebiotic molecules. Chondritic porous interplanetary dust particles (IDPs) collected in the stratosphere are thought to derive from comets based on their primitive properties and high atmospheric entry velocities. Large H and N isotopic anomalies are more common in IDPs than most meteorites, suggesting better preservation of primordial organics [2]. Yet, owing to their small sizes (10 µm), the nature of organic matter in cometary IDPs is not well known. Rosetta studies of comet 67P dust particles revealed organic species that resemble macromolecular material that is ubiquitous in carbonaceous chondrites [3].

Primitive meteorites and cometary IDPs contain µm-sized organic nanoglobules that often have large H and N isotopic anomalies. Coordinated in situ isotopic and organic measurements suggest that these organic nanoglobules formed prior to their incorporation in their parent bodies and may derive from interstellar environments [1]. Chemical measurements of organic globules in meteorites by in situ laser desorption-laser ionization mass spectrometry show high concentrations of organic species containing a carbonyl functionality such as formaldehyde

(H2C=O) and acetaldehyde (CH3C=OH). Since aldehydes and ketones readily undergo condensation/polymerization reactions, their association with nanoglobules is consistent with the suggestion that nanoglobules formed via carbonyl condensation reactions [4]. The presence of free carbonyl species indicates partial hydration of nanoglobules during parent body hydrothermal alteration.

NASA and JAXA are flying sample return missions to primitive, potentially organic-rich asteroids. The OSIRIS-REx [5] and Hayabusa2 [6] missions will map asteroids Bennu and Ryugu, respectively, in detail and return regolith samples to Earth. Laboratory analyses of these pristine asteroid samples will provide unprecedented views of asteroidal organic matter relatively free of terrestrial contamination within well-determined geological context. NASA also recently selected the proposed CAESAR comet sample return mission for phase A study within the New Frontiers 4 program. This mission would return the first direct sample of a comet nucleus (67P) to Earth in 2038 [7, 8]. Studies of extraterrestrial materials and returned samples are essential to understand the origins of Solar System organic material and the roles of comets and asteroids to providing the starting materials for the emergence of life.

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F3.2-0011-18 THE DIVERSITY OF REFRACTORY ORGANIC MATERIAL IN COMETS

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Organic matter exists in comets (most notably in 81P/Wild 2 [Stardust], 67P/ChuryomovGerasimenko (67P/C-G) [Rosetta], chondritic porous IDPS, and UCAMMs) and in primitive carbonaceous chondrites that likely retain some chemistry that reflects an origin in the prenatal cold molecular cloud (Alexander+2017). Heavy isotopic enrichments, 15N/14N and possibly D/H, signify preserved molecular cloud organics. In the cold outer disk, if grains are lofted above the disk mid-plane then organics likely experience significant UV processing (Ciesla+2012). In remote sensing of comet comae, organics in the dust are considered refractory or semirefractory. Semi-refractory organics have limited comae lifetimes and produce distributed sources of molecules (H2CO and CO). A close flyby of 67P/C-G's nucleus (10-15 km) reveals a distributed source of glycine, methyl amine and ethylamine (Altwegg+2016). Cometary samples and primitive meteorites have two types of organic matter: (1) acid-insoluble organic matter (IOM), which is a macromolecular polymer with a mixture of aromatic and aliphatic moieties, and (2) labile, soluble organics, which includes the amino acids, such as glycine (Stardust, Elsila+2009). Meteoritic IOM is robust, withstanding experimental temperatures of 1200 K (Dobrica+2011, Cody+2008). Nanoglobules are a type of IOM; they have a distinct physical structure, but often share the same chemistry as the other IOM from the same meteorite. Moderate-sized PAHs (20 C-atoms) are detected in Stardust samples (Clemett+2010). Refractory organic IOM is ubiquitous yet has a great diversity of abundances between cometary samples. IOM is in primitive chondrites, 67P/C-G (Rosetta), 81P/Wild 2 (Stardust), 1P/Halley, 26P/Grigg-Skjellerup, UCAMMs, anhydrous IDPs, and in chondritic porous IDPs (CP IDPs) and larger cluster IDPs (e.g., Fray+2016, Fomenkova+94, Busemann+09, Dobrica+2011, Dobrica+2012). 81P's refractory organic matter is of two types (De Gregorio+2011): nanoglobules of highly aromatic refractory organic matter and polyaromatic carbonyl-containing organic matter, which is similar to IOM in primitive meteorites and IDPs. Fray+2017 estimate that 50% of carbon in 67P/C-G is in IOM. 67P/C-G's organics appear to lack the soluble organic matter, aliphatic carbon, amino acids, and PAHs (Fray+2016). Other notable aspects of the diversity in IOM in cometary samples are the ranges of atomic ratios of N/C, O/C, and H/C, and the range of isotopic enrichments of 15N/14N and D/H.

F3.2-0012-18 THE ROSETTA MISSION AND ORGANIC MATERIAL IN 67P.

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On 30 September 2016 the European Space Agency's Rosetta spacecraft softly crash-landed on comet 67P/Churyumov-Gerasimenko and brought an intense period of more than 2 years of continuous investigation to an end. Rosetta data led to many discoveries about the origin of the material and the processing in our early Solar System. Among the payload instruments, ROSINA, the mass spectrometer suite, obtained fundamental properties of the comet by analysing the gases emanating from its nucleus. Besides detecting many organic molecules never seen in space before, ROSINA was also able to measure precise isotopic abundances for noble gases as well as D/H in water, NH3 and H2S. By following the comet from 3.8 AU to perihelion and out again to 3.8 AU desorption patterns could be followed for individual species, allowing deeper insights into the nature of cometary ice. Some of the findings clearly point to unprocessed ice from the prestellar stage which allows to study chemistry in the presolar cloud more or less "in situ". Detailed data analysis is still ongoing and many more results from the gas mass spectrometers are evolving. The most important of these findings like e.g. nitrogen isotopes and complex organics will be discussed in the presentation. The impact of those findings on the question of astrobiology are discussed. Finally, from the noble gases, we can deduce an answer to the question "How much material was delivered by comets to the early Earth?"

F3.2-0014-18 VOLATILE LINKS BETWEEN IRAS16293-2422B AND 67P/C-G

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Comet 67P/Churyumov-Gerasimenko has been studied with unique in situ measurements by various instruments aboard the Rosetta spacecraft. Data from ROSINA, COSAC, VIRTIS and MIRO have shown that the comet has a rich molecular inventory and that there is a complex relationship between production rates and correlations between various species. The currently available data on 67P/C-G is one of the best probes of the innate protosolar disk that evolved into our modern day Solar System. Similar chemical richness, including large complex organic species, extends beyond the Earth and our Solar System as attested by countless observations towards highand some low-mass protostars. One of the best-studied low-mass systems is IRAS16293-2422, which is thought to be analogous to the earlier phases of our Solar System. The region has been surveyed with the large unbiased Protostellar Interferometric Line Survey (PILS) with ALMA. This dataset has allowed this region to be studied within an unprecedentedly wide spectral range at high spectral and spatial resolutions; thereby, uncovering its full chemical inventory and the spatial distribution of the detected species. This ALMA data on IRAS16293-2422 can be used to probe the extrasolar chemical content and the Rosetta measurements of 67P/C-G as a Solar System diagnostic. By deriving the relative ratios for simple species and complex organic molecules, direct comparisons can be drawn between the two to go after the origins of the chemical content of our Solar System. In this talk, results of such a comparative study will be presented, based on relative ratios of major and minor volatile species and the derivation of relative ratios within hierarchical families (e.g., formaldehyde, methanol and ethanol) to access the degree of relative complexity stemming from common parent species. These results give clues to the different radicals available in the ices for subsequent synthesis of larger molecules, shedding light on the dominant pathways to chemical complexity and the physical conditions that optimize such enrichment. The carried out comparative work between protostars and 67P/C-G gives hints on the uniqueness of the ingredients to life.

F3.2-0015-18 ORGANIC CHEMISTRY IN PROTOPLANETARY DISKS

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Protoplanetary disks are the formation site of planetary systems. Earth-like planets are formed via coagulation of solid material. Since volatiles are one of the essential ingredients of habitable planets, distributions of volatiles among the solids and the gas phase, and their dependence on disk radius (i.e. snow lines) have been studied theoretically and observationally. While the molecular composition of volatile material would be significantly altered inside the planetesimals and their coagulation processes, comets may preserve their initial molecular composition, at least partially. A link between cometary molecules and ices and organics in disks has long been discussed.

Although the icy water, the dominant component of ice, is detected via the observations of absorption bands for edge-on disks and via scattered light for bright sources, direct observations of minor ices in disks are difficult. Alternatively, observations of molecular line emissions could tell us the gas-phase abundance of organic molecules, which can be used to estimate their abundances in ice mantles. The combination of observations and modeling of physical and chemical structures is important, since there are radial and vertical gradients of density, temperature, and UV radiation field in the disk.

Various organic molecules are detected in protoplanetary disks. As for simple molecules, such as HCO+, DCO+, CN, H2CO and carbon chains, their spatial distributions have been revealed by ALMA, and are discussed in relations to their formation paths, snow lines, and dust evolution. Complex organic molecules (COMs) such as CH3OH and CH3CN, have also been detected. Theoretical models show that their abundances and distributions depend on various parameters including photodesorption yield and turbulent diffusion.

F3.2-0016-18 CHEMICAL CHARACTERIZATION OF EXTRASOLAR PLANETS

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Exoplanetary discoveries in the past two decades have unveiled an astonishing diversity in the physical characteristics of exoplanetary systems, including their orbital properties, masses, radii, equilibrium temperatures, and stellar hosts. Exoplanets known today range from gasgiants to nearly Earth-size planets, and some even in the habitable zones of their host stars. Recent advances in exoplanet observations and theoretical methods are now leading to unprecedented constraints on the physicochemical properties of exoplanetary atmospheres, interiors, and their formation conditions. I will discuss the latest developments and future prospects of this new era of exoplanetary characterization. In particular, I will present some of the latest constraints on atmospheric chemical compositions of exoplanets, made possible by state-of-the-art high-precision observations from space and ground, and their implications for atmospheric processes and formation conditions of exoplanets. The emerging framework for using atmospheric elemental abundance ratios for constraining the origins and migration pathways of giant exoplanets will be discussed along with their implications for smaller rocky planets. A survey of theoretical and observational directions in the field will be presented along with several open questions on the horizon.

F3.2-0017-18 DREAMING OF ATMOSPHERES

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The field of exoplanetary spectroscopy is as fast moving as it is new. Analysing currently available observations of exoplanetary atmospheres often invoke large and correlated parameter spaces that can be difficult to map or constrain. This is true for both: the data analysis of observations as well as the theoretical modelling of their atmospheres. Modelling both sets of correlations in data and modelling is key to understanding the nature of exoplanet atmospheres. In this talk I will discuss how these improvements in machine learning can be applied to exoplanetary spectroscopy to solve some of said correlations in the parameter space. By designing deep neural networks, we can significantly speed up data analysis and interpretation and allow our current models to 'learn from experience'. Such AI driven systems will help to resolve model correlations, and allow us to build fully autonomous models. Finally, I will present a new deep neural network architecture, specifically designed to learn and classify data from the Cassini-VIMS instrument. This neural network takes both spectral and spatial distributions of surface or cloud compositions and can be shown to significantly out-perform traditional labelling techniques.

F3.2-0018-18 LIGHTNING AND CYANIDE CHEMISTRY ON EXOPLANETS

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Hydrogen cyanide (HCN) is a key molecule for a wide variety of prebiotic synthesis mechanisms, and it is therefore useful to determine how much HCN we expect on the surfaces of rocky exoplanets with N2-dominated atmospheres. To form HCN in an N2-rich environment, the first step is to cleave the N N triple bond, which requires energies in excess of 225 kcal/mol. This energy can take many forms, such as cosmic rays and solar energetic particles, UV photons, impacts, volcanism, and lightning. If there is any carbon and hydrogen in the same environment, some of that carbon will react with the atomic nitrogen to form the CN radical, which will proceed to HCN. If there is any oxygen in the environment, some of the oxygen will react with the atomic nitrogen to form nitrogen oxides (NOx). How much HCN vs NOx is produced is primarily determined by the C/O ratio.

I will use lightning-driven chemistry to illustrate this relationship between HCN and the C/O ratio.

I will discuss the application of a photochemistry-diffusion model (ARGO) using the STAND chemical network to a variety of atmospheres of different C/O ratios and different oxidation states of carbon. To model a lightning shock, this model is coupled to a hydrodynamics model (ATHENA). I show what range of HCN mixing ratios can be produced via lightning for this variety of environments. I then discuss how much HCN we can expect to rain out onto exoplanet surfaces, in comparison to the HCN concentrations necessary for prebiotic synthesis.

F3.2-0019-18 BASIC PROCESSES OF FORMATION AND EVOLUTION OF ICES IN PLANETARY AND INTERSTELLAR ENVIRONMENTS

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Ices, whether coating sub-micron interstellar grains or larger planetary grains and bodies, are repositories of atoms and molecules that, under the appropriate conditions, might give rise to complex molecules, some of which are strong candidates for the formation of amino-acids and other molecules of interest to origin-of-life investigations. In this review, I will examine those processes that are key to the formation and evolution of ices, and present key studies to show how modern laboratory techniques are being used to study these processes.

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F3.2-0020-18 FORMATION OF AMINO ACID PRECURSORS AND CARBOXYLIC ACIDS IN THE HADEAN EARTH'S ATMOSPHERE BY COSMIC RAYS AND SOLAR ENERGETIC PARTICLES FROM THE YOUNG SUN

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Over the last 60 years, a large number of laboratory experiments have been perfomed to examine pathways of formation of bioorganic compounds such as amino acids in primitive Earth atmosphere. Earlier experiments with strongly reducing gas mixtures containing methane and ammonia exposed to spark discharges and ultraviolet light sources suggested efficient production of a number of biologicaly important amino acids. Since 1980s, however, it was estimated that the early Earth atmosphere was less reducing with N2 and CO2 as the major atmospheric constituents including small amount of reducing carbon species like CH4 and/or CO [2]. Simulation experiments suggested, however, that amino acid formation was restricted under these conditions [3]. Galactic and solar cosmic rays (also known as solar energetic particles, SEPs) are known as the sources of energetic particles penetrate the Eath's lower atmosphere and facilitate chemical reactions with atmospheric consituents. However these energy sources have been ignored in experiments with initiation of prebiotic chemistry [4]. Here, we examine possible formation of amino acids from slightly reducing gas mixtures by applying ionizing radiation to simulate the action of galactic and solar cosmic rays.

We condiucted three sets of laboratory experiments using energetic particles, spark discharge and UV light as dominant energy sources. In these sets of experiments we used 400 mL of gas mixture of N2, CO2 and CH4 introduced to a Pyrex tube together with 5 mL of pure water under 700 Torr total gas pressure with varied mixing ratios of CH4 and CO2. In the first set of experiments, the gas mixture was irradiated with 2.5 MeV proton beam produced in the Tandem accelerator at Tokyo Tech, Japan. In the second set we exposed the same composition of gas mixtures to spark discharges by using a Tesla coil to simulate lightning conditions during thunderstorms on Hadean Earth. In the third set of experiments, the gas mixtures were irradiated with UV light at (what wavelength range) produced by a xenon lamp. Each product was acid-hydrolyzed and was subjected to amino acid analysis by HPLC and GC/MS, both after derivatization. Carboxylic acids were determined by GC/MS after derivatization. Resulting gas mixtures were analyzed with a quadrupole mass spectrometer.

Amino acids were detected in the hydrolyzed products when gas mixtures of N2, CO2, CH4 and H2O were irradiated with 2.5 MeV protons at the initial the molar ratio of methane (rCH4) in the starting gas mixture as low as 0.5 %. This is in sharp contrast with our experiments under the spark discharge exposures when amino acids were detected only when rCH4 was greater than 15 %. The experiments with UV irradiation source did not yield amino acids or their precursors even when rCH4 reached 50 %.

Carboxylic acids including oxalic acid and glyoxylic acid were detected from unhydrolized products derived from N2-CO2 gas mixtures exposed to spark discharges and proton irradiation. We show that some free carboxylic acids could be formed in non-reducing atmospheres as well as slightly reducing atmospheres either by proton irradiation or by spark discharges. It was suggested that the mechanism of formation of amino acid precursors from N2-CO2-CH4-H2O mixtures was quite different from that of carboxylic acids.

Considering the availability of various sources of ionizing radiation fluxes on the primitive Earth, energetic protons appear to be an efficient factor to produce N-containing organics via abiotic nitrogen fixation than any other conventional energy sources like thundering or solar UV emission irradiated the early Earth atmosphere. The production of these energetic particles can be associated with galactic cosmic rays and solar energetic particle events (SEPs) associated with solar coronal mass ejections and superflares from the young Sun [6-8]. Our experiments appear to be in good agreement with the recent model of initiation of prebiotic chemistry including efficient production of HCN and N2O in the early Earth's atmosphere exposed to frequent SEP events associated with solar magnetic storms could have been efficient in supplying energy for efficient production of HCN and N2O [7]. Thus, solar energetic particle events could have promoted the production of bioorganic compounds in primitive Earth atmosphere. Further experimental studies on such effects are in progress.

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F3.2-0021-18 HYDROGEN AND NITROGEN ISOTOPES FOLLOW DIFFERENT FRACTIONATION PATHWAYS IN STAR-FORMING CLOUDS

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Molecular isotope ratios are essential tools to investigate the origin of solar system materials and their possible chemical link with interstellar materials. The most primitive materials in the solar system, such as cometary ices, show the enrichment of both deuterium and 15N compared to the Sun. On the other hand, observations towards low-mass dense cores, where sun-like stars form, have found that molecules in the cold gas are highly enriched in deuterium, but do not show clear 15N enrichment. In particular, N2H+, which is a daughter molecule of N2 (i.e., possible main budget of gaseous nitrogen), is clearly depleted in 15N. It is unclear what the main 15N fractionation mechanism is, and why interstellar molecules in the gas phase tend to be depleted in 15N, while cometary volatiles are enriched in 15N.

In this presentation, we present results of a series of gas-ice astrochemical simulations including hydrogen and nitrogen isotopes, which traces the evolution from the formation of molecular clouds to protostellar cores. We find that nitrogen isotope fractionation mostly occurs in a molecular cloud by the combination of isotope selective photodissociation of N2 and ice formation. In the molecular cloud, where external UV radiation field is not fully shielded, N15N is selectively photodissociated w.r.t 14N2, which results in the enrichment of 15N in atomic nitrogen. As 15N-enriched atomic nitrogen is converted to ammonia ice and HCN ice via grain surface reactions, the bulk gas becomes depleted in 15N, while the icy species are enriched in 15N. Once external UV radiation field is sufficiently shielded (i.e., in dense cores), 15N fractionation does not proceed anymore and the molecular N/15N ratios established in the molecular cloud stage are largely conserved, because nitrogen isotope exchange reactions are not efficient even at 10 K. The 15N-rich ices could be eventually incorporated to protoplanetary disks, in which comets will form, while 15N is deficient in gases including N2H+ in dense cores. This situation is very different from deuterium fractionation; it is mostly driven by hydrogen isotope exchange reactions and becomes more efficient with time as long as temperature is cold. We compare the numerical results with the observations of dense cores and comets, and discuss possible observational tests for the 15N fractionation pathway.

F3.2-0022-18 MOLECULAR COMPLEXITY IN THE STAR FORMING REGIONS OF MAGELLANIC CLOUDS

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Recently, we studied chemical complexity in cold dense cores as well as hot core regions of the Large and Small Magellanic Clouds. These irregular satellite galaxies of Milky Way are metaland dust-poor, therefore, can serve as basic templates for the study of low metallicity early galaxies. Their relative proximity makes them excellent targets for observation. The dust temperature in these galaxies could also be higher compared with our Galaxy; this can have a profound effect on the synthesis of molecules in these galaxies. Our simulations show that both the cold, dense and hot core regions of LMC and SMC can exhibit rich chemistry. We found that important gas phase species, as well as water and CO2 ices, could be observed in abundant quantities. Our calculations show that some COMs can also be formed in reasonable amounts for hot cores in the Magellanic clouds when the initial grain temperature is lower than 25 K. In this presentation, I will discuss the complex organic molecules that are found in our Galaxy, and how their abundance varies in the Magellanic clouds. This comparison will help us to understand the role of metallicity and dust grain temperature in the formation of COMs.

F3.2-0023-18 DEUTERATION IN THE OUTFLOWS OF A LOW MASS PROTOSTAR SYSTEM HH212: AN ALMA OBSERVATION OF DEUTERATED FORMALDEHYDE

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HH212, a nearby (400 pc) object in Orion, is a Class 0 protostellar system with a Keplerian disk and collimated bipolar SiO jets. Deuterated water, HDO and a deuterated complex molecule, methanol (CH2DOH) have been reported in the source. Here, we report the HDCO (deuterated formaldehyde)line observation from ALMA data to probe the inner region of HH212. We compare HDCO line with other molecular lines to understand the possible chemistry and physics of the source. The distribution of HDCO emission suggests it may be associated with the base of the outflow. The emission also shows a rotation but it is not associated with the Keplerian rotation of disk or the rotating infalling envelope, rather it is associated with the outflow as previously seen in C34S. From the possible deuterium fractionation, we speculate that the gas phase formation of deuterated formaldehyde is active in the central hot region of the low-mass protostar system, HH212.

F3.2-0024-18 IDENTIFICATION OF CANDIDATE MOLECULES FOR THE BUILDING BLOCKS OF LIFE'S EARLIEST POLYMERS

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Chemists have yet to find a plausible prebiotic synthesis for RNA polymers, and most previously proposed mechanisms for prebiotic peptide synthesis are inefficient. We are exploring the hypothesis that RNA and polypeptides have both evolved from polymers with different chemical structures. We have found that molecules closely related to amino acids and the nucleobases of RNA, which were likely present on the prebiotic Earth, greatly facilitate the formation of polypeptides and RNA-like structures (Forsythe et al., 2015; Cafferty et al., 2017). The identification of molecules that may have served as precursors to the building blocks of extant polymers, or as prebiotic catalysts for biopolymer formation, has direct implications regarding which molecules that should be considered as possible signs of chemistries that can support the emergence of life in the universe. Furthermore, the possibility that life started with molecules that can be repeatedly cycled between their monomeric and polymeric states, as is still the case with extant biopolymers, suggests environmental characteristics that would have facilitated the formation and early evolution of functional biopolymers.

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F3.2-0025-18 EXPERIMENTAL SIMULATIONS OF PREBIOTIC CHEMISTRY DRIVEN BY HYDROTHERMAL GRADIENTS IN OCEAN WORLDS

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Planetary water-rock interfaces generate free energy in the form of redox, pH, and thermal gra-dients; these gradients sustain life in terrestrial hydrothermal systems and are of great interest in the search for life on ocean worlds such as Europa and Enceladus. Sediments and chimneys pre-cipitated in hydrothermal systems formed by water-rock chemistry on the early Earth could have contained reactive minerals such as iron (-nickel) sulfides and iron oxyhydroxides (including green rust). These minerals may have promoted various reactions of interest to the emergence of life including amino acid synthesis, concentration and retention of organic products, phosphorus redox and polymerization, and rudimentary energetic processes by electrochemistry [1]. We have developed various experimental systems for simulating the effects of geochemical gradients on prebiotic reactions in seafloor / hydrothermal systems, including the formation and electrochemi-cal characterization of simulated hydrothermal chimneys and membranes, synthesis of reactive hydrothermal sediments over a range of pH / redox states, and concentration of phosphorus spe-cies in hydrothermal minerals. Vent systems constitute flow-through chemical reactors [2] and the suite of amino acids (or other organics) that may be found in a particular mineral system is determined by what is synthesized there, what is preferentially concentrated / retained there, and what is preserved against degradation under the ambient hydrothermal conditions. Consequently, the chemistry of organic and phosphorus species formed in vent systems would depend on the ad/absorptive capacity of the ambient minerals, and the mineral reactivity would correspondingly be affected by the presence of trace organic / phosphorus species. These emerging organic-mineral feedbacks in gradient systems, combined with the forced diffusion of products to encoun-ter different geochemical disequilibria in a porous sediment or chimney structure, warrant further experimental investigaton to determine how prebiotic chemistry may have proceeded on early Earth as well as ocean worlds.

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F3.2-0026-18 PEPTIDE ORIENTED ORIGIN OF LIFE SCENARIO

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Life as we know is capable to harvest energy from surrounding environment and able to reproduce their organic constituents through chemical reaction sustained by metal-assisted polypeptides. Meanwhile evolvability of the system is maintained by exchange or vertical decent of genetic information carried by nucleotide polymers. Where and how did these polymers originated and integrated into the biological system? Are polymers able to bridge abiotic geochemical processes to biochemistry? To address these questions, I will overview several ongoing experimental approaches focusing on the abiotic synthesis of peptides in hydrothermal conditions, functionality of simple metallo-peptides and coevolution of peptides with RNA to understand the dynamic roles of peptides during the origin of life.

F3.2-0027-18 KINETIC MONTE CARLO SIMULATIONS OF ICE PROCESSING: FROM THE LAB TO INTERSTELLAR ENVIRONMENTS

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Ices make up a critical component of the chemistry in various star-forming sources, including pre-stellar cores and protoplanetary disks. During the star-formation process, ices composed of simple molecules build up on the surfaces of interstellar dust grains. These ices are thought to be the precursors of complex organic molecules (COMs) that may later be delivered to planetary bodies and comets. The formation of molecules on grain surfaces, and the subsequent production of COMs, has been demonstrated in laboratory experiments. However, interstellar physical conditions can never be exactly reproduced, and the timescales are vastly different (minutes in the lab versus many thousands of years in the ISM), making the correspondence of the two regimes highly uncertain.

Here we use the off-lattice Monte Carlo kinetics model MIMICK to investigate the effects that various deposition parameters have on laboratory ice structures, and extend the study to interstellar conditions. We reproduce experimental trends in the density of amorphous solid water (ASW) for varied deposition angle, rate and surface temperature; ice density decreases when the incident angle or deposition rate is increased, while increasing temperature results in a more-compact water ice. Extrapolation of the model to conditions appropriate to protoplanetary disks, in which direct accretion of water from the gas-phase may be the dominant ice formation mechanism, indicate that these ices may be less porous than laboratory ices.

We extend our study to include a warm up phase like those used in temperature programmed desorption (TPD) experiments, where a mixed molecular ice is heated and thermal desorption is monitored. These experiments show CO has a unique desorption profile upon heating, caused by diffusion and subsequent trapping of CO in the porous water structure. We have utilized the model to replicate these TPD experiments and have found similar behavior is replicated, with CO trapped and released at high temperatures (60 K). The behavior of the system can be directly extrapolated to interstellar conditions using the same chemical code.

F3.2-0028-18 SIMULATIONS OF COMPLEX ORGANIC MOLECULE CHEMISTRY IN HOT CORES WITH AN IMPROVED THREE-PHASE MODEL

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Photodissociation and bulk diffusion are very important to the formation of intersteller complex organic moleculars(COMs). Motivated by the “multilayer” model and microscopic Monte Carlo model,we modified the “multilayer” model by added some mantle reactions include photodissociation and interstial diffusion. The self-shielding effects of CO and H2 ,reaction desorption and an accelerate Monte Carl algorithm are also included in our models. This new fully three phase model was used to simulate the process of chemistry in hot cores, including cold collapse stage and warm-up to 400K stage. Glycine(NH2CH2COOH) and related species, have possible to present in hot cores, are included in the network.The result show that abundant radicals are produced in mantle phase during the collapse stage, and when temperature increase radicals can diffuse and reaction to produce COMs in mantle phase. Methyl formate and dimethyl ether producted in mantle phase occurs over temperature 30-80K.Glycine produced in mantle phase occurs over temperature 70-130K.In addition, we study the effect of ratio of photodissotiation produce species enter to interstial phase (alpha) and the ratio of diffusion energy and desorption energy (Eb/Ed) for mantle phase on the formation of COMs. The result show that the COMs increase with the alpha grow(but only a little bit).When alpha equal to 0.5 and Eb/Ed equal to 0.7 ,the model can reproduce the observation results.

F3.2-0029-18 CHEMICAL EVOLUTION: ROCKS AND MINERALS AND THE CHEMISTRY OF LIFE'S ORIGIN

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Our current understanding is that the first life forms came into existence through chemical evolution. About four billion years ago, the number, amount and complexity of abiotic organic molecules on Earth continuously grew, ultimately leading to the first protometabolisms. Already hundreds of minerals were present on Earth at this time [1]. It has been shown in laboratory simulation experiments that minerals could have played an important role in organic chemical evolution by protecting organic molecules against ultraviolet radiation and by altering organic reactivity. The evolutionary effectiveness of minerals in altering organic molecule reactivity has been demonstrated with the amino acid glycine. In the absence of minerals, heating of glycine resulted in a black polymer, while glycine that was intercalated in silicates—under otherwise identical conditions—gave oligopeptides [2, 3].

Other minerals are also important to the topic. Magnetite, for example, is involved in reactions that can proceed in deep-sea hydrothermal systems. It is produced in serpentinization reactions and can also act as a catalyst in Fischer-Tropsch syntheses. There has been debate over whether deep-sea hydrothermal systems are more of a source or sink for abiotic organic molecules. Minerals may have also played a key role in the origin of biological homochirality. Quartz and calcite, for example, form enantiomorphic and scalenohedral crystals, respectively. Prebiotic chiral molecules may have been enantioselectively adsorbed onto the mirror-image faces of such minerals.

Minerals could have provided metal ions to abiotically formed porphyrins [4] and metalloprotein precursors. Our laboratory experiments strongly indicated that prebiotic metal porphyrin complexes could have formed by the interaction of porphyrins with metal ions from minerals (e.g., Fe^{2+}). These complexes were potential early functional analogues of cytochromes and other proteins.

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F3.2-0030-18 AN EXPANDED GAS-GRAIN MODEL FOR INTERSTELLAR GLYCINE

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The study of the chemical evolution of glycine in the interstellar medium is one of challenging topics in astrochemistry. In this conference, we present the chemical modeling of glycine in hot cores using the state-of-the-art three-phase chemical model NAUTILUS, which is focused on the latest glycine chemistry. For the formation process of glycine on the grain surface, we obtained consistent results with previous studies that glycine would be formed via the reactions of COOH with CH2NH2. However, we will report three important findings regarding the chemical evolution and the detectability of interstellar glycine. First, with the experimentally obtained binding energy from the temperature programmed thermal desorption (TPD) experiment, large part of glycine was destroyed through the grain surface reactions with NH or CH3O radicals before it fully evaporates. As a result, the formation process in the gas phase is more important than thermal evaporation from grains. If this is the case, NH2OH and CH3COOH rather than CH3NH2 and CH2NH would be the essential precursors to the gas phase glycine. Secondly, since the gas phase glycine will be quickly destroyed by positive ions or radicals, early evolutionary phase of the hot cores would be the preferable target for the future glycine surveys. Thirdly, we suggest the possibility that the suprathermal hydrogen atoms can strongly accelerate the formation of COOH radicals from CO2, resulting in the dramatic increase of formation rate of glycine on grains. The efficiency of this process should be investigated in detail by theoretical and experimental studies in the future.

F3.2-0031-18 AN EXTENDED PUBLIC DEUTERIUM FRACTIONATION MODEL FOR THE ASTROCHEMICAL COMMUNITY

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Deuterated species are unique and powerful tools in astronomy since deuterium-to-hydrogen (D/H) enrichment in molecular species provides clues about their original environment of formation, chemistry, and the ionization level of the medium. But the study of the deuterium chemistry is a challenging task because of the limited number of accurately determined rate coefficients and the sheer number of hydrogen-dominated reactions in astrochemical networks. Here, we will present a new extended publicly available deuterium fractionation model available in KIDA database which includes ortho/para chemistry of major protonated species.

We will try to highlight the following key questions:

How observing few selected deuterated species can be a very effective tool to characterize cold and dark media where most molecules are depleted?

Does spin chemistry change the deuterium enrichment of the ISM?

Prediction for future observations for deuterated species in dense cores and protoplanetary disks.

We will also show and discuss our recent observation to measure the D/H ratio of c-C3H2 in cold envelope of IRAS 16293-2422 as an application. We will also show our prediction to map the D/H ratio of essential molecules in protostellar envelopes and disks using ALMA (and ngVLA in the future).

F3.2-0032-18 EFFECT OF STOCHASTIC GRAIN HEATING ON COLD DENSE CLOUDS CHEMISTRY

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The size and temperature of the dust grain plays an important role in the chemistry of molecular clouds. For a typical dust grain size (0.1 mum), its temperature keeps a constant value. However, due to the distribution of dust grain size in the molecular clouds, the temperature of small dust grains can reach a higher level because of the interaction with the interstellar radiation field. We considered a set of dust grain radius using the classical MRN grain size distribution, and using the Monte Carlo method to stimulating the real-time dust grain's temperature fluctuation, and applying it to a fully gas/grain reaction network. Finally, we present the time-dependent abundances of the gas-phase and grain surface species.

F3.2-0033-18 THE ESO DIFFUSE INTERSTELLAR BAND LARGE EXPLORATION SURVEY: FIRST RESULTS.

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The ESO Diffuse Interstellar Band Large Exploration Survey (EDIBLES) is Large Programme that is collecting high-signal-to-noise (S/N) spectra of a large sample of O and B-type stars covering a large spectral range using the UVES spectrograph mounted on the Very Large Telescope (VLT). The goal of the programme is to extract a unique sample of high-quality interstellar spectra from these data that represent different physical and chemical environments, and to characterise these environments in great detail. An important component of interstellar spectra are the diffuse interstellar bands (DIBs), a set of hundreds of unidentified interstellar absorption lines that are commonly found in the spectra of reddened targets. With the detailed line-of-sight information derived from these high-quality spectra, EDIBLES will derive strong constraints on the potential DIB carrier molecules. EDIBLES will thus guide the laboratory experiments necessary to identify these interstellar "mystery molecules", and will turn the DIBs into powerful diagnostics of their environments in our Milky Way Galaxy and beyond. Here, we will present some of our first results showing the unique capabilities of the EDIBLES programme.

F3.2-0035-18 ROLE OF METAL OXIDES IN CHEMICAL EVOLUTION: INTERACTION OF VALINE AND GLYCINE WITH ALUMINUM, IRON AND ZINC OXIDES

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Amino acids are essential components of living matter and the description of their initial polymerization to form peptides remains a major problem in establishment of reasonable origins of life scenario [1]. It has been proposed [2] that the prebiotic polymerization of the amino acids occurred in the absorbed state on mineral oxide surfaces because the reaction is thermodynamically unfavourable in aqueous phase. This could have occurred at the surface of the primitive earth and/or on interstellar space. Amino acid adsorption on mineral surfaces has attracted much interest because mineral surfaces may have played important role in prebiotic peptide bond formation [3]. The present work described interaction of amino acids (glycine and valine

) with alumina (acidic, basic and neutral), iron and zinc oxides. Glycine showed higher adsorption on all adsorbents in comparison to valine. Adsorption of amino acids on metal oxides surface follow the order: Alumina > iron oxide > zinc oxide. On alumina adsorption follow the order acidic > neutral > basic. Adsorption data obtained followed Langmuir adsorption isotherm and b and Qo values were calculated. Result of present study may indicate the importance of alumina in concentrating organic molecules form dilute aqueous solution in primeval seas during the course of chemical evolution on primitive earth. Detail will be presented. References: 1. Lambert J.F., Adsorption and polymerization of amino acid on mineral surfaces, Orig. Life Evol. Biosph. 39 (2009) 247. 2. Bernal, D. The Physical basic of life. Proc. Phys. Soc. 61 (10) (1951) 597-618. 3. Ferris, J.P., Hills Jr., A.R., Liu, R., Orgel, L.E. Synthesis of long prebiotic oligomers on mineral surfaces, Nature 381 (1996) 59-61.

F3.2-0036-18 FORMATION OF COMPLEX ORGANIC MOLECULES IN COLD ENVIRONMENTS

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According to the currently known scenario of complex organic molecules (COMs) formation, the COMs mainly form on the interstellar dust particles rather than in the gas-phase, and are effectively synthesized at temperature above 20-30 K due to immobility of heavy species at lower temperature. However, it has been observed in the past several years that some COMs actively form even at temperature as cold as 10 K, challenging the previous formation scenario. This research aims to address a new formation mechanism, so-called excited formation, by modeling the chemical evolution of acetaldehyde (CH_3CHO) in this cold environment. The following text suggests that the acetyl, the precursor of CH_3CHO, is synthesized by hydrogenation of CH_2 situated on top of a surface CO molecule. This significantly enhances a population of CH_3CHO in the cold environment, successfully reproducing the observational results, and application of this mechanism to other COMs (e.g. methyl formate) is being tested. Once this new mechanism is confirmed, more generalized scenario of COM formation can be provided, which is of considerable interest to the study of origins of life.

F3.2-0037-18 HYDROGENATION AND DEHYDROGENATION OF SUBSTITUTED BENZENE RINGS IN ASTROPHYSICAL ICE ANALOGS

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Since the detection of methylidyne (CH) in 1937, more than 200 different molecules have been identified in the interstellar (ISM) and circumstellar (CSM) media. Some of these molecules freeze out at the cold temperatures (10-20 K) of such environments, leading to the forma- tion of molecular ices on the surface of dust grains. This provides extraordinary conditions for the formation of complex organic molecules (COMs), which could be produced by chemical transformation processes catalyzed by external agents, such as cosmic rays, photons and charged particles. In this context, ionization, fragmentation and protonation of molecules could occur, leading to the formation of distinct neutral, ionized and radical species, eventually enriching the gas phase with COMs after desorption processes. In this study, we use the electron-stimulated ion desorption (ESID) technique to determine the positively charged fragments desorbed from pure benzene (C6H6), chlorobenzene (C6H5Cl) and cyclohexane (C6H12)

astrophysical ice analogs. The samples are condensed at 125 K into a ultrahigh vacuum (UHV) chamber at 10−9 mbar base pressure. The ices are then bombarded by a focused electron beam of 2.3 keV. The positively charged ions desorbed from the ices are analyzed using the time-offlight mass spectrometry (TOF-MS) technique. Among the produced C6H+ species, we show that benzene and chlorobenzene present a remarkable resemblance: in both cases the protonated benzene ion (C6H+) is predominantly formed, and dehydrogenation is observed as far as the formation of the cyclohexatriyne cation, C+. Apart from dehydrogenation, we also observe that both molecules are capable of forming hydrogenated products up to the complete loss of aromaticity on the carbon ring, resulting in the production of the cyclohexane cation (C6H+) and the protonated cyclohexane (C6H12H+) species. For chlorobenzene, C6HnCl+ species are observed for n = 0 11, and the hydrogenation leads preferentially to C6H8Cl+ and C6H10Cl+. For cyclohexane ices, we show that the hydrogenation process is effective up to the formation of C6H+, evidencing a ring opening mechanism activation after electron impact. Finally, quantum chemical calculations are used to elucidate the ground state and low-lying isomers of the most produced molecular ions. We suggest that highly hydrogenated molecules, such as alkanes and cycloalkanes, could be formed in the ISM and CSM as desorption products of benzeneand substituted benzene-rich astrophysical ices.

F3.2-0038-18 SERACH FOR PROPARGYL ALCOHOL IN THE INTERSTELLAR MEDIUM

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Propargyl alcohol (HC2CH2OH, PA) has yet to be observed in the interstellar medium (ISM) although one of its stable isomers, propenal (CH2CHCHO), has already been detected in Sagittarius B2(N) with the 100-meter Green Bank Telescope in the frequency range 18 26 GHz. In this work, we investigate the formation of propargyl alcohol along with one of its deuterated isotopomers, HC2CH2OD (OD-PA), in a dense molecular cloud. Various pathways for the formation of PA in the gas and on ice mantles surrounding dust particles are discussed. We use a large gas-grain chemical network to study the chemical evolution of PA and its deuterated isotopomer. Our results suggest that gaseous HC2CH2OH can most likely be detected in hot cores or in collections of hot cores such as the star-forming region Sgr B2(N). A simple LTE (Local thermodynamic equilibrium) radiative transfer model is employed to check the possibility of detecting PA and OD-PA in the millimeter-wave regime. In addition, we have carried out quantum chemical calculations to compute the vibrational transition frequencies and intensities of these species in the infrared for perhaps future use in studies with the James Webb Space Telescope (JWST).

F3.2-0039-18 STUDIES ON KNOWN AND POTENTIAL INTERSTELLAR PROTONATED MOLECULAR SPECIES

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Majority of the known interstellar cations are protonated species believed to be the natural precursors for their corresponding neutral analogues formed via the dissociative recombination process. The protonation of a neutral species can occur in more than one position on the molecular structure thus resulting in more than one proton binding energy value and different protonated species for the same neutral species. In the present work, ab initio quantum calculations are employed to calculate accurate proton binding energies for over 100 neutral interstellar molecules of which majority of the neutral molecules are protonated in more than one position. From the results, protonated species resulting from a high proton binding energy prefers to remain protonated rather than transferring a proton and returning to its neutral form as compared to its analogue that gives rise to a lower proton binding energy (PBE) from the same neutral species. For two protonated species resulting from the same neutral molecule, the one that results in a higher PBE is more stable as compared to its counterpart that is responsible for the lower PBE for the same neutral species. Here, the most stable species are highlighted for all the systems considered.

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F3.2-0040-18 ACHIEVING ACCURATE ROTATIONAL CONSTANTS FOR LINEAR CARBON CHAINS OF ASTROPHYSICAL INTEREST

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Linear carbon chain molecular species remain the dominant theme in interstellar chemistry. Their continuous astronomical observation depends on the availability of accurate spectroscopic parameters. Accurate rotational constants are reported for hundreds of molecular species of astrophysical, spectroscopy and chemical interests from the different linear carbon chains; CnH, CnH, CnN, CnN, CnO, CnS, HCnS, CnSi, CH3(CC)nH, HCnN, DC2n+1N, HC2nNC, and

CH3(C C)nCN using three to four moments of inertia calculated from the experimental rotational constants coupled with those obtained from the optimized geometries at the Hartree Fock level. The calculated rotational constants are obtained from the corrected moments of inertia at the Hartfree Fock geometries. The calculated rotational constants show accuracy of few kHz below irrespective of the chain length and terminating groups. The obtained accuracy of few kHz places these rotational constants as excellent tools for both astronomical and laboratory detection of these molecular species of astrophysical interest. From the numerous unidentified lines from different astronomical surveys, transitions corresponding to known and new linear carbon chains could be found using these rotational constants. The astrophysical, spectroscopic and chemical implications of these results will be presented. Keywords: Astrochemistry, Molecules, Spectroscopy, Carbon-chains

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LIFE SCIENCES AS RELATED TO SPACE (F)

THE PAST, PRESENT AND FUTURE HABITABILITY OF MARS (F3.3)

F3.3-0001-18 RADIOLYSIS: A POTENTIAL PATHWAY TO PEROXIDE AND PERCHLORATE OXIDANTS ON MARS AND THE ICY GALILEAN MOONS

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Oxidants are omnipresent in the solar system. They play a central role in the habitability of Mars and serve as tracers of energetics at the surfaces of the icy Galilean satellites. Hydrogen peroxide detected in the surface ice of Europa, Ganymede and Callisto by Galileo [1,2] most likely results from the impact of radiation. On Mars, oxidants have been implicated in the destruction of surface organics since the time of Viking in 1976 [3] and more recently, in the occurrence of (water-driven) recurring slope lineae [4]. Hydrogen peroxide was first detected in the martian atmosphere in 2003 [5,6], and perchlorates were first detected in the surface of Mars in 2008 by Phoenix in the polar region [7] and in the equatorial region by MSL/SAM in 2012 [8,9]. Homogeneous gas phase photochemistry, possibly aided by heterogeneous processes

[10] and electrochemistry [11] on airborne dust, results in the formation of peroxide in the atmosphere. While current techniques do not permit detection of peroxide in the martian surface, it is expected to be present in the surface and the regolith due to diffusion from the atmosphere [12] and radiolysis-initiated mineral chemistry in the surface [13]. The commonly accepted mechanism for the bulk of perchlorate production on Earth is photochemistry in the atmosphere [14]. That same mechanism fails at Mars, however. Alternate mechanisms proposed for Mars are formation in an ancient aqueous environment [15] and radiolysis of chlorine containing surface ice [16]. The latter mechanism seems more favorable for perchlorate formation on Mars [17], but further laboratory and modeling work is most desirable. References: [1] Carlson, R.W et al. Science 283, 2652, 1999. [2]Hendrix, A. et al. LPSC Abst. 2043, 1999. [3]Oyama, V. et al., JGR 82, 4669, 1977. [4] Ojha et al. NGeo, DOI: 10.1038/NGEO2546, 2015. [5]Encrenaz, T., et al. (2004) Icarus 170, 424. [6]Clancy, R.T., et al. (2004) Icarus 168, 116. [7]Hecht, M.H., et al. (2009) Science, 325(5936), 64. [8]Glavin, D.P., et al. (2013) JGR

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F3.3-0002-18 ENVIRONMENTAL OBSERVATIONS OF PRESENT DAY MARS AND IMPLICATIONS FOR HABITABILITY

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The history of life on Earth, as we known it, began about 3.8 billion years ago, initially with single-celled life forms that evolved to the variety of life forms that we know now. As for Mars, it has been recently concluded, based on the observations of NASA,s Curiosity rover at Gale crater, near the equator of Mars, that the physical, chemical, and energy conditions that were required to establish a habitable environment were present on Mars between 3.8 billion and 3.1 billion years ago [Hurowitz et al. 2017]. However, the habitability of present day Mars is still open to debate. An environment is defined as habitable if it is capable of supporting the activity (metabolic activity for survival, growth, and reproduction) of at least one organism [Cockell et al. 2016]. In order to investigate the present-day habitability of Mars, we review the Curiosity observations at Gale crater of the environmental and regolith properties that may affect life, based on our knowledge of life on Earth. We analyse the potential present day habitability of Mars as constrained by temperature, cosmic radiation, UV radiation, presence of carbon compounds, nitrogen, phosphate minerals, and Fe and S minerals, in a variety of redox states within the regolith, and, in particular, we discuss where and when liquid may be transiently stable on present day Mars [Martín-Torres et al. 2015]. We discuss where in the surface or subsurface of Mars life could exist and obtain energy from photosynthesis or chemosynthesis. Based on these parameters we discuss about the kind of instrument and sample measurements that may be required to assess unequivocally the habitability of present day Mars and the implications that this may have on the future exploration of Mars.

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F3.3-0003-18 MARS METHANE: ATMOSPHERIC CHEMISTRY, SUBSURFACE BIOLOGY OR GEOPHYSICS, SURFACE INTERACTIONS OR GLOBAL TRANSPORT?

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Since 1969 when Pimental first observed [1] what he thought was high amounts of methane in the martian atmosphere, the planetary science community and the public have been fascinated with the possibility that by analogy with Earth, the existence of Mars methane may be a signature of biological production [2]. Subsequent observations by Earth telescopes, orbiting spacecraft and a surface rover have been highly varied, puzzling and unpredictable: Mars methane has been a story of continued surprises and controversy.

We will review the observations of Mars methane to date, including ground-based observations of Krasnopolsky [3], the plumes seen by Mumma [4], the orbital measurements from Mars Express [5,6], and the more recent measurements from the Tunable Laser Spectrometer (TLS) instrument in the Sample Analysis at Mars (SAM) suite on the Mars Science Laboratory's Curiosity rover [7]. The TLS-SAM measurements have followed the theme of Mars methane in being surprising and disagreeing with models for both the background amounts and the high spikes sporadically observed. However, for the first time observations of Mars methane show repeatable seasonal variations that offer a mechanism for understanding and modeling the generation, transport and loss of this enigmatic gas. Sources and sinks will be carefully reviewed in light of contributions from possible microbial production, geophysical and chemical sources, surface uptake and release [8] and how atmospheric transport may play a crucial role as evidenced from the latest high-resolution wind-field modeling [9].

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F3.3-0004-18 NITROGEN ON MARS: INSIGHTS FROM CURIOSITY

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The detection of “fixed” nitrogen on Mars in the form of nitrate by the Sample Analysis at Mars (SAM) instrument suite on the Mars Science Laboratory (MSL) Curiosity Rover [1] has major implications for martian habitability. “Follow the nitrogen” has been proposed as a strategy in the search for both extant and extinct life on Mars [e.g., 2]. Nitrogen is so crucial to life on Earth that life developed metabolic pathways to break the triple bond of N2 and “fix” atmospheric nitrogen to more biologically available molecules for use in proteins and informational polymers. Sequestration of nitrate in regolith has long been predicted to contribute to the removal of N from the martian atmosphere [e.g., 3], and our detections confirm that nitrogen fixation was occurring on ancient Mars. But was this fixed N transformed once deposited, and if so, by what mechanism? An indicator of more complex chemistry would be reduced N, which has, as yet, not been definitively detected on Mars [4]. For example, reduced N in the form of NH3 or NH4+ would suggest reduction of nitrate by Fe(II) [5], or even biological fixation or ammonification of atmospheric N. Understanding our detections of nitrogen, particularly within the context of the habitable environment in Yellowknife Bay characterized by the MSL payload, is crucial to assess whether life ever could have existed on ancient Mars. We present 5+ years of analyses and interpretation of nitrate in solid martian drilled and scooped samples by SAM on MSL. Nitrate abundance reported by SAM in situ measurements ranges from non-detection to 681 ± 304 mg/kg [1,6] in the samples examined to date. The measured abundances are consistent with nitrogen fixation via impact generated thermal shock on ancient Mars and/or dry deposition from photochemistry of thermospheric NO. We review the integration of SAM data with terrestrial Mars analog work in order to better understand the timing of nitrogen fixation and mobility of nitrogen on Mars, and thus its availability to putative biology. In particular, the relationship between nitrate and other soluble salts, such as perchlorate, may help reveal the timing of nitrogen fixation and post-depositional behavior of nitrate on Mars [6]. We also discuss potential evidence from SAM data for reduced nitrogen compounds [7]. Finally, we discuss how a comparison of isotopic composition (delta15N) of nitrate with delta15N of atmospheric nitrate (delta15N 574‰, [8]) could to constrain atmospheric loss of N2 and model the evolution of the atmosphere on Mars.

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F3.3-0005-18 ORGANIC MATTER PRESERVED IN 3-BILLION-YEAR-OLD LACUSTRINE MUDSTONES AT GALE CRATER, MARS

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In situ analyses of lacustrine mudstones (Murray formation) at Pahrump Hills, Gale crater, Mars show the presence of alkyl, aromatic, and sulfur-bearing organic volatiles upon heating to 500-860°C, as detected by the Sample Analysis at Mars (SAM) instrument suite onboard the Mars Science Laboratory's Curiosity rover. Organic-sulfur compounds, including thiophenes, dimethylsulfide and thiols were identified by gas chromatography-mass spectrometry (GCMS) and indicated in evolved gas analyses (EGA). Aromatic and alkyl hydrocarbon components were indicated by EGA. The molecular distributions observed are specific to samples and cannot be explained by SAM's instrument background. The EGA observations are at temperatures consistent with the pyrolytic cleavage of organic fragments from large molecules (macromolecules) indigenous to the mudstones, and some portion could be derived from the thermal release of organics entrained within minerals

Given that the release of organic-sulfur compounds occurs at high temperatures in the SAM oven, these compounds are most likely derived from sulfurized organics in the sediments and are not an artifact of sulfurization reactions in the oven. On Earth, sulfurization is a key process that aids organic matter preservation over geological time-scales by converting organic molecules into recalcitrant macromolecules. Organic matter of the lowermost Murray formation most likely underwent sulfurization either prior to deposition or during early diagenesis.

Multiple factors likely attribute to organic preservation in the Gale crater mudstones, however, sulfurization may be largely responsible for the greater abundance and the molecular diversity observed in the lower Murray formation.

F3.3-0006-18 THE INSTRUMENT HABIT (HABITABILITY, BRINE IRRADIATION AND TEMPERATURE) ON THE EXOMARS PLATFORM

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HABIT (HabitAbility, Brine Irradiation and Temperature) is an edge-breaking and multipurpose instrument: it is a surface station devoted to evaluating the habitability of Mars, but also an In-situ Resource Utilization instrument for future Mars exploration.

The search for present life and habitability on Mars is conditioned by the availability of liquid water. It has recently been shown that liquid water is stable on Mars in the form of brines [Martín-Torres et al., Nature Geoscience 2015]. Two other environmental conditions constrain the habitability of the near surface of Mars, the thermal range and the UV radiation dose [Rummel et al. Astrobiology, 2014]. The HABIT (HAbitability, Brine Irradiation and Temperature) instrument is dedicated to investigating the habitability on present day Mars by quantifying the availability of liquid water, the thermal ranges and UV doses. It includes the BOTTLE (Brine Observation Transition To Liquid Experiment) compartment to capture at night-time atmospheric water by deliquescence of four different types of salts: calcium perchlorate, magnesium perchlorate, sodium perchlorate and calcium chloride, and 3 environmental sensors devoted to monitoring the full diurnal and seasonal variations of the ground and air temperature, and the UV irradiance. These three sensors shall complement the existing environmental package of the spacecraft, which has Pressure and Relative Humidity sensors.

HABIT measurements will allow to constrain the habitability at the landing site in terms of metabolic and reproduction temperature, calculating the heat-flux and the UV biological dose, providing the Relative Humidity of the ground and air, to study the atmosphere/surface water interchange, provide information about winds (which shall be useful also for the rover drilling and sampling operations), and about thermal inertia and subsurface thermal profile and hydration level complementing the studies of the other platform and rover instruments. It will also provide the concentration of the atmospheric trace gas ozone (complementing orbiter observations from NOMAD-Trace Gas Orbiter) and atmospheric UV opacity (providing continuous monitoring of the dust cycle). The BOTTLE unit is furthermore designed as an ISRU (In-situ Resource Utilization) demonstrator that shall quantify the amount of water (and derived products such as H2 and O2) available for future landed missions on Mars. HABIT will provide environmental information that will allow for extra-long term climate and atmospheric monitoring and will measure for the first-time liquid water on Mars in a controlled way, while providing ISRU possibilities.

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Rummel et al. “A New Analysis of Mars ”Special Regions”: Findings of the Second MEPAG Special RegionsScience Analysis Group (SR-SAG2)”, Astrobiology, Volume 14, Number 11, 2014.

F3.3-0007-18 HABITABLE CONDITIONS ON MODERN MARS MOTIVATE A SEARCH FOR LIFE MISSION.

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The 2008 Phoenix Mars lander mission sampled ground ice at 68oN latitude. Mission results, considered along with climate modeling studies, suggest that high latitude ice-rich regolith at low elevations is habitable for life[1]. This talk will review the evidence and describe a low cost life search mission to search for modern life on Mars. The Phoenix lander dug with a robotic arm to reveal an ice table near the surface. Evidence for liquid water processes was observed including: 1) beneath 3-5 cm of dry soil, segregated pure ice was discovered in patches covering 10% of the area explored, 2) pure calcite mineral, which forms under aqueous conditions, was detected in the soil, 3) perchlorate salt, highly soluble in liquid water, was observed at varying concentrations with higher concentrations seen in soil clods[2]. Carbon and nitrogen sources are available to support chemoautotrophic metabolism. The Thermal Evolved Gas Analysis (TEGA) instrument searched for soil organics but perchlorate was discovered in the soil[3]; any organic carbon in the soil would not have been detectable due to reaction with perchlorate during the heating step used for releasing volatiles. While current climate conditions are too cold to support metabolism, climate modeling studies[4] show that variations in solar insolation associated with changes in the season of perihelion occurring on 25 kyr timescales and obliquity variations on 125 kyr timescales[5] cause warmer and colder periods to occur in the N. polar region. The current epoch is cold because orbital tilt is low and summer occurs at apehelion. As recently as 17 kyr ago, when summer solstice was at perihelion, temperatures were warm enough to allow pure liquid water to form at the surface[4]. At orbital tilts > 35o, insolation is equivalent to levels experienced in Earth's polar regions at the present time. At 45o temperatures allowing microbial growth persist to 75 cm depth[6]. Terrestrial permafrost communities are an example of possible life in the ice-rich regolith. Studies in permafrost have shown that microorganisms can function in ice-soil mixtures at temperatures as low as - 20oC, living in the thin films of interfacial water[7]. In addition, it is well established that ground ice preserves living cells, biological material, and organic compounds for long periods of time, and living microorganisms have been preserved under frozen conditions for thousands and sometimes millions of years[8]. If life survives in these areas, growing when conditions allow, biomolecular evidence of life should accumulate in the soils. The presence of habitable conditions on Mars that persist over geological timescales to the present suggests that searching for biochemical evidence of modern life is warranted. The Mars Icebreaker Life mission[9] was proposed with that goal to the NASA Discovery call in 2015 and a future proposal is planned. The mission plans to land in high latitude ice rich terrain with a payload designed to address the following science goals: (1) search for biomolecular evidence of life; (2) search for organic matter from either exogeneous or endogeneous sources using methods not impacted by the presence of perchlorate;

(3) assess the habitability of the ice bearing soils. The Icebreaker Life payload features a 1-m drill to auger subsurface icy material to the surface where it is delivered to payload instruments. Three instruments were proposed in Discovery 2015: The Signs of Life Detector (SOLID)[10] uses immunoassay to search for up to 300 biomolecules that are universally present and deeply rooted in the tree of Earth life. The Laser Desorption Mass Spectrometer (LDMS)[11] performs a broad search for organic compounds of low to moderate molecular weight with either biological or cosmogenic origin. The LDMS method is not impacted by the presence of perchlorate. The Wet Chemistry Laboratory (WCL) [3] detects soluble species of potential nutrients and reactive oxidants, providing insight into the habitability potential of icy soils. The Icebreaker payload fits on the same spacecraft/ lander used by Phoenix. The mission can be accomplished for modest cost, searching for a record of modern life on Mars while meeting planetary protection requirements.

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F3.3-0008-18 MID-IR SPECTROSCOPY OF PERCHLORATES

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The presence of perchlorates and other oxyhalides on Mars needs to be considered in the context of habitability and the preservation of biomarkers on Mars. It has been suggested that "activated halides" could play a role in the oxidizing nature of martian soils. More recently, perchlorate was recognized by researchers as one of a number of oxidized salts present in the Atacama Desert, but the roles of perchlorate and perchlorate formation as they may relate to the presence and preservation of organics on Mars have not been thoroughly explored. Following the discovery of perchlorate on Mars during the Phoenix Mission, products formed by perchlorate radiolysis were shown to reproduce the results of the Viking Biology Experiments. The reactive intermediates and secondary products that are formed in processes that generate and decompose perchlorate may have significant impacts on the chemistry of surface materials, soil habitability, preservation of biomarkers, and the ability to analyze organics.

The recent detection of perchlorate, and likely other oxychlorine species, in the subsurface (5cm) of ancient sedimentary deposits by MSL indicates that the formation and presence of reactive oxidants on Mars may not be limited to UV-processes in the regolith, as previously suggested. Results suggest that there are major spatial variations in oxidant distributions, even for samples collected in very close proximity (e. g., MSL John Klein and Cumberland samples). Data indicate the presence of different types of perchlorates, other oxychlorine species, and possibly other oxidants including ROS. Suggesting that the chemical alteration of geological materials is more extensive and complex than previously thought.

To support the detection and characterization of perchlorates on Mars, K+, Na+, Ca2+, Mg2+, Fe2+, Fe3+, and Al3+ perchlorate salts were studied to provide spectral data for detecting and characterizing their possible presence. To extend earlier work to the mid-IR, they were characterized by IR microscopy and Raman spectroscopy). This included anhydrous samples, samples with adsorbed water, and samples exposed to humidity during analysis to observe changes. With divalent cations, changes during hydration of peaks due to water at 1600 cm^2– and 5100-5200 cm^2– showed evidence of different peaks and different states.

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F3.5-0001-18 COMPUTATIONAL STUDY OF THE FORMATION AND DETECTION OF PREBIOTIC MOLECULES IN ASTROPHYSICAL ENVIRONMENTS

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In recent years, our group has studied the formation mechanisms of the various RNA and DNA bases (Uracil, Cytosine, Thymine, Guanine, and Adenine) in mixed water ices seeded with either pyrimidine or purine and irradiated under astrophysical conditions. Our computational studies have been used to interpret the results from laboratory experimental studies to help explain which bases are found, what other products are synthesized, and their relative abundances. One interesting conclusion from our work is that only condensed-phase formation mechanisms are found to be feasible with these multistep reaction mechanisms. We will describe our latest research in this series of studies and discuss what our results may mean for the origins of life studies. Our group has also been actively studying the formation of larger ringed organic compounds starting from small C2 organic species in the gas-phase, as occurs in the outflow of carbon stars or in the interstellar medium. Most of these studies have also been performed in collaboration with laboratory experiments. Finally, our group has used state-of-the art ab initio methods to study the spectroscopic properties of the resulting molecules, allowing for their detection in astronomical observations. All of these studies will be discussed.

F3.5-0002-18 FORMATION PATHWAYS OF COMPLEX ORGANIC MOLECULES IN SPACE

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Several theoretical astrochemistry and molecular astrophysics models are in agreement with observed interstellar molecules; nevertheless, many of those models are unable to reproduce molecular abundances, which have led us to develop new models and approximations to calculate important information (i. e. spectroscopic data) in order to reproduce the observed abundances in the ISM. Grain-surface chemistry involves predominantly hydrogenation and oxidation reactions and leads to the formation of simple species; e.g., H2O, CO, CO2, CH3OH, H2CO, CH4, and NH3. Energetic processes (through UV photons or cosmic rays) convert these molecules into complexes organic molecules (COM's) as dimethyl ether (CH3OCH3), ethanol (CH3CH2OH), acetaldehyde (CH3CHO), and methyl formate (CH3COOH)1. In addition, ion-neutral processes produce radicals, like H+ and OH-, which may react with other molecules2. In this work, the reaction between ice mantles of methanol and the hydroxyl ion as projectile has been calculated using the Bohr-Oppenheimer Molecular Dynamics Theory (1600 timesteps with wb97x/6- 31+g(d,p) level of theory. The projectile was vibrationally excited with different energies, from 10 eV up to 22 eV at 30K As a preliminary result, it a new chemical network of all reactions involved in the impact of OH radical with methanol was found. 15 of 24 reactions studied with minimal velocity resulted in CH3O (metoxy radical). 4 reactions show the methylenglycol as a primary product. The deprotonation of methanol and the formation of the methoxy molecule are in agreement with experimental data3. In all cases, carbohydrate formation is shown, i.e. formaldehyde and methylenglycol, thus, the methanol ice mantles could be an important source of carbohydrates in the interstellar medium, as well as a source of molecular hydrogen.

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F3.5-0003-18 ADSORPTION ENERGIES OF ATOMS AND MOLECULES ON THE LOWTEMPERATURE AMORPHOUS WATER ICE: A SYSTEMATIC ESTIMATION FROM QUANTUM CHEMISTRY CALCULATIONS

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We propose a new computational model to estimate adsorption energies of atoms and molecules to inter-stellar ice surface, in which large time-scale fluctuation at the low-temperature is incorporated approximately. Based on our model, we theoretically investigated the adsorption energies of C, N, and O atoms by using quantum chemistry calculations. The adsorption energies were 14100, 400, and 1440 K for C, N, and O, respectively, and these of N and O are well consistent with the experimentally reported values. Consequently, we found that the binding of N atom is purely physisorption, while that of C atom is chemisorption in which a chemical bond to an O atom of a water molecule is formed. The chemisorption of C atom indicated that the further chemical reactions might be possible to form molecules bearing a C-O bond. We also investigated effects of newly estimated adsorption energies onto simulated chemical compositions based on rate-equation method.

F3.5-0004-18 THE CHEMICAL EVOLUTION OF COMPLEX MOLECULES IN SPACE

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Interstellar ice dust grains are the place where prebiotic molecules that feeds nascent solar-like systems, including planets and planetesimals, form. Recent ALMA observation of complex organic molecules (COMs) in cold dark clouds and the upcoming JWST mission highlight the importance of the interplay between gas and dust to the formation and survival of COMs in space throughout the process of star and planet formation. In this talk, I will present recent laboratory work on the formation and destruction of COMs in the solid phase under dark molecular cloud conditions. During the talk, I will show and compare energetic (UV photolysis) and non-energetic (atom bombardment) routes. This laboratory work ultimately contributes to our understanding of the origin of life in the Universe.

F3.5-0005-18 INFRARED MEASUREMENTS ON EFFICIENT CHEMICAL DESORPTION OF HYDROGEN SULFIDE FROM AMORPHOUS SOLID WATER

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Desorption processes of adsorbate atoms and molecules on dust are very important for understanding chemical evolution. In warm regions above about 100 K, molecules on dust are efficiently released into gas phase by thermal desorption, while in colder regions, nonthermal processes like photodesorption dominates. The photodesorption of some molecules such as H2O and CO has been well-studied and in fact those rates were reported. However, photodesorption is significantly suppressed in cold dense regions at around 10 K where the UV field is very weak. Therefore, additional nonenergetic desorption process caused by heat of reaction, socalled chemical desorption or reactive desorption has been proposed. In recent years, attempts to determine the rate of chemical desorption for some molecules have been started experimentally. However, the reported values often have significant uncertainties probably due to the intrinsic difficulty in detection methods of a typical quadrupole mass spectrometer. It is still desirable to clarify the details of chemical desorption for various species. We here report the first infrared measurements on chemical desorption which efficiently occurred for reaction of H2S with H atoms at 10 K on amorphous solid water as an ice dust analogue. Our experiment clearly demonstrates that chemical desorption is more efficient than previously believed. The obtained effective cross section for chemical desorption indicates that the chemical desorption rate exceeds the photodesorption rate in typical dense clouds.

F3.5-0006-18 THE INFLUENCE OF WET–DRY CYCLES ON ORGANIC MOLECULES IN SIMULATED PRIMORDIAL ROCK POOLS

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Rock pools on primordial volcanic islands could have acted as natural "chemical reaction flasks." They were regularly filled with seawater by tides or sporadically with freshwater by rainfall. Warm to hot environments, occurring at locations of geothermal activity, caused the evaporation of the water and enabled wet–dry cycling. Rock pools were associated with different igneous rock, minerals and weathering products thereof, such as clays. Particularly, clay minerals could have played an important role as they promote peptide formation under the influence of wet–dry cycles (see, e.g., Lahav et al., 1978) and can protect amino acids against thermal degradation in the dry state (Dalai et al., 2017). In order to perform laboratory simulations of prebiotic wet–dry cycles under strict exclusion of O2, we have designed a special apparatus (Fox et al., 2018). We tested its novel design by investigating the behavior of glycine (i.e., decomposition and peptide formation) in wet–dry cycles in the presence of clay minerals. In another set of experiments, we observed complexation reactions between a hydrophobic model porphyrin and metal ions (e.g., Fe2+ and Cu2+) of various minerals. These experiments demonstrated that wet–dry cycling could have been important for the formation of prebiotic metalloporphyrins. Detailed results of these and other experiments and a description of the setup and operating principle of the apparatus will be presented. Furthermore, the general role of rock pools in chemical evolution will be discussed against the background of our experimental results.

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F3.5-0007-18 FLUORINE AND CHLORINE CHEMISTRY IN THE INTERSTELLAR MEDIUM

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We have studied the formation of fluorineand chlorine-bearing species for a variety of interstellar conditions using a gas-grain network. Our homogeneous (0D) models are designed for isothermal diffuse, translucent, and dense clouds, as well as warm-up regions. In addition to the regularly observed species, we have added a number of additional halogen-containing molecules and explored their gas-phase and grain surface chemistry. Other molecules include neutral species such as Cl2, ClO, and CCl, as well as the carbon-halogen species CH3Cl, and ionic species such as CCl+, ClO+, HF+, SiF+, and H2F+. Predictions are made for the abundances of these species as functions of time and comparisons are made with the observed abundances obtained for halogen species. The peak fractional abundance of the newly detected gas-phase

CH3Cl is predicted to be 10−10 - 5.4 × 10−8 in our warm-up simulations depending upon the density and the age of the pre-warm-up phase at which warm-up begins. These values can be compared with the observed abundance of methyl chloride in the hot corino IRAS 16293-2422 if the abundance of methanol is known. Finally, we have shown that the inclusion of halogenbearing species into our gas-grain network is not likely to affect the destruction rate of existing non-halogen-bearing molecules, but may affect their formation rate through the formation of intermediate radicals, as has already been shown for methyl formate.

F3.5-0008-18 OBSERVATIONAL DIAGNOSTICS OF TWO-FLUID TURBULENCE IN MOLECULAR CLOUDS - AS SUGGESTED BY SIMULATIONS

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The star-forming plasma in molecular clouds is indeed partially ionized. The low level of ionization in the plasma makes it possible to sustain several interesting phenomena that do not occur in single fluid MHD turbulence. In this talk we first analyze MHD wave propagation in such a partially ionized plasma, showing that only certain waves might propagate on the shorter length scales where ions and neutrals decouple. This length scale, known as the ambipolar diffusion length scale, is also interesting because the formation of molecular cores takes place on those length scales.

We then simulate this two fluid turbulence and analyze its properties. Several trends are shown to conform to the theoretical analysis in the previous paragraph. Based on that, we extract observational diagnostics associated with linewidth-size relationships of isophotologues and also density PDFs. The first diagnostic is shown to match up with observed data. The second diagnostic is entirely new, and awaits observational confirmation. Taken together, these two diagnostics might give us a different handle on the direction of the magnetic field in three dimensions. Further theoretical analysis of the turbulence is also presented.

F3.5-0009-18 THE DETECTION OF ABUNDANT COLD METHANOL GAS AT 0.2 SOLAR METALLICITY

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Observations of complex organic molecules in metal-poor environments will be crucial information for understanding organic chemistry in high-redshift galaxies where the metallicity was significantly lower than the present solar neighborhood. The Small Magellanic Cloud (SMC) is a nearby star-forming dwarf galaxy, whose metallicity is lower than typical Galactic values by a factor of five. Here we report the first detection of a complex organic molecule, methanol (CH3OH), in the SMC based on submillimeter observations towards a high-mass young stellar object with the Atacama Large Millimeter/submillimeter Array. Besides CH3OH, we also detect the dust continuum as well as emission lines of CS, C33S, H2CS, SO, SO2, H13CO+, H13CN, SiO, and tentatively HDS from the observed region. The target infrared point source is spatially resolved into two dense cores; one is associated with an embedded high-mass young stellar object, another is not associated with an infrared source but shows rich molecular lines. The first detection of CH3OH in the SMC has a strong impact on the formation of complex organic molecules in metal-poor environments. The fractional abundance of CH3OH gas in the observed dense core is estimated to be (0.5–2) x 10–8, which is comparable with those of similar

Galactic cold sources despite a factor of five lower metallicity in the SMC. This would indicate an enhanced production or a suppressed destruction of gas-phase CH3OH in the observed SMC source compared to Galactic counterparts. The gas temperature is estimated to be about 10 K based on the rotation analysis of CH3OH lines, suggesting that non-thermal desorption would contribute to the production of gas-phase CH3OH in the observed dense core. This work provides observational evidence that an

organic molecule like CH3OH, which are largely formed on grain surfaces, can be produced even in a significantly lower metallicity environment compared to our Galaxy.

F3.5-0010-18 POSSIBILITY OF PROTOSTELLAR INHERITANCE OF ORGANICS TO JUPITERFAMILY COMET 67P/C-G

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Complex organic molecules (COMs) play an essential role in the emergence of life. Understanding how, when and where COMs (including potentially prebiotic molecules) are formed is one of the most critical questions in the “Cradle of Life” science theme of astronomy. COMs have been detected in prestellar cores, protostars, and protoplanetary disks. Is it possible to preserve part of the molecular content during protostellar stage which can be incorporated into comets? By looking at the cometary compositions, observations of solar-type protostars can help to address this fundamental question. In this context, here we will present our observations towards the solar-type protostar IRAS 16293-2422 in the 3mm band of the IRAM 30m telescope along with current ALMA observations. We will describe how an integrative study using observations and chemo-dynamical simulations (using the state-of-the-art gas-grain-bulk (3 Phase) chemical-kinetic model) can help us to understand the chemical composition both on the surface as well as on the coma of comet 67P/C-G observed by the COSAC and ROSINA instruments onboard Rosetta spacecraft.

F3.5-0011-18 GLYCINE IN 67P/ CHURYUMOV GERASIMENKO: ASSESSMENTS ABOUT ITS ABUNDANCE AND ORIGIN

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Comets play a major role in the study of the physico-chemical processes that took place in our early Solar System. Moreover, they could have brought organic compounds to the primitive Earth that contributed to the chemical evolution that lead to the origin of life on Earth [1]. Thanks to groundbased observations and space missions, it is possible to measure the composition of these small bodies. Although most of the gaseous molecules detected in cometary atmospheres are produced from the sublimation of nucleus ices, other sources have to be taken into account, such as distributed sources, which provide further insight about the composition of the nucleus. Glycine, the simplest amino acid, has detected in the atmosphere of comet 67P/ Churyumov-Gerasimenko by the instrument ROSINA (Rosetta Orbiter Spectrometer Ion and Neutral Analysis) aboard the Rosetta probe. Its density presents a particular profile as a function of the distance from the nucleus [2]. In order to interpret these observations, a numerical model has been developed to calculate the abundance of glycine in the atmosphere of the comet 67P as a function of the distance from the nucleus, and derive its initial abundance in the nucleus. Three cases have been considered: (i) glycine emitted directly and only from the nucleus, (ii) glycine emitted from the sublimation of solid glycine on the particles ejected from the nucleus and (iii) glycine embedded in water ice and emitted from the sublimation of this ice from the particles ejected from the nucleus. The last two cases are called distributed source. Our results show that a unique source from the nucleus does not explain the profile of density measured by ROSINA. The best fit to the observations corresponds to a distributed source of glycine embedded in sublimating water ice from dust particles. We will discuss the abundance of glycine in these dust particles resulting from this modelling, and consequences on the chemical mechanisms that could have led to its formation in the cometary ices.

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F3.5-0012-18 THE ROLE OF COSMIC RAYS IN SETTING THE CHEMICAL CONTENT OF PROTOPLANETARY DISK MIDPLANES

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The chemical evolution of volatiles in protoplanetary disks begins in the earliest prestellar phase of star formation. Under the dark, cold conditions of cores the initial icy mantles of grains are built up. Already at this point, grain-surface chemistry starts to set the composition of these icy layers. Cosmic rays play a pivotal role here by setting the abundances of radicals available for the synthesis of more complex molecules and also for maintaining low abundances of gaseous molecules directly via spot heating and indirectly via reactive desorption. Protoplanetary disks are built up from the collapsing core materials, which are exposed to variable intensities of UV irradiation and heating. Cosmic rays continuously play a sub-dominant role in chemical processing during the collapse of the system and also in the outer, lower density regions of disks. Only in the innermost, high-density regions do they become attenuated. In this talk, the history of the protoplanetary disk composition will be unraveled with the help of sophisticated physicochemical models for a range of cosmic ray ionization rates (expansion of Drozdovskaya et al. 2014, 2016). The models will be used to access the degree of importance of cosmic rays in setting the abundance of volatiles in protoplanetary disk midplanes. Cometary data will be contrasted against the modeled volatile quantities, taking into account a range of possible cosmic ray ionization rates.

F3.5-0013-18 ORIGIN OF COMPLEX LIFE GIVING MOLECULES THROUGH GAS, GRAIN, ICE, CLAY AND OCEAN CHEMISTRY

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In the cold and tenuous environs of interstellar medium dusts act as catalysts to produce the simplest molecules in space. During the collapse of a proto-stellar cloud, through repeated gasgrain interaction these simple molecules become more complex. In presence of cosmic rays, ice chemistry can contribute to further complexation. After these are bombarded by comets and meteorites on planetary surfaces two more processes, namely the clay chemistry and the ocean chemistry may be very important to have life giving molecules. I review these processes and conjecture some essential requirements on the way to producing the biomolecules. Observations of the key molecules at each stage, or at least the precursors would be required to pinpoint the complete route to life out of the sea of random processes.

F3.5-0014-18 DEUTERATION OF THE INTERSTELLAR MEDIUM

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Despite the low elemental abundance of atomic deuterium in the interstellar medium (ISM), observational evidence suggests that several species, both in the gas phase and in ices, could be heavily fractionated. The high abundance of some abundant and simple interstellar species could be explained by considering the chemistry that occurs in interstellar dust. Because of its simplicity, the rate equation method is widely used to study the surface chemistry. However, because the recombination efficiency for the formation of any surface species is highly dependent on various physical and chemical parameters, the Monte Carlo method is best suited for addressing the randomness of the processes. We carry out Monte-Carlo simulation to study deuterium enrichment of interstellar grain mantle under various physical conditions. Moreover, we explore various aspects of deuterium enrichment by constructing a chemical evolution model in both gaseous and granular phases (by considering the rate equation method). Depending on various physical parameters, gases and grains are allowed to interact with each other through the exchange of their chemical species. Obtained deuterium fractionation of some abundant interstellar ions is then used to predict the ionization degree around the various region of a molecular cloud. This gas-grain model is further utilized to predict the abundances of some new complex deuterated species. Quantum chemical calculations were implemented in our computation to prepare the reaction pathways of these deuterated species and supplement our results with the observation-specific information. The simple radiative transfer method is also used to justify our results.

F3.5-0015-18 COMPLEX MOLECULES AND DEUTERATION IN A PRISTINE JET-DISK SYSTEM, HH212

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The HH212 is a Class 0 protostar in Orion. The source has bipolar jet and a rotating disk. The disk shape is like a hamburger as recently resolved by an ALMA observation. Complex molecules like methanol(CH3OH), formamide (NH2CHO), methanethiol (CH3SH) and deuterated complex moleculeCH2DOH has been observed in the rotating environment near the disk surface and central hot source. There are other molecules, e.g., deuterated water (HDO), deuterated formaldehyde (HDCO) which has been observed near the central source and in some cases in the outflow region. The deuteration of molecule mainly occurs in cold prestellar phase via the reaction pathways involving the H2D+ ion. Here, we will discuss the origin of complex molecules (6 atoms or higher) in disk environment and deuterium fractionation in different regions of the HH212 system. Studying deuterium fraction of molecules like methanol and formaldehyde, we speculate possible reaction pathways of molecules in gas phase or dust/grain phase

F3.5-0016-18 PRESENCE OF HIGHER ORDER THIOLS IN STAR-FORMING REGION

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Alcohol and thiol have a similar chemical structure where only O atom in alcohol is replaced by S atom in thiol. In the Interstellar medium, an interesting relationship exists between the alcohol and thiol. Methanol and ethanol are widely observed and 1-propanol was recently claimed to have been detected in Orion KL. Methanethiol (chemical analog of methanol) has been firmly identified in the diverse region of the ISM. Presence of ethanethiol (chemical analog of ethanol) towards the dense and warm region of the ISM such as Orion KL, Sgr B2 is questionable. Higher order thiols could be observed in these regions. Here we study the formation of monohydric alcohols and their analogous thiols. Based on quantum chemical calculation and chemical modeling, we find that the Tg conformer of 1-propanethiol is a potential candidate of astronomical interest. We present various spectroscopically relevant parameters of this molecule to assist its future detection in the warm region of the interstellar medium.

F3.5-0017-18 A SYSTEMATIC STUDY OF PRE-BIOTIC ALDIMINES AND AMINES IN HOT CORES

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A thorough understanding of the formation of biomolecules in space is an demanding topic of scientific interest for a very long time. Among almost 200 interstellar and/or circumstellar species (most of them are organic in nature) detected in space, aldimines and amines are basic building blocks of amino acids which are the main biological components for life formation. We consider six isomeric groups (CH3N, CH5N, C2H5N, C2H7N, C3H7N and C3H9N) containing at least one aldimine or amine to review the presence of amines and aldimines within the ISM. The simplest amino acid, namely, glycine could have been formed by the reaction between methanimine and formic acid. Again methylamine could be produced by two successive hydrogen addition reactions with methanimine. In that sense, they are both the precursor of simplest amino acid. Methanimine (CH2NH) from CH3N and methylamine (CH3NH2) from CH5N isomeric group were detected in Sgr B2 a few decades ago. Recently, the presence of ethanimine (CH3CHNH) from C2H5N isomeric group has been discovered in the ISM towards Sgr B2(N). This prompted us to investigate the possibility of detecting any aldimine or amine from the very next three isomeric groups in this sequence; i.e., C2H7N, C3H7N and C3H9N. We employ high level quantum chemical calculations to estimate accurate energies of all the species considered. According to calculated chemical abundances, enthalpies of formation, optimized energies, and expected intensity ratio, we found that ethylamine (also the precursor of glycine) from C2H7N isomeric group, (1Z)-1-propanimine from C3H7N isomeric group, and trimethylamine from C3H9N isomeric group are the most viable candidates for the future astronomical detection. Based on our quantum chemical calculations and from other approximations (from prevailing similar types of reactions), a complete set of reaction pathways to the synthesis of ethylamine and (1Z)-1-propanimine is prepared. Moreover, a large gas-grain chemical model is employed to study the abundance of these species in the ISM. Our modeling results suggest that ethylamine and (1Z)-1-propanimine could efficiently be formed in hot-core regions and could be observed with present astronomical facilities.

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F3.5-0018-18 A NEW CHEMICAL MODEL OF THE LOW-MASS PROTOSTAR IRAS 16293- 2422

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IRAS 16293-2422 (hereafter IRAS16293) is a deeply embedded low-mass protostar at a distance of 120 pc from the Sun. It has been identified as a binary, with sources A and B separated by 620 AU. The ALMA survey PILS (Protostellar Interferometric Line Survey) has identified a rich chemistry toward IRAS 16293 (Jorgensen et al. 2016., [1]), including the first detections toward a low-mass source of the complex organic molecules glycolaldehyde (CH2OHCHO), ethylene oxide (c-C2H4O) and propanal (C2H5CHO).

We have run chemical simulations of IRAS16293 using the coupled gas-phase, grain-surface, and ice-mantle chemical kinetics model MAGICKAL (Garrod 2013, [2]). However, the simple, single-point treatments that are used in hot core-type models to reproduce generic physical conditions in such sources do not appear to completely reproduce the observed abundances. It is likely that more specific, self-consistent treatments are required for the spatio-temporal evolution of the physical parameters such as gas density, temperature, and UV radiation field strength.

We present physical/chemical simulations of IRAS16293 as a spherical symmetric core with a single protostellar heating source. We compute the density profile by combining the observationally determined profile of Schöier et al. [3] with a free-fall collapse, assuming that the final stage of stage collapse corresponds to the current state of IRAS16293. Thus, we obtain the spatiotemporal evolution of the density that we then feed into the radiative transfer code RADMC- 3D (Dullemond 2012, [4]) to produce temperature and radiation field intensity profiles. These physical parameter profiles are then used in MAGICKAL for specific trajectories, to obtain the evolution of the chemical species abundances, including complex organics. Preliminary chemical abundances and spectral simulations are presented with comparisons to recent PILS detections. These represent the most chemically-complex simulations to date of IRAS16293.

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F3.5-0019-18 RADIATIVE TRANSFER MODELING OF SOME POTENTIALLY OBSERVABLE INTERSTELLAR SPECIES

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In case of Astrochemistry, the main application of radiative transfer is the estimation of molecular abundances from line spectra. Using LTE approximation is comparatively easier as it requires a minimal amount of parameters but not suitable to use at lower densities because at lower densities Tex < Tkin. The non-LTE approximation is required in such cases but it often requires molecular collision data as an additional input which is often missing. Recently, Sil et al. (2017) and Gorai et al. (2017) proposed ethylamine, (1Z)-1-propanimine and propargyl alcohols as strong candidates for future astronomical detection. Here, we have performed both the LTE and non-LTE calculations for these species under various physical circumstances. In absence of measured or calculated collisional data files, we have used our estimated collisional rate (which was parametrized to have an educated estimation). for the non-LTE calculations. Calculated LTE and non-LTE transitions are compared under various physical condition.

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F3.5-0021-18 THEORETICAL INVESTIGATION OF INTERSTELLAR C-C-O AND C-O-C BONDING BACKBONE MOLECULES

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There are numerous complex organic molecules containing carbon and oxygen atoms which show either C-C-O or C-O-C bonding backbone. This paper examines altogether 51 C-C-O and C-O-C bonding backbone molecules from ten different isomeric groups (C_2H_2O, C_3H_2O, C_2H_4O, $C_2H_4O_2$, C_3H_4O, C_2H_6O, $C_2H_6O_2$, C_3H_6O, $C_3H_6O_2$, C_3H_8O) to summarize the present astronomical status of these molecules. Accurate calculations of enthalpy of formation of these molecules show that the isomers with C-C-O backbone are more stable than the C-O-C backbone. Interestingly, a detailed analysis of relevant astromolecules indicates that most of the observed astromolecules have the C-C-O backbone. As a matter of fact, of all the molecules examined in this study, 80% of the astronomically observed species have the C-C-O backbone while only 20% have the C-O-C backbone. In general, interstellar abundance of a molecule is controlled by some factors such as kinetics, formation and destruction pathways,thermodynamics etc. A proper consideration of these factors could explain the observed abundances of these molecules. All these possible key factors will be discussed during the presentation.

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F3.5-0022-18 QUANTUM CALCULATIONS OF REACTIONS ON A SURFACE; APPROXIMATIONS, PITFALLS, AND SUCCESSES

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The darkness readily observed between the stars on a clear night is far from empty. The low temperatures (T = 10 K) in dark molecular clouds combined with the low particle densities (n= 104 cm3) make it seem unlikely for chemistry to take place efficiently. The chemistry that occurs can be partly explained by the presence of ice-coated dust grains on which molecules freeze out and, when they find each other, react. These grains act both as a molecule reservoir and as an energy sink for exothermic reactions. As such they allow a rich chemistry to occur.

To be able to explain, or better yet, to make predictions on astronomical observations, it is crucial to have an accurate understanding of the elementary processes that occur on these icy grains. They consist - amongst others - of adsorption, diffusion, reaction, evaporation, and energy dissipation. In this talk I aim to provide an overview of computationally feasible methods that allow the above processes to be quantified.

Adsorption and evaporation are both dictated by the binding energy of species on the surface. I will comment on several recent works that have shown that binding of atoms and molecules is not well-described by a single binding energy or orientation, but rather that a distribution should be considered.

For barrierless reactions, the orientation of the reactants with respect to each other as well as on the surface plays a role in determining which reactions can take place. Radical-radical reactions often have various possible outcomes and branching ratios need to be defined. In this presentation I will discuss an approximate way to calculate such branching ratios, which pitfalls may arise in doing so and point out what the influence of surface molecules can be.

Barriers at cryogenic temperatures, on the other hand, can only be overcome when tunneling is invoked as a crucial component of the reaction mechanism. Hydrogen is very abundant in the interstellar medium and many surface reactions involve H transfer reactions, ultimately leading to the formation of saturated species. I will elaborate on recent findings of the influence of an ice environment on reaction rate constants, how and when an ice can be approximated without taking into account all degrees of freedom, and how the rate constants are to be interpreted in the light of astrochemical mean-field models and observations.

Especially for reactions with H atoms, the competition between diffusion and reaction needs to be taken into account in astrochemical models. However, diffusion rate constants for H atoms have been shown to range over many (10) orders of magnitude and therefore competition with reaction depends heavily on the assumption which binding sites are most probable. I will comment on the competition under various assumptions, i.e., high and low H and H2 coverage.

Finally, energy dissipation after reaction is taken care of by the third body of the reaction, which is the icy grain itself. There is currently relatively little known on how the energy is distributed between various rotational, vibrational, and/or translational modes as well as on which typical timescales are involved. I propose a method based on a phonon projection scheme to understand energy dissipation on an atomistic level.

F3.5-0023-18 THERMODYNAMICS EQUILIBRIUM ON GAS PHASE UNDER LOW PRESSURE AND LOWER TEMPERATURES

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More than 200 organic and inorganic molecular species consisting of up to 13 atoms have been identified in space, of which about 10% are molecular ions. The rich variety of the observed molecules implies that much more relevant yet undiscovered species must be involved in the formation and destruction processes of theirs. However, the formation of these molecules it has not been yet fully understood. The formation/destruction pathways of molecules via gas phase or grain-surface pathways must be very sensitive to the activation energy barrier, isomerization process and electronic state from both reactants and products. The majority of, if not all, hydrocarbons with more than two carbon atoms have at least two and often more isomers with similar frequencies (within a few cm-1) for their vibrational transitions. Also, the number of isomeric form increase as the number of atoms in molecules is increasing. Also, reaction networks made by the Astronomers and astrophysics are not saying anything regarding the structure isomer possibility, is because is not well known the isomeric effect on the structure and chemical reactivity in those kinds of reactions. If so, it must be considered few aspects regarding isomerization and electronic state of molecules. In this work, we would like to present a theoretical study of reaction channels and spectroscopic constants for essential astrophysical molecules as SiC3H+, SiC3H, and HCO+. The geometries and vibrational frequencies of the most relevant isomers and cations were optimized with the hybrid density functional method B3LYP/cc-pvTZ with the non-local correlation functional of Lee and the Dunning's correlation consistent basis set cc-pvTZ (Dunning 1989). We included CCSD(T)/cc pvTZ single point energy to obtain more reliable energies using the B3LYP/cc-pvTZ geometries. Anharmonic spectroscopic parameters for the ground electronic state of the most stable structures were also obtained from anharmonic force fields using second-order perturbation theory at B3LYP/cc-pvTZ level of theory. Our data is helpful for understanding structures and properties of SiC3H+, SiC3H, and HCO+ families, being valuable data for their detections in the interstellar space and laboratory. Knowing which molecules are in the interstellar medium will allow a better understanding of what types of chemical reactions are possible in space.

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F3.5-0024-18 PHOTOCHEMISTRY OF ORGANIC MOLECULES IN THE SOLAR SYSTEM: EXPERIMENTAL STUDIES OUTSIDE THE INTERNATIONAL SPACE STATION. THE CASES OF GLYCINE, AND NUCLEOBASES

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Solar UV radiation is a major source of energy for initiating chemical evolution towards complex organic structures, but it can also photo-dissociate even the most complex molecules. Thus, solar UV can erase the organic traces of past life at the surface of planets, such as Mars, destroy organic molecules present on meteorites and micrometeorites, influence the production of distributed sources in comets or initiate chemistry in Titan's atmosphere. In the interstellar medium, the UV radiation field emitted by stars in the galaxy is also responsible for the chemical evolution and the extraordinary diversity of organic molecules detected.

PSS (Photochemistry on the Space Station) was a Low Earth Orbit (LEO) experiment, implemented from mid-2014 to early 2016 on the EXPOSE-R2 platform outside the International Space Station. Its goal was to improve our knowledge about the chemical nature and evolution of organic molecules with astrobiological implications in space environments. It was a new step in a series of experiments conducted outside the MIR space station, in the ESA BIOPAN and previous EXPOSE facilities. In PSS, both vented and sealed cells were used allowing exposure of both solid and gaseous samples. Five kinds of experiments was carried out exposing molecules related to different environmental factors of astrobiological significance: the interstellar medium, comets meteorites, Titan, Mars, as well as a set of samples to test the stability of biochips in space.

In this talk we will describe the PSS experiment and focus on some results related to the stability of some prebioticaly relevant compounds such as glycine, the simplest amino acid, and nucleobases such as uracil, guanine and adenine. These molecules were both exposed in Low Earth Orbit and studied in the laboratory in order to derive their photochemical lifetime if they are ejected from comets on dust particles and orbit around the Sun before reaching the Earth as micrometeorites. The results can lead to better understand the contribution of cometary particles in the establishment of an organic reservoir on primitive Earth.

F3.5-0026-18 STUDIES ON KNOWN AND POTENTIAL INTERSTELLAR CARBON CHAIN MOLECULAR SPECIES

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This work reports the computational studies and chemical modelling on one of the main themes in interstellar chemistry; the interstellar carbon chains molecular species such as Cn, H2Cn, HCnN and CnX (X = N, O, Si, S, H, P, H, N). These sets of molecules account for about 20% of all the known interstellar and circumstellar molecules. Their high abundances, therefore, demand serious attention. High-level ab initio quantum chemical calculations are employed to accurately estimate the enthalpy of formation, chemical reactivity indices, global hardness and softness, and other chemical parameters of these molecules. Chemical modeling of the abundances of these molecular species has also been performed. Of the 89 molecules considered from these groups, 47 have been astronomically observed, and these observed molecules are found to be more stable with respect to other members of the group. Of the 47 observed molecules, 60% are odd-numbered carbon chains. Interstellar chemistry is not actually driven by thermodynamics, but it is primarily dependent on various kinetic parameters. However, we found that the detectability of the odd-numbered carbon chains could be correlated due to the fact that they are more stable than the corresponding even-numbered carbon chains. Based on this aspect, the next possible carbon chain molecule for astronomical observation in each group is proposed. The effect of kinetics in the formation of some of these carbon chain molecules is also discussed.

Keywords: Interstellar medium, abundance, astrochemistry, stability, carbon-chains

References: Anderson, J. K., Ziurys, L. M. 2014, ApJL, 795, L1 Etim, E. E., Gorai, P., Das, A., Chakrabati, S. K., Arunan, E. 2016 ApJ, 832, 144. Doi:10.3847/0004-637X/832/2/144

F3.5-0027-18 INVESTIGATIONS OF PHOTOCHEMISTRY AND SPECTROSCOPY OF INTERSTELLAR ICY MOLECULES AND MATERIALS UPON EXCITATION WITH FUV LIGHT

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FUV photochemistry and spectroscopy of interstellar icy molecules and materials attract interest because information from these studies yields detailed knowledge about chemical transformations in extraterrestrial environments. To study the photochemistry and spectroscopy of solid interstellar molecules and materials, we have performed experiments using far-ultraviolet light dispersed from synchrotron beamlines coupled to the Taiwan Light Source (TLS) at National Synchrotron Radiation Research Center (NSRRC) in Taiwan. Taking the advantage of the unique property of synchrotron, we are exploring the FUV photochemistry and spectroscopy of interstellar icy molecules and materials with exciting prospects. In this presentation, we will discuss the FUV photochemical processes of icy molecules containing N2 and O2. These investigations improve our understandings of the transformations of oxygen and nitrogen species and open windows for perceptions of the mechanisms of photolysis in a solid phase. Also, we will present the first direct experimental evidence that diamond nanoparticles containing nitrogen-vacancy (NV) defects are capable of emitting red photons upon exposure to FUV radiation. The knowledge is crucial for the identification of NV as the carrier of extended red emission (ERE) bands detected in diverse astrophysical environments. Our results provide strong evidence that nanodiamonds are a major component of cosmic dust in the interstellar medium. Our model lends strong support to the notion that diamond nanoparticles are a major component of interstellar dust in space.

F3.6-0001-18 THE MAPPING IMAGING SPECTROMETER FOR EUROPA (MISE) INVESTIGATION: EXPLORING EUROPA USING COMPOSITIONAL MAPPING

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Introduction: The Mapping Imaging Spectrometer for Europa (MISE) is being designed as a high-optical throughput pushbroom spectrometer that can collect measurements within Europa's challenging radiation environment. MISE is planned to cover a spectral range from 0.8-5 µm with a spectral sampling of 10 nm. With an instantaneous field of view of 250 µrad/pixel and a swath width of 300 pixels, this design yields 25 µm/pixel spatial sampling in a swath 7.5 km wide at 100 km altitude, and 10 km/pixel scale full disk images at 40,000 km. MISE could return composition information for each pixel in the image measured. MISE could be used to identify and map the distributions of organics, salts, acid hydrates, water ice phases, altered silicates, radiolytic compounds and warm thermal anomalies. Mapping the composition of specific landforms is critical to understand surface and subsurface geologic processes, including recent or current activity. High spatial resolution compositional mapping is also essential for detecting small outcrops of potentially recent endogenic material.

Assessing Habitability and Potential Biosignatures: MISE is suited for assessing habitability and potentially detecting biosignatures. A potentially habitable environment is one that is capable of supporting life, though it may not be inhabited [1]. The generally accepted ingredients for an environment capable of hosting life as we know it include a source of "free energy" (available to do work of some sort), organics, and liquid water. In addition, contact of liquid water with rock, providing a source of the elements needed for biological processes, is also assumed to be essential. Given the determination that a global layer of liquid water exists below Europa's crust, three lines of evidence will be investigated to assess habitability: 1) presence and distribution of organics including complex organics such as amino acids; 2) salt chemistry of the ocean; and 3) evidence of current and recent surface change as a proxy for internal activity. A biosignatures are any substance that provides evidence of past or present life [2]. The challenges and potential for biosignature detection with MISE will also be explored and will focus on the key question: what types of biosignatures might be present and preserved on the surface that are detectible by MISE? [1] McKay C. P. (1991) Icarus, 91(1), 93-100. [2] Europa Lander

Science Definition Team https://solarsystem.nasa.gov/docs/EuropaLanderSDTReport2016.pdf

F3.6-0002-18 DETECTING LIFE IN ICY WORLDS: KEEP IT SIMPLE

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Looking for life in any extraterrestrial environment should revolve around a few major assumptions that one hopes must be common to all life: 1) life will need a structure capable of separating the living interior from the non-living exterior environment - i.e., it will be membrane-bound and therefore cellular; 2) life will have an elemental composition that distinguishes it from the non-living world; and, 3) life will have a complex chemical composition that distinguishes it from non-life. No matter how one defines it, life will need energy and a way to store that energy and use it as needed. Of necessity, this will require a structure that separates the metabolism of the life form from the exterior environment. This should be recognizable as a cell-like structure, and should be the first goal of life detection. Life on our planet is distinguishable from non-life by its elemental composition. Any small structures can be easily tagged as potential life by its elemental composition (C,N,P,H,O with a predictable cadre of minor elements). There are no abundant minerals that contain anything near the elemental ratio of earthly life, and one might expect a similar situation for life anywhere. Not that it be the same as our earthly life, but that it be distinct from the abiotic part of the environment. Elemental analysis of cell-like structures will separate the cell-like inorganics from the potential life forms. Find the structures and measure their composition. While organics such as amino acids, fatty acids, and sugars can be found "everywhere", life on our planet is rather picky about which of these components it has chosen. Of the hundreds of amino acids that could be formed (many of which have been detected in meteorites and interstellar space), only 20 are major components of earthly life. Furthermore, their abundance is in no way predictable by thermodynamics - they are in the abundance needed to make life's complex proteins. The same can be said of fatty acids - their abundance in living systems, which can be easily measured, is not consistent with thermodynamics: life makes what it needs. When structures are found, make simple organic measurements - amino acid and fatty acid content - it doesn't have to be like earthly life, but it needs to be something unique for life. These ideas will be discussed with thermodynamic calculations to back them up and suggestions for making the measurements.

F3.6-0003-18 SEARCHING FOR LIFE IN AN OCEAN WORLD: THE ENCELADUS LIFE SIGNATURES AND HABITABILITY (ELSAH) MISSION CONCEPT

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The Enceladus Life Signatures and Habitability (ELSAH) mission concept aims to directly sample the plume of Enceladus, a moon of Saturn, to search for evidence of life and to assess the habitability of its subsurface ocean. It was proposed to New Frontiers 4 in 2017 and was judged selectable. ELSAH was awarded technology development funding to develop cost-effective techniques that limit spacecraft contamination and thereby enable life detection measurements on cost-capped missions.

Through repeated flythroughs of the plume, the Cassini Mission has shown that the ice particles originate from a interior ocean, that the ocean is slightly salty, that hydrothermal activity is occurring and water is in contact with rock, that organic material, sulfur and nitrogen are present in forms that can be used by biology, and that there are chemical energy sources that on Earth can sustain metabolic activity.

ELSAH flies to Enceladus to follow up on these exciting discoveries, and to determine if life is present in the ocean. As the spacecraft flies through the plume, it will collect ice particles and then melt them. The resulting liquid sample will then be delivered to the analytical instruments that are capable of identifying four key life signatures: 1) relative concentrations of proteinogenic amino acids, 2) amino acid enantiomeric excess, 3) lipid molecular patterns, and 4) lipid distributions. Together these four measurements will be used to assess if ocean life is present on Enceladus and its signatures are found in the plume particulates. The same measurements will also support the detection of abiotic signatures, assessing the role that cometary and meteoritic material may be directly contributing to the organics in the plume. In addition, ELSAH will measure properties of the ice-water plume particles (pH, salinity, etc.) to further understand the habitability of the ocean and corroborate Cassini findings. Imagers will document surface and vent features on Enceladus to further our understanding of plume sources.

The Enceladus ocean may be the most characterized habitable environment for extant life beyond Earth known today and the Enceladus plume is beckoning as a door of opportunity for us to study its ocean without having to land or drill through the ice cover. ELSAH builds on these prospects to address NASA's goal to search for life in our Solar System and open a new frontier in space science.

F3.6-0004-18 THE SEARCH FOR LIFE ON ICY WORLDS: LUMINESCENCE IMAGER FOR EXPLORATION

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A major lesson learned from the Viking Mission search for life on Mars, that should be applied to Icy World exploration, is that an appropriate understanding of the exploration environment is needed to inform both instrument design and interpretation of results. Target biosignatures may be affected by naturally occurring changes in environmental conditions over time, well as by rapid perturbation of samples from their natural environments during sample excavation and analysis. A lack of a priori understanding of the Viking lander environmental context resulted in both false positives (Labeled Release Experiment) and false negatives (Viking Gas Chromatograph Mass Spectrometer), which have taken decades to recognize and resolve. The 2016 Europa Lander Science Definition Team (SDT) Report has now defined a model payload for an anticipated Europa mission focused on the search for life. The primary classes of mission instruments selected by the SDT are an Organic Compositional Analyzer (OCA), a Microscope for Life Detection (MLD), and a Vibrational Spectrometer (VS). The specific instruments baselined by the SDT for each instrument class are: a Gas Chromatograph-Mass Spectrometer (OCA-class); combinations of spectroscopy and atomic force microscopy or optical light microscopy (MLD-class); and a Raman and Deep UV fluorescence spectrometer (VS-class). Consideration of the Europa Lander SDT-defined science traceability matrix and model payload in the context of lessons learned from Viking is guiding our development of a microscope for life detection, the Luminescence Imager for Exploration (LIfE), with submicron dark-field and fluorescence imaging, as well as integrated microfluidic sample handling and processing capability. This NASA COLDTech-funded development entails modification of a 2U cubesat fluorescence imager, designed and built at NASA Ames Research Center, for the autonomous study of microbial biology in low earth orbit. In addition to using this modified platform to search for potential biostructures using UV-Vis optical imaging, our goal is to characterize critical sample geological and chemical parameters. These measurement parameters, which include sample pH, conductivity, and redox potential, not only provide major science return independent of the presence or absence of chemical and/or structural indicators of life, they are also used as information drivers for the autonomous processing of samples for fluorescence imaging. Through automated measurement and control, the sample environment is manipulated to allow staining of key chemical and structural indicators of microbial life (proteins, lipid membranes, nucleic acids) for fluorescence microscopic detection. We will discuss LIfE technologies and measurement strategies in the context of the search for biomarkers in poorly understood and changing environmental conditions.

F3.6-0005-18 A UNIVERSAL APPROACH IN THE SEARCH FOR LIFE AT THE MOLECULAR LEVEL

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An extremely powerful approach in the search for life on icy worlds is to search for molecular biosignatures [1]. On planetary missions, these biosignatures could be sought directly from a physical sample in situ using techniques that take a holistic approach to assessing the chemical inventory. This is possible by not only searching for the presence of known, potentially biogenic organic molecules (such as proteins, DNA, RNA, etc.), but also by capturing a broadly representative chemical profile of the population of molecular species and structures (e.g. intrinsic complexity, ligand and carbon-number patterns, and stereochemical properties). This approach, in which relative populations of molecules and molecular properties are measured objectively, enables a thorough, low-ambiguity means for biosignature identification.

Enacting a semi-exhaustive and universal molecular search for life on an astrobiology mission presents significant technical challenges, and necessitates new, highly-integrated approaches to be implemented in space-ready instrumentation. Mass spectrometry (MS) has a long history of successful spaceflight implementation and for the identification of molecules in an unknown sample it is a powerful technique. However, each environment and mission opportunity levies unique challenges and requirements on a mass spectrometer investigation, with a key missionspecific factor being the proper design of the sampling "front end" of the MS, as this is the interface between the sample and its analytical detector. In order to compile the broadest possible inventory of organic molecules required for a universal search for life, the investigation must efficiently transfer a statistically unbiased majority of the sample's native organics into a mass spectrometer where they can be analyzed. No single technique is capable of accomplishing this transfer efficiently for all possible molecules encompassing a wide range of chemical properties. In particular, one such parameter that strongly determines the optimal route to transfer a molecule into a mass spectrometer is its polarity. To gain access to both polar and non-polar organics more than one analytical technique will need to be interfaced with the MS.

Gas chromatography-MS (GC-MS) is readily amenable to the analysis of non-polar, volatile, and semi-volatile molecules; however, it is generally challenged when presented with polar, water-soluble, less-volatile organics. For the water-soluble fraction, liquid-based separation techniques such as capillary electrophoresis are analogous to GC in their ability to sensitively and quantitatively elucidate molecular structure when coupled to MS. Significant progress in liquid extraction, liquid sample handling, liquid separations, and the interfacing of liquid analyses to mass spectrometers has been made in the last decade. These functionalities are now ready for incorporation into an MS-based instrument suite in order to provide the remaining capabilities needed for the most exhaustive, universal search for life at the molecular level. This capability will be particularly important on missions to ocean worlds such as Europa or Enceladus where a spectrum of complex water-soluble organic molecules would be expected to govern the potential emergence of life and its biochemistry.

This presentation will present the current state of the art in instrument developments from the past several years and describe how they could be leveraged to support an MS-based instrument suite capable of analyzing gas, liquid, and solid samples representing a broad and robust approach to analysis of potentially-biogenic organic molecules on icy worlds.

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F3.6-0006-18 THE WATSON PROJECT: BIOSIGNATURE MAPPING IN SUBSURFACE ICE

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The WATSON Project

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We are developing a down-borehole deep-UV (248 nm) fluorescence/Raman instrument coupled to an ice drill for in situ analysis and characterization of glacial ice microenvironments. Referred to the as the Wireline Analysis Tool for Subsurface Observation of Northernice sheets (WATSON) Project, the ultimate goal of our program is to provide an understanding of microbial and organic distribution in terrestrial ice cores as well as develop in situ techniques adaptable for the exploration of the ice crusts of Ocean Worlds and the polar ice caps of Mars.

Subsurface ice environments, such as those in Greenland, provide a historical record of the microbial surface for a microbiome trapped in ice. The current assessment of these low bioload environments, from 100 to 1000 microbial cells per mL, is that their distribution is confined to discrete depositional layers and in brine channels. However, the spatial distribution of microbes and organic and their correlation to dust particles and brine channels, and has not been demonstrated in natural ice cores. Understanding this provides 1) an understanding of the “habitable” zones within ice 2) provides a unique assessment of whether the bioload is active and 3) demonstrating that down-borehole sensing can be used to target areas of organics/microbial layers.

In early April of 2017, we conducted a field campaign to the Greenland ice sheet near Kangerlussuaq, Greenland. We used a Kovacs manual coring drill to acquire several 14-cm and 9-cm ice cores over several locations on the ice sheet. Each core was scanned in the field using a multi-band UV-fluorescence system to obtain a baseline for contamination. The cores were then shipped and stored at the Subzero Research Facility at Montana State University. After shipment and storage, the core sections were rescanned in a 1000 class cleanroom/cold room using a UV-fluorescence system to assess contamination from transport and storage. Core sections were then cleanly cut and spectral maps of the freshly exposed surface taken. Following the examination of the spectral maps, key layers were systematically sectioned, scanned sagittally, and then melted and the bulk melt examined for total organic carbon (TOC), total nitrogen (TN), epifluorescence microscopy, scanning electron microscopy (SEM), and Excitation/Emission Maps (EEMs). These traditional bulk analysis techniques were used to ground truth the spectral maps.

We observed that the contamination from the exterior of the core extended up to 2 cm into the core and appeared as spectral hot spots and diffuse organics signatures, correlating to a TOC level of up to 1 ppm; a value that was 10x greater than the interior. The spectral and spatial diversity of the 150 ppb TOC interior shows that the lateral distribution of organics and microbes are highly clumped in some layers but diffuse in others. analytical instrumentation allows us to spatially map and characterize features of interest that correlate to more traditional bulk melt methods to understand habitable zones within the ice and factors than drive these distributions.

F3.6-0007-18 OCEAN WORLD ICY PLUME SAMPLE RETURN: INTACT COLLECTION AND ENCAPSULATED SAMPLE ANALYSES

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A combination of intact capture and in-situ detection of organic molecules from extraterrestrial environments is a key step towards understanding the variety and distribution of the building blocks of life other than the terrestrial one. The best candidate in terms of technical feasibility of our time is to sample currently ejecting icy plumes of the Satrun’s satellite Enceladus.

While gas chromatography/mass spectrometry (GC/MS) has been dominantly used as successful and robust organic detection system in space, it is not suited for the separation and detection of non-volatile, heat-degradable organic molecules. Using polypeptides as a candidate molecule target, we we able to separate 16 out of the 17 tripeptides consisting of abiotically available amino acids by using capillary electrophoresis (CE). This can be regarded an example of possible bio-signatures that can be found in habitable extraterrestrial environments such as deep habitats of internal oceans of satellites of gas giants like Enceladus.

We further used these peptides for the simulated Enceladus sample return using hypervelocity impact experiment facility at the same encountering velocity (i.e., 4-6 km/s) as flying through sampling mission to its plumes like the LIFE mission concept. As a result by using the spaceproven 0.01g/cc aerogels, two peptide peaks corresponding to negatively charged peptides were detected, thus representing a full simulation of the capture, extraction and analysis of peptides from plume particles. Since the aerogel module is crushable and can be soaked with the electrophoresis agents/solutions and injected to capillary, this media can be used for in-situ wet analysis, in addition to previously known usage for sample return missions.

Planetary protection is considered to be one of the most crucial challenges to enable sample return missions from “Ocean Worlds”, internal oceans of icy satellites as potential deep habitat such as Enceladus and Europa, due to the risk of backward contamination of bringing back potential biology-related matters or at most, possible extraterrestrial living signatures to the Earth.

Here we propose an innovative technological solution for both life detection and planetary protection of such returned samples, namely by conducting all major life signature searches, which are also a critical path of quarantine processes of planetary protection, inside the Earth return capsule, prior to open the canister and expose to the terrestrial environment.

We plan to test the latest sample capture and recovery methods of preparing multiple aliquot chambers in the sample return capsule. Each aliquot chamber will trap, for instance, plume particles and ambient volatiles during the spacecraft flying through Enceladus plumes so that respective analyses can be performed focusing on volatiles and minerals (i.e., habitability for life), organics (i.e., ingredients for life), biosignatures (i.e., activity of life) and for archiving the samples for future investigations at the same time.

In-situ analysis will be conducted under complete containment through an optical interface port that allows pre-installed fiber optic cables to perform non-contact measurements and capillary tubing for extraction/injection of gas and liquids through metal barriers to be punctuated inside a controlled environment.

Once primary investigations are completed, the interior of the capsule will be sterilized by gamma rays and UV irradiation. Post-sterilized aliquot chambers will be further analyzed under enclosed and ultraclean environment at BAL 2-3 facilities, rather than BSL4. We consider that this is an unique solution that can cope with severe requirements set for the Category-V sample returns for astrobiology-driven missions.

F3.6-0008-18 SPLICE: A MICROFLUIDIC SAMPLE PROCESSOR TO ENABLE THE SEARCH FOR LIFE ON ICY WORLDS

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We will report the design, development, and laboratory testing of the Sample Processor for Life on Icy Worlds (SPLIce) system, a microfluidic sample processing "front end" to enable autonomous detection of signatures of life and measurements of habitability parameters on Ocean Worlds. Multiple versions of this monolithic fluid processing-and-handling system (mass 0.5 kg) are under development to support two nominal mission scenarios: a fly-through of Enceladus' icy plumes, which is expected to yield 2 µL of ice particles/m2 of collector area per pass at 20 km elevation, and a Europan lander, the drill-based sampling system of which is anticipated to deliver 1 - 5 mL of icy solids.

The analytical instruments and sensors for which SPLIce sample preparation sequences are being explicitly tailored and developed include microchip capillary electrophoresis [1] combined with laser-induced fluorescence detection; mass spectroscopy detection [2] of samples following either derivatization and separation by gas chromatography, or separation by capillary electrophoresis; a suite of electrochemical sensors, including ion-selective electrodes [3]; and multiwavelength fluorescence microscopy.

The SPLIce monolithic-manifold processes, distributes blanks, standards, controls, and samples by integrating a wide range of fluidic functions under autonomous control, including: 1) retrieval of fluid samples from a sample collection chamber; 2) onboard multi-year storage of dehydrated reagents, including fluorescent labeling compounds, contained in multiple isolated microchambers; 3) integrated pressure, pH, redox potential, and conductivity sensors; 4) filtration, retention, and fluorescent staining of insoluble sample fractions for characterization by microscopy; 5) dilution or vacuum-driven concentration of samples tailored to instrument detection capabilities; 6) removal of gas bubbles from fluid; 7) directional flow control; 8) active, multiple flow-path routing and 9) metered microvolume pumping. Current SPLIce design and prototype test results will be presented. Preliminary test results will be presented for these functionalities as implemented by the first laboratory.

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F3.6-0009-18 IN-SITU DETECTION OF ORGANICS AND BIOMOLECULES VIA NATIVE FLUORESCENCE

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A key goal for astrobiology is the search for evidence of life on other worlds - in particular Mars, Europa, and Enceladeus .In the near term such a search will be conducted by rovers. Experience with the Mars Exploration Rovers, Spirit and Opportunity, shows that it is difficult for the rovers to obtain samples. For this reason, a method for detecting organic chemicals and/or microorganisms without collecting a sample is needed and UV fluorescence is a strong candidate. Indeed non-contact determination of microbial content using native/intrinsic fluorescence is already in use in the food, pharmaceutical, and water quality industries [2]. Traditional methods for determining microbial content in such environments require sample collection followed by laboratory analysis. This procedure disturbs the soil environment, requires time for transit, and alters the sample as it is analyzed possibly rendering the soil useless for further stud- ies. The capability to directly determine soil microbial content in situ without contacting or disturbing the soil is important when studying fragile or extreme ecosystems on Earth, such as cryptobiotic crusts. Many molecules found in living cells exhibit characteristic fluorescence. Characterization of fluorescence involves both an excitation wavelength range and an emission wavelength range. In biological systems, the emission wavelength range often overlaps the excitation wavelength range, so these ranges must be judiciously chosen. Results suggest emission wavelength is generally 50 to 100 nm longer than the excitation wavelength. The emission intensity is directly related to the amount of the specific biomolecule present and to the intensity of the excitation [1]. References: [1] Smith, H.D et al. 2012. Astrobiology. [2] Lloyd et al. 2003. IEEE Special Proc Chemical Biol Microsens

F3.6-0010-18 ON THE DETECTABILITY OF ORGANICS IN HYPERVELOCITY IMPACT ICE SPECTRA

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Because liquid water is regarded as a prerequisite for life, icy ocean worlds such as Europa and Enceladus are the focus of several planned or proposed NASA and ESA fly-by missions. Water plumes originating from the subsurface ocean have been observed on Enceladus, and there have been suggestions that similar processes may be at work on Europa. Further, micrometeoroid impacts onto the surface are known to eject material into the local environment. These observations indicate that the environment around these bodies is rich with dust from both the subsurface oceans and the surface itself and that fly-by spacecraft with time-of-flight spectrometers will be able to study the ocean chemistry on icy worlds, including the potential detection of amino acids or other complex organic molecules. With the creation of a cryogenically cooled ice target for the dust accelerator facility at the NASA SSERVI Institute for Modeling Plasma, Atmospheres, and Cosmic Dust (IMPACT), it is now possible to study actual dust impacts into ice water doped with amino acids or other types of complex organic molecules at speeds relevant to fly-by spacecraft. Ice surfaces are prepared either by vapor deposition or by flashfreezing an aquatic solution of desired composition. Iron dust is accelerated to 3-50 km/s and impacted onto the surface. Time-of-flight mass spectra of the dust impact ejecta show that amino acids and even the more fragile di-peptide amino acid chains can survive impact and be detected. Future experiments will probe characteristic fragmentation patterns that can be used to identify amino acids even after breakup. Results from recent and ongoing investigations will be presented.

F3.6-0011-18 PERMIAN EVAPORITE PRESERVATION OF CHEMICAL BIOMARKERS: IMPLICATIONS FOR IN-SITU HYDRATED MINERAL AND HYPERSALINE BRINE SYSTEMS

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Evaporite minerals formed in ancient and modern environments can preserve fluids and chemical biomarkers which are products of the halophilic microbial life that once inhabited the ancient aqueous environment. Recent work conducted on modern hypersaline evaporitic systems shows likely pathways in which biomarkers and fluid inclusions were preserved, and how to quantify biomarkers from field site salts both for microbiology measurements and future in-situ planetary investigations. Similar evaporites utilized in our studies have been detected on Mars from orbit via the CRISM spectrometer onboard the Mars Reconnaissance Orbiter as well as likely to be on the surfaces of icy moons Europa and Enceladus, in addition to brine systems.

Applying Raman spectroscopy, bacterial qPCR, next generation DNA sequencing techniques, and optical mineral-microbial mapping, we have determined the likely preservation conditions and metrics within brine and evaporite samples in modern timescales with the goal of illustrating the differences between younger salts and ancient evaporitic preservation. Moreover, we are establishing methods for specifically extracting biomarker evidence from hypersaline systems such that the measured biogenic material is 1:1 to the preserved setting.

The purpose of this work is to take our current state of knowledge from the modern evaporite preservation within our fieldsite at the

northern arm of Great Salt Lake to the Permian environment where these hydrated minerals have recorded waters as well as potential microbial life previously residing in ancient water columns in the region. This relationship has allowed us to make inferences on the relative timeline of chemical biomarker production and how that effects the physical biosignatures of the mineral evaporite record.

The Permian salts examined consist of halite (NaCl) with visible traces of graphite, potash

(KCl) with significant Fe microtextures embedded within the salt matrix, and polyhalite ($K_2Ca_2Mg(SO_4)_4$· a complex fine-grained sulfate. All three mineral sets are a product of 255 Myr ponding from

Zechstein Sea waters and preserved 1.2km below the Earth's surface.

F3.6-0012-18 A NEW APPROACH TO IN-SITU BIOMARKER EXTRACTION AND ANALYSIS FOR OCEAN WORLDS

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With in-situ lander missions being considered for a variety of Solar System targets, robust and streamlined instrumentation for analysis of surface material is needed. In particular, the search for extinct or extant life on these bodies requires low-risk techniques that minimize the amount of solvent needed for operation. Life detection for planetary applications has thus far relied upon high-temperature extraction and separation techniques that degrade organics and can complicate the analysis. To address these issues, we have developed an online, automated, Supercritical CO_2 Extraction - Supercritical Fluid Chromatography (SCE-SFC) benchtop instrument in a proof-of-concept study for extraction of relevant biomarkers from aqueous or mixed samples. Extraction and analysis with supercritical CO_2 sidesteps some of the major analytic challenges of conventional techniques such as pyrolysis and conventional liquid extractions with GC-MS, and requires minimal sample preparation and minimal organic solvent waste.

Supercritical CO_2, with higher diffusivity and lower viscosity than typical organic solvents, is a stable inorganic extraction fluid that is increasingly used for industrial and environmental analyses. Over the past decade, our team has worked to evaluate supercritical CO_2 as a method for low-temperature (40 °C) extraction of polar and nonpolar organics [McCaig et al. 2016,

Menlyadiev et al. 2018). Although initial studies were focused primarily on Mars in-situ analysis applications, we have now successfully extended this method to analyze lipophilic biomarkers from water samples without degradation of organics or interference from salt. In principle, this extraction technique can be used to extract from a variety of sample types of varying water content. To further broaden the applicability of this technique,

we have now begun to integrate supercritical CO2 extraction technology with supercritical fluid chromatography into a single life-detection instrument that can extract and separate a wide variety of organics (including chiral species) from complex sample materials in their native states. We have successfully demonstrated on-line supercritical extraction, separation, and detection of lipophilic biomarkers with this instrument, and are now testing its range with more polar biomarkers.

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F3.6-0013-18 BACTERIAL SURVIVABILITY IN PLUME FORMATION AND CAPTURE PROCESSES

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The plumes emitted by the south pole of Enceladus may provide access to material from the global ocean that is believed to be under the thick icy surface. If supplied by the bulk fluid of the ocean, the plumes may provide an opportunity to look for extant life on Enceladus without having to penetrate the ice cap, or even land on the surface of the moon. What remains uncertain is how likely it is that signs of life, if present, will make it into the plumes and how the process of plume formation and capture will affect our ability to determine the presence of extant life vs. chemical precursors. In this paper, we present experimental results on capture of bacteria during droplet and ice crystal formation and the effects of medium velocity capture on survivability of these bacteria.

From Cassini INMS data, plumes on Enceladus contain mostly water with small amounts of volatile gases embedded within, and are ejected into the vacuum of space. We have initiated a series of tests to experimentally determine whether bacteria can survive ejection into vacuum and to explore different conditions that may promote or hinder survival during this process.

We find that concentration of bacteria in droplets formed by expansion into a vacuum is straindependent, consistent with many other studies on sea spray and "bubble scrubbing." We settled on Serratia marcescens as a test organism because of its concentration in escaping bubbles, both in atmosphere and under vacuum. We studied controlled bubble formation (with use of a micro-bubbler) in atmosphere, as well as spontaneous bubbling from both degassed and fully oxygenated solutions in vacuum. We found that S. marcescens is able to grow and form colonies under both conditions down to at least -15 °C when captured onto frozen nutrient agar. Capture of spontaneous bubbles onto plastic Petri dishes led to no bacterial survival, even at room temperature.

To determine the effect of ice formation on bacteria survivability in cold plumes, we have also developed a cold Enceladus ice crystal generator, where we co-mix water containing bacteria with pressurized liquid CO2 in a two-fluid external-mixed nozzle. The expansion of the gas from the nozzle cools the water droplets and freezes them to produce snow crystals with bacteria, which are then collected for survivability and impact shock studies. These ice grains were packed into a stainless steel sample chamber and a 20 mm bore propellant-driven plate impact gunwas used to launch a projectile at this chamber at a velocity of 850 m/s. Following impact, the liquid was retrieved from the sample and spread onto plates to determine survivability from colony counts.

F3.6-0014-18 CREATIVE INSTRUMENTATION FOR IN-SITU ELECTROCHEMICAL CHARACTERIZATION OF GEOCHEMICAL GRADIENTS IN PLANETARY MINERALS

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NASA's future missions will focus on discovering evidence of life under extreme environments. In addition to bio-signatures in a global scale such cold arid planets (Mars) and icy worlds (Europa), localized geochemical systems that host gradients are also of great interest for determining the potential for life to thrive or to originate in these environments. Such gradient-driven systems include, for example, layering of minerals of varying oxidation states in the Martian subsurface or in Earth's seafloor sediments; chemical precipitates separating fluids of different pH or Eh such as in a hydrothermal vent; or radiation-induced oxidant production in planetary ices. A challenge is that these simulated precipitates are redox sensitive and evolve over a relatively short lifetime (1-4 hrs) necessitating viable in-situ, non-destructive techniques. Promising techniques for such studies are electrochemical methods, which are particularly suited for characterizing interfaces and chemical gradients. For planetary applications, microbial reactions in water-mineral environments have important geobiological and geochemical implications which are preserved at these interfaces for future in-situ electrochemical analyses. Combined with recent advances in electrochemical instrument technologies, new methods have been developed toward integrating portable, electrochemical systems (i.e., software controls, sensors, detectors, etc.) without compromising measurement sensitivity and robustness for ex-situ and/or in-situ chemical characterization. JPL has already made significant progress in developing these new technologies, particularly electrochemical impedance spectroscopies (EIS) for in-situ characterization of geochemical materials (i.e., soils ice mineralogy, and brines) [1][2]. More recently, we have adapted electrochemical techniques life detection purposes such as measuring amino acids. Combined microstructure enhanced electrodes enable concentration

levels to be measured in the parts-per-billion (bbp) range which represents a 100x enhancement in sensitivities relative to our state of the art remote-sensing capabilities typically deployed for space exploratory programs [3]. We have also successfully developed electrochemical systems with a programmable microelectrode array using more advanced driver controls to perform continuous monitoring and real-time characterization of simulated planetary vent systems. This technique was successfully utilized in laboratory simulations of astrobiological / emergence of life processes on early Earth. It can also be used with other rocky planets, as well as icy moons, which emulate localized geochemical disequilibria that can support potential microbial life or drive prebiotic carbon fixation (prior to any microbial interaction such as on early Earth). Along with discussions on instrument technologies for future astrobiology applications, we will highlight some of our group's successes and preliminary results of geochemical experimentation using various electrochemical techniques. • References: [1] S. Seshadri, et. al., Astrobiology (2008). [2] M.

G. Buehler, et. al., IEEE Aerospace Conference Proceedings (2007). [3] Chin, et. al., Review of Scientific Instruments (2018), in review.

F3.6-0016-18 KEY PROBLEMS OF LIFE'S ORIGIN: NECESSARY AND SUFFICIENT CONDITIONS FOR STARTING CHEMICAL EVOLUTION AND TRANSFORMING IT INTO BIOLOGICAL ONE

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According to science methodology any hypothesis to become a theory has to obtain experimental confirmation. The same requirement has to be applied to modern hypotheses on life's origin. The problem of the origin of life will be resolved when some experiment produces an "entity" that can be identified as "life". However a plan of experiments on the origin of life must necessarily be based on preliminary theoretical development, which should define the conditions for the origin of this "entity" and propose a credible scenario, i.e. a scenario compatible with contemporary physical and chemical laws. For instance, the scenario of self-assembling a primitive living cell directly from a set of chemical compounds is not verifiable experimentally due to the probability of this even is so low that the methodology of natural sciences deems this variant of the emergence of life unrealistic. Oparin (1924) suggested that modern-type cells "had originated from simpler forms through sequential changes and improvements". The same idea was mentioned casually by Haldane (1929). These studies provided a basis for postulating that biological evolution had been preceded by chemical evolution, which resulted in the occurrence of cells that were chemically similar to the modern type. To resolve the paradox of the discrepancy between the actual existence of life on Earth and zero probability of a living cell emerging by self-assembly from scratch, the probability of the formation of the primitive precursor stages must be quite perceptible. Hence, chemical evolution is a necessary component of any scientific scenario of the emergence of life. At the present time, general scientific notions can only provide a basis for defining the necessary conditions for the emergence of life. Whether the list of necessary conditions is complete is a very difficult question, and whether it is sufficient can only be determined experimentally. One cannot construct a specific scenario of chemical evolution without defining its outcome - the product resulting from chemical evolution and the phase in which it is transformed into biological evolution. The literature analysis shows that researchers' attitudes to the outcome of the scenario of chemical evolution can be of two kinds:

studies attempting to find out the conditions and stages of the origin of life on Earth, as we know it; b) studies examining the conditions and stages of the emergence of any life form conceivable scientifically. In fact, any idea of the outcome falls within one of the two frameworks of research, which we conveniently denote by Earth Life Origin (ELO) and General Life Origin (GLO), respectively. The differentiation between ELO and GLO frameworks is a critical issue, as it concerns fundamentally different approaches to the problem of the origin of life. Specific drawbacks and advantages of these ways are discussed.

F3.6-0017-18 CHEMICAL ANALYSIS OF LIPOPHILIC BIOMARKERS USING CARBON DIOXIDE AS A SOLVENT

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The search for life in the solar system is currently one of the major goals in space exploration, and in-situ analysis of complex organic molecules is a key component in the effort to evaluate habitability of other worlds. Robust chemical analysis techniques are essential in this endeavor, especially those that can enable detection and identification of unknown complex molecules at low concentrations with high precision.

Previous missions to Mars have employed primarily pyrolysis - and to a lesser extent liquid extraction combined with derivatization - as sample preparation techniques, followed by separation by gas chromatography and detection by mass spectrometry. We have been developing instrumentation that can extract, separate and detect organic molecules using CO2 as a solvent in its supercritical state. This approach completely avoids derivatization and the use of organic solvents, and the extraction and separation is performed at mild temperatures (30-60

°C) as opposed to high-temperature techniques such as pyrolysis [1, 2]. This reduces the risk of degradation and of unwanted reactions between the native compounds and other species.

Our developed methodology involves extraction of lipophilic biomarkers, pre-concentration on a solid-phase trapping material, and release (elution) followed by separation using chromatography with mass spectrometry detection. In modern-day analytical chemistry, supercritical fluid extraction and chromatography has become immensely popular due to its faster analysis time, however, it typically requires mixing the supercritical CO2 with a polar organic solvent to break molecular interactions [3]. We have completely avoided organic solvents by saturating the supercritical CO2 with water and by identifying suitable chemistries of the trap and chromatography columns.

Although we have previously demonstrated supercritical CO2 extraction of organics from solid samples [4, 5], we have recently modified the method to enable extraction of organics from aqueous samples with high salt content, such as is expected on Europa [6]. Here, we demonstrate how a completely automated quantitative analysis (including extraction, separation and detection) of intact lipids, such as free fatty acids, heterocycles and pigments, from aqueous samples in the presence of salts can be performed under mild conditions by using supercritical CO2 as a solvent at a benchtop scale.

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F3.6-0018-18 PANSPERMIA IN SOLAR SYSTEM: A COMPARISON OF POSSIBLE SOURCE BODIES

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We consider here conditions for origin of life in the early Enceladus and other bodies and possible proliferation of the life. Enceladus is the smallest body in the Solar System where volcanic activity is observed. According to [1]: "For life to have emerged [.] chemically transducible energy was essential. The serpentinization process is emerging as an increasingly likely source of that energy. Serpentinization of ultramafic crust would have continuously supplied hydrogen, methane, [.] " (see also [2]). [3] consider the following reaction of serpentinization: (forsterite)

+ (enstatite) + 2(water) -> (antigorite). It releases 241 000 J per kg of serpentine produced. Calculations (e.g. [4]) indicate that in Enceladus the total mass of its silicate is 6.97 1019kg and most of this mass could undergo serpentinization. Investigating thermal conditions in its core leads [4] to the conclusion that it was an appropriate place for origin of life. The hypothesis that Enceladus could be a cradle of life in the Solar System was presented in [5] and [6]. [6] indicated a few possible mechanisms and scenarios for transport of simple organisms from the interior of Enceladus to terrestrial planets of the Solar System. In the present paper we compare possibility of transport of living organisms from Europa, Ganymede, Titan, Mars and the Earth to other celestial bodies in Solar System. Several mechanisms of transport are considered - impacts, volcanism, gravity assistance, Poynting-Robertson effect and others. We conclude that interior of Enceladus offers good conditions for origin of life. Moreover we find that transport of living organisms from the interior of Enceladus is more probable than from any other celestial body.

Acknowledgements: The research is supported by BST fund od University of Warsaw. References [1] Russell, M. J., Hall, A. J., And Martin W. (2010). Geobiology (2010), 8, 355-371.

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F3.6-0019-18 CONSTRAINTS ON EUROPA'S OCEAN COMPOSITION IMPOSED BY ITS SURFACE COMPOSITION

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Of the non-terrestrial environments within our Solar System, Europa's global liquid water ocean is arguably the most likely to be habitable. As such, understanding the habitability of Europa's ocean is of great interest to astrobiology and is the focus of missions currently being considered for further exploration of Europa. However, direct analysis of the ocean is unlikely in the foreseeable future. As such, our best means of constraining the subsurface ocean composition and its subsequent habitability currently is by further study of Europa's surface chemical composition. Recently, there has been a body of work published that looks at the chemistry of frozen brines representing putative ocean compositions. Here we take a simplified model of a four ionic component (Na, Mg, SO4, Cl) solution and map out what minerals are formed upon freezing as a function of relative ionic concentration, pH, etc. A 'flow-chart' of the freezing sequence was developed based on both published and recently acquired experimental results. In performing this exercise, we are able to begin making meaningful links between observations of the surface chemistry and the chemical environment of the internal ocean.

F3.6-0020-18 IN SEARCH FOR BIOMARKERS ON PLANETARY BODIES

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One of the major goals in the exploration of space is the search for evidence of life in the solar system. Organic analyses and biomarker detection will play a pivotal role in this endeavor as part of in situ robotic missions to planetary bodies by major space agencies such as NASA and ESA. Looking beyond Earth recent efforts in searching for chemical signatures of life have focused primarily on Mars, Europa, Enceladus, and Titan which may have biochemistry similar to that of life on Earth.[1] A primary goal of searching life on other bodies should be to search for specific biomolecules that would be conclusive evidence of life. One of the main difficulties in this endeavor, however, is that biologically relevant properties of biomarkers rapidly disappear over time intervals of thousands to millions of years due to hydrolysis, racemization, and other forms of chemical degradation.[2] As a result distinguishing between biological and non-biological origins of potential biomarkers that could plausibly be present on planetary bodies is extremely challenging. Lipids are waxy, organic molecules soluble in nonpolar solvents that are utilized by organisms to form cell membranes, and eventually buried and preserved in sediments. Also, they also arguably the most useful molecular biomarkers for studying the origins and evolution of life on earth over the past 3 billion years. Membrane lipids were found in 2700-million-year old kerogen-rich shales.[3] Carboxylic acids are potentially stable over geological time scales in ices as well as in cold anoxic sedimentary materials. Analysis of the types and distribution of carboxylic acids present in planetary materials can potentially indicate biological activity as well as the relative contributions of hydrothermal and exogenous delivery. In this presentation, we argue that lipids which are essential to life with best potential of surviving under the harsh planetary conditions (over long geological time scale of several millions to billions of years) should be on the top of our list for future life-detection missions to Mars, Europa, Enceladus, Titan, and other planetary bodies. We also review new technologies under development for lipid biomarker analysis both in searching for life and for understanding the geochemical and perhaps biological evolution that has occurred on planetary bodies.

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F3.6-0021-18 IMPACT SYNTHESIS OF AMINO ACIDS BY A LIGHT GAS GUN TO SIMULATE IMPACT REACTIONS ON TITAN

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We assume that large amount of amino acids have been synthesized on Titan's surface by asteroid's impacts, and they are stored on the dark and cold surface. To simulate the impact reactions, impact experiment using a light gas gun has been carried out. A polycarbonate projectile (7.1 mm diam.) is accelerated to 7.0 km/s, injected into a pressurized chamber (10 inch diam, 25 cm high), which is filled with 100 kPa of nitrogen, and hits an iron target (76 mm in diam.). The target is cooled by liquid nitrogen, and ice or ice + hexane can be added on the surface. After the impact, a hot gas plume generates for about 100 μs, which has temperature of about 5000 K and strong CN emission. After the impact, deposited black soot is carefully collected, part of which is refluxed using pure water. The sample is dabsylized and analyzed using HPLC [1]. As a result we could obtain many kinds of amino acids (glycine, alanine, leucine, serine etc.). About 2 nmol of glycine and 0.9 nmol of alanine are included in 1.0 mg of the soot. By the 2D chromatograph method, both D and L type alanine isomers are detected. It is conjectured that in the hot gas plume, C_2 molecules react with N_2 molecules to make CN radicals. Other radicals react with CN to make amino acids during the cooling process after the impact. We believe that the asteroid's impacts also could do further reactions and diffuse organic materials into the underworld. We are doing further experiment to make clear the synthesis properties. [1] K. Okochi, T. Mieno et al., Orig. Life Evol Biosph (2015) 45: 195-205.

F3.6-0022-18 PYROPHOSPHATE SYNTHESIS CATALYZED BY MINERAL PRECIPITATE MEMBRANES IN MICROFLUIDIC DEVICES SIMULATING HYDROTHERMAL VENT CONDITIONS

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Inorganic precipitate membranes play an important role in biomineralization, chemobrionics, and origin-of-life research. We produce such membranes in a microfluidic device at the reactive interface between laminar streams of an alkaline solution and a metal salt solution. The steep chemical and pH gradients across the membrane can experimentally simulate the geochemical gradients in the hydrothermal vents. We show that in the presence of acetyl-phosphate, the membrane causes the formation of pyrophosphate which might have served as the energy currency of early life emerging in hydrothermal vents. The latter product is identified by aqueous 31P-NMR spectroscopy from samples removed from the microfluidic device. This result demonstrates the usefulness of microfluidics-based synthesis for origin-of-life studies that require the exploration of vast parameter spaces. Furthermore, the membrane experiments simulating habitability in hydrothermal vents can also involve polyphosphates compounds which are curial for life and could be a biosignature.

F3.6-0023-18 SIMULTANEOUS ANALYSIS OF INORGANIC SALTS AND AMINO ACIDS BY CAPILLARY ELECTROPHORESIS AND CONTACTLESS CONDUCTIVITY DETECTION FOR ASTROBIOLOGY STUDIES

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Capillary electrophoresis (CE) has tremendous promise for in situ planetary investigations. Depending on the detection method used, CE allows the analysis of a wide range of organics as well as inorganic ions. In general, the detection method is selected based on the properties of the analytes of interest. For example, laser-induced fluorescence is the preferred method for the analysis of amino acids as it provides unparalleled sensitivity. On the other hand, for analysis of inorganic ions, conductivity detection is a better and simpler candidate. Choosing a specific method for a specific analyte works well when analyzing relatively well understood samples in a lab on Earth. However, analyzing unknown samples, like the ones expected on alien worlds, presents a more challenging scenario. An ideal in situ instrument would allow the analysis of multiple analytes (like salts and amino acids) with a single detection system. Capacitively coupled contactless conductivity detection (C4D) is a method that is widely used in conjunction with CE. C4D allows the detection of any charged species, as such, it would allow the simultaneous analysis of inorganic salts and charged organics. We are developing CE-C4D methods to simultaneously analyze inorganic and organic ions (i.e. calcium, sodium, perchlorate, amino acids, carboxylic acids etc.), as they are likely to be present at the same time on samples collected from the most relevant astrobiology targets like Mars, Enceladus, or Europa. Soluble salts present are of importance to biological activity, prebiotic organic synthesis, and the thermophysical properties of most liquid mixtures. Amino

acids are the building blocks of proteins and are essential for all terrestrial life. The distribution of amino acids on a sample is one important potential indicator for determining the presence of life. CE-C4D does not require derivatization of the sample, providing an attractive and robust alternative to other more labor-intensive detection methods. Although CE-C4D cannot yet achieve the sensitivity of some optical methods, it can be used as a screening platform before performing more sensitive analyses that required more sample preparation. Using CE-C4D as a screening platform is especially useful because it can help determine the proper sample preparation steps before analysis with other techniques. For example, the presence of salts in combination with organics can sometimes hinder their detection by methods that require derivatization. So, it is essential to identify the ions present in the sample in order of select the proper technique to successfully detect organic biosignatures. CE-C4D has a small footprint and analyses take less than 10 min so it can be readily integrated to other more complex instrumentation. Moreover, the CE-C4D protocols could be adapted to the environmental requirements of a variety of astrobiologically interesting targets like Europa, Enceladus, or Titan. This type of instrument also offers key capabilities for human flight applications. For example, we are currently working in collaboration with SBIR partners on the development of a miniaturized instrument to monitor water quality in the ISS.

F3.6-0024-18 EXPLORATION OF ICY MOONS AROUND GIANT PLANETS: ASTROBIOLOGICAL ASPECTS

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When looking for habitable conditions in the solar system, recent studies focus on the natural satellites of gas giants. Indeed, liquid water may be present underneath the surfaces of the natural satellites around Jupiter and Saturn [1]. And several of these satellites show in addition evidence for harboring organic chemistry in their atmospheres or exospheres, as well as energy sources. Measurements from the ground but also by the Voyager, Galileo and the Cassini spacecraft revealed the potential of these satellites in this context, and our understanding of habitability in the solar system and beyond can be greatly enhanced by investigating several of these bodies. Indeed, several of the moons show promising conditions for habitability and the development and/or maintenance of life. Europa, Callisto and Ganymede are hiding, under their icy crust, undersurface liquid water oceans which, in the case of Europa, may be in direct contact with a silicate mantle floor and kept warm by tidally generated heat. Titan and Enceladus, Saturn's satellites, were found by the Cassini-Huygens mission to possess active organic chemistry with seasonal variations, unique geological features and possibly internal liquid water oceans. As revealed by Cassini, the liquid hydrocarbon lakes currently distributed mainly at polar latitudes on Titan are ideal isolated environments to look for biomarkers. If the silicate mantles of Europa and Ganymede and the liquid sources of Titan and Enceladus are geologically active as on Earth, giving rise to the equivalent of hydrothermal systems, the simultaneous presence of water, geodynamic interactions, chemical energy sources and a diversity of key chemical elements may fulfil the basic conditions for habitability. These would be investigated with future space missions. Such potential habitats can only be investigated with appropriate designed space missions, like ESA's L1 JUICE and NASA's Europa Clipper mission. I will discuss current and future means of exploration, with a focus on JUICE and also laboratory and theoretical measurements within the ANR French project that led to new methane coefficients for Titan [2,3].

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LIFE SCIENCES AS RELATED TO SPACE (F)

BIOSIGNATURE DETECTION IN THE SOLAR SYSTEM. PART II: MARS, EARTH, AND EXOPLANETS (F3.7)

F3.7-0001-18 EXTRATERRESTRIAL BIOSIGNATURES

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The search for extraterrestrial biosignatures is conditioned, in the first place, by the kind of life that one expects to find. While biosignatures on exoplanets are necessarily restricted to those represented by life forms that have developed at least oxygenic photosynthesis or are even more evolved, our understanding of the emergence and evolution of life (as we know it) on Earth suggests that extraterrestrial life forms on other planets and satellites in the Solar System are more likely to be represented by primitive, anaerobic chemotrophic microorganisms.

Great advances have been made over the past decades in our understanding of the nature of extremophiles and the limits of life. We know that life can inhabit ephemeral habitats for the brief periods that they are habitable. The vast majority of these kinds of habitats, for example endolithic, dry arid, salty, or icy environments to name just a few, are typified by oxygenic phototrophs as primary producers. Are these kinds of habitats suitable for chemotrophs as primary producers? What would the potential carbon, nutrient and energy sources be? What kinds of biosignatures would they produce and can these biosignatures be preserved on long geological time scales? Experimentation along these lines is essential to help us to know what to look for on another planet, how to look for it, how to sample it and how (where?) to analyse it.

The next decades will see sample return missions from Mars and missions to icy satellites, some of them potentially sample return missions. At the moment, with our limited understanding of the nature, distribution and preservation of biosignatures of chemotrophic life, we are searching almost blindly. The closest analogue to an anaerobic planet inhabited by chemotrophs is the early Earth [1]. This example shows us that chemotrophs are most "happy" cavorting in and around nutrient-rich hydrothermal systems, producing a significant amount of biomass that is durably preserved by hydrothermal silica over very long geological time scales. They also occur in oligotrophic settings but their biomass here is very low and subsequent biosignatures extremely subtle. Such findings, combined with experimental data on chemotrophs biosignature preservation in extreme environments, are what is needed to for mission planning and instrument development.

Acknowledgements: The CNES, ANR, FP7 project MASE, and the H2020 project EUROCARES are thanked for funding. References: [1] Westall et al. (2015) Astrobiology, 15, 998.

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F3.7-0002-18 MARTIAN ENVIRONMENTS AND BIOSIGNATURES

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With increasing capabilities, the exploration of Mars and in particular, the search for life on the red planet continues to be of increasing importance to nations and space agencies around the world. However, the search for life on Mars has already resulted in two false positives that have significantly affected how we search for life outside the Earth. It is crucial to consider not only the biosignatures that should be sought but almost more importantly the most likely environments for their preservation and detection by the fleet of robotic missions currently in development. Five analog environments of interest have been evaluated by the mars analogue community, hydrothermal spring systems, subaqueous environments, subaerial environments, subsurface environments, and iron-rich systems [1]. All have strengths recommending them, as well as challenges to observations unique to each, and understanding these can help guide the astrobiological exploration of Mars. Additionally, the newly proposed tool, the Ladder of Life Detection [2], is a unique tool that helps to focus on rigorous investigations of specific biosignatures, or combination of biosignatures, most likely to yield a positive result in the search for life.

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F3.7-0003-18 BIOSIGNATURE SEARCHES WITH THE LUVOIR DECADAL MISSION CONCEPT

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The Large UV-Optical-Infrared (LUVOIR) Surveyor is one of four mission concepts being studied by NASA in preparation for the 2020 Astrophysics Decadal Survey. LUVOIR is a general-purpose space-based observatory with a large aperture in the 8-15 m range and a total bandpass spanning from the far-UV to the near-infrared. This observatory will enable revolutionary new studies in many areas of astronomy, including planetary science within and beyond our Solar System. One of LUVOIR’s main science objectives will be to directly image rocky Earth-sized planets in the habitable zones of other stars, measure their spectra, analyze the chemistry of their atmospheres, and obtain information about their surfaces. Such observations will allow us to evaluate these worlds’ habitability and search for the presence of biosignatures. We will review the specific observational strategies needed for astrobiological assessments of exoplanetary environments with LUVOIR, including the wavelength range, spectral resolution, and integration time required for these habitability analyses and biosignature searches. The survey of the atmospheric composition of dozens of potentially habitable worlds would bring about a revolution in our understanding of planetary formation and evolution, and may usher in a new era of comparative astrobiology.

F3.7-0004-18 CHEMICAL BIOSIGNATURES: ALL THAT GLITTERS IS NOT GOLD

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Chemistry offers sophisticated analytical tools that allow the detection and identification of, for example, organic molecules even if present in only minute quantities. This makes chemical biosignatures attractive as means for life detection on other planets and moons. However, the various kinds of chemical biosignatures are not equally useful in the search for extraterrestrial life, and there are many potential pitfalls in interpreting them (Fox and Strasdeit, 2017).

The most important type of misinterpretation is probably false positive results. It occurs when terrestrial biogenic or abiogenic contaminants are mistaken as extraterrestrial biosignatures or when products of natural abiotic syntheses are not recognized as such. Terrestrial contamination is a permanent problem in many astrobiology space missions, especially in those to the surfaces of solar system bodies. False negative results are also possible. They may occur, for example, when a chemical compound simultaneously has productive abiotic and less productive biological sources. In such a situation the biotic source may be overlooked. Methane on other planets and moons is a candidate for this kind of chemical compound.

"Strong" chemical biosignatures have a low risk of misinterpretation. Homochiral polymers of defined length and sequence, such as proteins and polynucleotides, undoubtedly belong to this group. Abiotic organic syntheses almost always produce a continuous spectrum of molecules, as, for example, in the case of α-alkyl-α-amino acids. However, when only a subset of these molecules is found, this strongly indicates biogenicity (McKay, 2004). Stability over long periods of time of a chemical biosignature (or at least of easily recognizable alteration products thereof) also increases its "strength." One reason that some molecules are regarded as good biosignatures is because no natural abiotic syntheses of them are known. However, when an abiotic pathway is discovered—as was the case with porphyrins (Fox and Strasdeit, 2013)—the picture changes. "Weak" chemical biosignatures are by no means useless, but they need a stronger integration into the context (for example, the geological one) to avoid misinterpretation.

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F3.7-0005-18 IN SITU IMAGING OF LIVING CELLS ON SURFACE OF MARS BY LIFE DETECTION MICROSCOPE (LDM)

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Recent findings on Mars, such as organic compounds, methane, reduced compounds for microorganism energy sources, possible presence of liquid water at Recurring Slope Lineae, tend to support the possible presence of living microbes near the surface of Mars. For in situ detection of microbial cells, we propose the Life Detection Microscope (LDM) which visualizes organic compounds by staining the samples with fluorescent pigments. The LDM scans a volume of 1 mm3 and detects organic compounds including cells and other biological materials in high sensitivity (<104 cells per gram clay). The fluorescent pigments have been selected to identify the fundamental features of cells by differentiating among organic compounds surrounded by membranes or enzyme activity: the mixed dye of SYTO24 and propidium iodide stains living cells in green and dead cells in red depending on their membrane permeability and CFDA-AM detects cells possessing esterase activity. The LDM is also equipped with a high resolution imaging system (1 μm/pixel) which visualizes detailed life forms as well as regolith and dust particles.

F3.7-0006-18 TRANSITS IN THE SOLAR SYSTEM AND THE COMPOSITION OF THE EXOPLANET ATMOSPHERES

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Our knowledge about exoplanets depends on very limited measurements and resolution. Atmospheric compositions are limited only to hot Jupiters and Neptunes. Detection of possible biosignatures on Earth-sized planets is not possible today. However, upcoming space missions, e.g. TESS, JWST, CHEOPS, and PLATO will give us unprecedented access to exoplanet light curves and other observations. Before the new results arrive, it could be useful to collect the only known living planet's and other well known planet's light curves and spectra for the future comparison and habitability modeling. For this, we need to seek possibilities to measure Earth's and other terrestrial planet's transits, occultations, and reflections from different locations in the Solar System. I will present some past events and experiments, potential locations and events, probes, and their instruments that could be used, as well some limitations and challenges.

F3.7-0007-18 AGNOSTIC APPROACHES TO LIFE DETECTION

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A key question in astrobiology is how to search for signs of life regardless of underlying biochemistry. Current strategies for biosignature detection rely mainly on identification of wellestablished and widely accepted features associated with terran life and signatures of biologic processes, such as particular classes of molecules and isotopic signatures, enantiomeric excesses, and patterns within the molecular weights of fatty acids or other lipids. Yet as we begin to explore icy moons of Jupiter and Saturn and other destinations beyond Earth, we must develop life detection methods that identify unknowable, unfamiliar features and chemistries that may represent processes of life as-yet unrecognized. Accomplishing this goal will entail not only developing new techniques but also synthesizing data with probabilistic approaches, as agnostic methods may trade definitiveness for inclusivity.

F3.7-0008-18 LIFE ON MARS? WHAT TO LOOK FOR WITH MOMA ON EXOMARS 2020?

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It is likely that the first terrestrial life was quite different from the current DNA world. Thus even if we assume that life arose on Mars from a chemical evolution similar to the terrestrial one, and that the primitive life on Mars was similar to the first terrestrial living system, it may have been very different from the present terrestrial life. Moreover, it is far from obvious that martian biological evolution followed the same ways than on Earth, because of a different evolution of the red planet and different physical and chemical conditions. Thus when searching for extant martian life, one should not look exclusively for life as we know it today on Earth. We should also - and as first priority - look for life similar to the early terrestrial life, and more generally life based on similar but not identical replicating macromolecules, as well as protein-like macromolecules. Search for extinct martian life must also take into consideration the large differences in environmental conditions on both planets. In particular, it is likely that the degradation of potential living systems, and biomolecules on Mars, will yield breakdown products quite different from what is observed on Earth (like humic and fluvic acids). Consequently, the search for molecular biosignatures of extant and/or extinct life on Mars must be largely open and use non molecular specific analytical tools, able of analyzing a very wide range of chemical families. This is the case with the MOMA instrumentation on the rover of the ExoMars 2020 ESA/Roscosmos mission. This presentation will discuss these important aspects of possible Martian biosignatures and the capabilities of the MOMA instrumentation to analyse them.

F3.7-0009-18 INFLUENCE OF TEMPERATURE ON FLUORESCENCE DETECTION LIMITS OF UBIQUITOUS TERRESTRIAL BIOCOMPOUNDS

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Finding appropriate criteria for recognizing, detection and comprehension of life phenomena is one of the “eternal” problems in astrophysics, geology, glaciology and marine ecology. Photometric technologies offer a repertoire of fast, simple and reliable identification and characterization methods for chemical compounds and microorganisms in their natural environments via their signatures. Very suitable for this purpose is fluorescence spectroscopy that allows quantitative measurements of an analyte in solution and provides information on dynamic processes on molecular environment down to the nanosecond timescale. Our approach primarily focused on fluorescence spectroscopy measurements of selected species of ubiquitous terrestrial bio-compounds as a model for future terrestrial and extraterrestrial applications. The main aims were (a) to verify that autofluorescence can be successfully used to differentiate between various biogenic compounds and (b) to determine their minimal dilutions/concentrations that could be still detected. We applied conventional fluorimetry to obtain cumulative spectra for bacteriorhodopsin, RNA, chlorophyll, histidine, ATP, NADH, tryptophan, phenylalanine, pyridoxine, riboflavin, arginine, alanine and FAD. For all 13 substances, 20 mL aliquots of six tenfold dilutions were prepared. The signals were plotted as a function of the concentration. The obtained results allowed determination of absorbance/emittance peaks characteristic for the examined molecular species. The lowest still detectable concentrations (0.1-1 M) were found for FAD, NADH, pyridoxine hydrochloride, tryptophan and riboflavin. L-histidine, L-arginine and L-alanine were only detectable starting from 1 mM. L-phenylalanine and ATP could be detected down to 10 M-concentrations. A further goal was to investigate the temperature dependency of intensity. For this, the fluorescence signal of all compounds was measured at peak intensity wavelength at 5°C, 25°C and 45°C. For tryptophan, L-phenylalanine, L-histidine, L-alanine, NADH, bacteriorhodopsin and pyridoxine hydrochloride, the highest measured sensitivity of the detection was at 5°C, and exceeded the 25°C-sensitifity approximately by factor 2. Interestingly, L-arginine, FAD and ATP demonstrated better detectability at 25°C. The information related to specific absorption/emission maxima will be used in designing and developing of compact LED-based fluorescence spectroscopy module that is supposed to be a part of the payload of the future autonomous sampling probes (for both terrestrial and space exploration missions).

F3.7-0010-18 THEORETICAL SEARCH FOR PHOTOSYNTHETIC PIGMENTS APPLICABLE TO THE M DWARF ENVIRONMENT USING AB INITIO CALCULATIONS AND THE MACHINE LEARNING

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As planets around M dwarfs will be good targets in near future observations, detecting photosynthetic biosignatures is a possible way to find life there. The surface vegetation can be distinguished from disk-averaged spectra of the Earth as the vegetation red edge. However, a lot of uncertainties and assumptions lie in the extraterrestrial photosynthesis. At least, we can observe the photosynthesis on the Earth thoroughly and examine its possible form around different photoenvironment from the Sun. In this research, we focus mainly on absorption properties of photosynthesis at the molecular level and search strategically for photosynthetic pigments absorbing longer wavelength radiation. Under planetary atmospheres, available radiation varies depending on their niches, e. g. underwater, clouds. Therefore, excited states of the pigments in varieties of conditions are estimated using ab initio calculations and collected as a database for future observations. Starting with the existing pigments such as chlorophylls and bacteriochlorophylls, artificial pigments are calculated with minor difference like central metal, side chain or solvent as a result from another possible evolution. At least, under given radiation spectrum in surface environments of a planet, we can guess from the database whether the pigments can absorb available light effectively or not combined to possible structures and conditions. To design the new pigments strategically, machine learning methods are applied to explain electronic structures for lower excitation energy.

F3.7-0011-18 URACIL EVOLUTION UNDER MARS SURFACE-LIKE UV RADIATION CONDITIONS WITH THE MOMIE (MARS ORGANIC MATTER IRRADIATION AND EVOLUTION) EXPERIMENT

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The detection and identification of organic molecules at Mars are of primary importance for astrobiology, as some of these molecules are life precursors and components. While in situ exploration missions are searching for them at the surface of the planet, it is essential to understand how organic molecules evolve and are preserved at the surface of Mars. Indeed the harsh conditions of the environment of Mars, such as ultraviolet (UV) radiation or oxidative processes, due for example to perchlorate ions, could explain the low abundance and diversity of organic molecules detected so far [1][2]. The MOMIE (Mars Organic Matter Irradiation and Evolution) experiment has been set up to study the evolution of organic matter under simulated martian radiation within the laboratory [3]. Organic samples are exposed under a wide range UV lamp (200-400 nm) as thin homogenous solid films (a fraction of µm thick), by a mean temperature of -55°C and a mean pressure of 6 mbar, close to Mars surface conditions. Most of the organic molecules studied so far were quickly destroyed under Mars surface-like

UV radiation conditions [4]. Uracil is a one-ringed heterocyclic compound, a nucleobase found in RNA, and has been detected in meteorites thus is likely to be found at Mars [5]. Pure uracil samples were irradiated for several weeks in the MOMIE experiment, as well as uracil mixed with perchlorate salts. To characterize the evolution of uracil samples, analyses by infrared spectroscopy (FTIR) were performed all along the experiment. These analyses allowed determining whether uracil is preserved or photodegraded, and if so, its photolysis rate. The FTIR successive analysis showed new absorption band appearance and increase along the UV irradiation. High-Resolution Mass Spectrometry (HRMS) analysis of irradiated uracil samples has shown that uracil seems to form polymers under martian-like UV radiation. These polymers are far more resistant to UV radiation. The effect of perchlorates salts on uracil evolution and preservation has been investigated as well. The MOMIE experiment allows to understand which organic molecules in situ missions should target, as some of them are quickly destroyed in Mars surface-like conditions while others are likely to form new compounds. Uracil polymers, formed by uracil molecules under Mars surface-like radiation conditions, would be very relevant compounds to search for at the surface of Mars.

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F3.7-0012-18 MARS ORGANIC MOLECULE ANALYZER (MOMA) LASER DESORPTION IONIZATION (LDI) AND ANALYSIS OF NONVOLATILE COMPOUNDS ON EXOMARS

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The Mars Organic Molecule Analyzer (MOMA) is a key instrument on the Pasteur Payload of the ExoMars rover, which will operate in the harsh Martian environment. MOMA is a lightweight (sim12 kg), low power (75 W in average), dual-source, mass spectrometer-based instrument, utilizing a miniaturized linear ion trap (LIT). This instrument enables two modes of operation: i) pyrolysis/gas chromatography mass spectrometry (pyr/GC-MS); and, ii) laser desorption/ionization mass spectrometry (LDI-MS) at ambient Mars pressures. It will be the first to employ an LIT in space, as well as conduct LDI-MS on another solar system body.

MOMA will examine the chemical composition of samples acquired by a drill from depths up to 2 m where organics may be protected from radiation, oxidation and other mechanisms of degradation.

The LDI mode enables MOMA to examine nonvolatile organic compounds up to high molecular weights (1000 Da) that are not easily detected by GC/MS. The collected samples are irradiated by a 266 nm Nd:YAG laser (Laser Zentrum Hannover, e.V.) that can be programmed with 1 to 20 laser shots per burst, at laser energies from 13 uJ to 130 uJ, and is focused to a spot of diameter 400 um. Organics with strong UV absorptivity volatilize and photoionize well from most geological samples. Example compounds that exhibit such behavior are carboxylic acids, aromatic amino acids, nucleobases, polycyclic aromatic hydrocarbons, and kerogen. During LDI a carefully designed piston valve separates the sample held at Mars pressure from the much lower ion trap pressure. This valve is opened before laser irradiation allowing thereafter-ionized compounds to enter the trap via a pressure restricting tube. After irradiation, the valve is quickly closed allowing the LIT to analyze ions from the unprocessed sample and using Martian atmosphere as a buffer gas for ion cooling, removing the need for additional helium. The LIT also offers the ability to enrich low-abundance species and perform structural characterization of complex molecules via multi-frequency waveforms and tandem mass spectrometry techniques. Advanced ion manipulation is partially enabled by the Stored Waveform Inverse Fourier Transform (SWIFT) technique. SWIFT allows for the isolation of a selected mass range for enhanced signal detection, and tandem mass spectrometry (MS/MS) allows for the fragmentation of individual parent ions into a series of product ions. These advanced techniques could help to identify functional groups and the potential origins of compounds detected in the Martian near subsurface, thus enabling molecular structural information to be derived from Martian samples in situ.

In summary, the MOMA instrument provides a great opportunity to advance our knowledge of organic preservation and prospect for life on Mars. The mass spectral results can potentially provide guidance for the definition of analytical capability requirements for Mars Sample Return (MSR).

F3.7-0013-18 CHARACTERIZATION OF THE MARS ORGANIC MOLECULE ANALYZER (MOMA) CHROMATOGRAPHIC COLUMNS FOR ORGANIC MATTER INVENTORY AND ENANTIOMERIC RESOLUTION OF AMINO ACIDS ON MARS WITH THE EXOMARS 2020 MISSION

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The Mars Organic Molecule Analyzer (MOMA) experiment will travel to Mars onboard the joint ESA/Roscosmos ExoMars 2020 rover. MOMA is a miniaturized chemical laboratory specifically dedicated to analyzing the organic and inorganic content of samples collected by the rover at the martian surface and subsurface down to 2 meters deep [1]. Through these measurements, MOMA will contribute to characterizing the potential past, present, and future habitability of Mars. MOMA will also go a step beyond habitability and will search for traces of life, or biomarkers, with its unique capability to separate the enantiomers of chiral amino acids, fundamental building blocks of terrestrial life [2]. To reach that goal, MOMA includes a gas chromatograph (GC) and a mass spectrometer (MS). Coupled together, these instruments will respectively separate the volatile compounds produced from heating or chemical treatment of the samples, and provide a spectral signature of each compound. This combination allows the identification of organic molecules. In order to achieve the separation of a wide range of volatile compounds potentially produced from sample treatment, the GC will include four capillary columns, each one dedicated to a specific range of chemical species. Now that the flight model of MOMA is finalized, and the range of operating conditions of the instrument under the Mars surface environmental conditions has been constrained, it is paramount to understand each column's general capability for detecting compounds of interest, and more particularly the specific capability for enantiomeric separation of the onboard chiral column. Evaluation of the column performance was performed on four capillary columns identical to those integrated in the flight model, and using a laboratory setting that allowed the reproduction of MOMA GCMS operating conditions expected to be used on Mars. A set of chemical compounds of interest for Mars surface science and astrobiology was selected and analyzed with the four columns. The use of these chemical standards allowed the optimization of column operating conditions (flow rate and temperature program) based on peak resolution and separation performance. We show that under these optimized operating conditions the columns can detect a wide range of organic and inorganic volatile compounds, and we provide here a first overview of these separation capabilities, with a specific focus on the enantiomeric separation achieved by the MOMA chiral column. These results were tested and validated using two different martian analog samples which underwent the MOMA thermal and chemical treatment processes. This paper presents the performances of the MOMA GC columns and their capability to detect a wide range of compounds, specifically chiral amino acids, on Mars and under the constraints of MOMA operating conditions.

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F3.7-0014-18 OPTIMIZATION OF THE SAMPLE PRE-TREATMENT AND WET CHEMISTRY EXPERIMENTS ON MARS ORGANIC MOLECULES ANALYZER (MOMA), EXOMARS2020

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The Mars Organic Molecule Analyzer (MOMA) experiment aboard the ExoMars 2020 rover will analyze the catalog of organic molecules present in samples collected at the surface and subsurface (down to 2 meters) of Mars. MOMA has two complementary analytical modes: Laser Desorption/Ionization-Mass Spectrometry (LDI-MS) and pyrolysis-Gas Chromatography-Mass Spectrometry (Pyr-GC-MS). In addition to the pyrolysis analysis, three types of

derivatization reagents are present in nine capsules (9 out of 30 total cups) and can be used to enable the analysis of refractory compounds by increasing their volatility and protecting labile chemical groups via (N-methyl-N-tert-butyldimethylsilyl-trifluoroacetamide - MTBSTFA, dimethylformamide dimethyl-acetal - DMF-DMA and tetramethylammonium hydroxide TMAH). MTBSTFA is the most versatile reagent. It is dedicated to analyze the labile compounds with a very high sensitivity. DMF-DMA preserves the chiral center of molecules and will allow for their enantiomeric separation. TMAH will be used to extract and characterize potential refractory compounds (macromolecules, kerogen, etc.) and protect polar compounds (alkylation) released from the pyrolysis experiment. In the context of the Exomars 2020 mission and the MOMA experiment, these three techniques have been optimized (volume of reagent, temperature, time of reaction) and tested on several martian analogues. The effect of the presence of perchlorate on each reagent has been examined. By using pyrolysis, DMF/DMA, MTBSTFA and TMAH derivatization chemistry, the MOMA experiment will be able to characterize the presence and the amount of key molecules indicating prebiotic chemistry and life (e.g. amino acids) as well as the enantiomeric ratio of key chiral molecules, used as a bioindicator. These measurements will also give us a first insight into the potential presence of living organisms in the soil of Mars.

F3.7-0015-18 THE LADDER OF LIFE DETECTION

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Life detection includes measurements seeking to find life: searching for biosignatures (features that evidence ongoing or past biological processes) and establishing context (properties and processes inherent to the sample's current and past settings). To guide the development of missions seeking to find life on Mars, ocean worlds, and exoplanets, we have built a Ladder of Life Detection (https://astrobiology.nasa.gov/research/life-detection/ladder) [1].

This tool, meant to be challenged and upgraded, lists features of life and assesses their potential for providing conclusive evidence for life through the following criteria: * Sensitivity includes all aspects of instrumental performance (e.g. selectivity, dynamic range). The instrument must detect the feature of life within set performance thresholds, to avoid instrumental false negatives.

* Discrimination from contamination interfering with the measurement, to avoid instrumental false positives and contamination by hardware or other samples. * Replicability: As many measurements and samples as needed to meet predefined goals and capture the heterogeneity of the setting. * Detectability: Physical, chemical, or geological conditions in the sample's current environment must not prevent the measurement to be made. * Survivability: The feature of life must not have been destroyed in the environments encountered by the sample between its synthesis and its measurement. * Reliability: is the propensity for the feature to be produced by life and distinguished from abiotic backgrounds from any of the environments encountered between feature synthesis and measurement. * Compatibility: The feature must be consistent with what is known of life. This criterion assesses the feature's genericity vs. specificity to life on Earth [2]. * Last-resort hypothesis: The measurement (alone or part of a set) must preclude an abiotic origin to a given statistical significance.

Features of life: The Ladder details the propensity for each feature to meet the above criteria. We combine this into a subjective "likelihood" that the feature is diagnostic of life. Features below are loosely ranked from highest to lowest likelihood. We encourage the community to refine this ordering. * Darwinian evolution takes place over many generations of organisms as conditions change. There is no widely accepted means to detect or measure it. It is not practical to detect in unexplored natural environments in the time frame of missions. * Growth and reproduction are evidenced by morphologies of concurrent life stages or a reproductive form, such as cell-like structures in multiple stages, including motility. * Metabolism: Organisms derive energy from their environment and convert it to forms used for growth, reproduction, or repair. Conversion is not fully efficient, so metabolism results in waste. Conversion and waste intermediates or products deviate from abiotic thermodynamic equilibrium or kinetically limited abiotic steady states. Such deviations include elemental or isotopic fractionations, colocation of oxidants and reductants, or a response to substrate addition. * Molecules and structures conferring function include polymers that support information storage or transfer (e.g. DNA, RNA) and functions such as catalysis (proteins), specific structural preferences in organic molecules (e.g. homochirality, repeating charge), and pigments (detectable by remote sensing). * Potential biomolecule components comprise organic compounds not found abiotically (e.g. hopanes, ATP, histidine), complex organics (nucleic acid oligomers, peptides, PAHs), and monomeric units of biopolymers. * Potential metabolic byproducts are distributions of species that differ from those resulting solely from abiotic thermodynamic equilibrium or kinetic steady state. They include distributions of elements present at trace levels in biological matter and patterns of complexity in mixtures of organics. * Biofabrics: Microbial communities can affect the morphology of their environment, creating laminations, mounds, or microbially induced sedimentary structures.

Beyond measurement interpretations and payload design, we anticipate that the Ladder will spur discussion and progress in life detection, leading to improvements to the Ladder itself.

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F3.8-0001-18 FAST AND SETI

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Five-hundred-meter Aperture Spherical radio Telescope (FAST) have listed SETI as a science goal. For this, FAST team have collaborated with Berkeley to develop a SETI backend. This backend will be used in the Commensal Radio Astronomy FAST Survey (CRAFTS) that is going to start soon. SETI will be done simultaneously with other observations. Currently, AI technology has been implemented in the FAST pulsar search. In the future, AI will play an important role in the FAST SETI studies.

F3.8-0002-18 INAF-UC BERKELEY COLLABORATION ON SETI ACTIVITIES

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The year 1998 marked the start of a collaboration in SETI activities between research institutions in Italy (now belonging to the Italian National Institute for Astrophysics, INAF)

and the SETI group at the University of California, Berkeley. In that year, a prototype of the SERENDIP IV was installed on the INAF 32-m diameter Medicina radio telescope (near Bologna, Italy) and used in piggy-back mode to conduct SETI observations for several years. In 2013, the new 64-m diameter Sardinia Radio Telescope (SRT), located near San Basilio, Italy, was inaugurated, and a six-month early science program was conducted in single-dish mode in 2016. Among the several scientific activities to which the SRT will be devoted, SETI is going to be a commensal one. A collaboration between the Italian research groups of INAF and the UC-Berkeley SETI team restarted in 2014; today, the status of the collaboration includes the following activities: 1) Analysis of data taken by the 100-m diameter Green Bank Telescope (GBT) and by the 64-m diameter Parkes radio telescope in the context of the Breakthrough Listen program; 2) SETI observations at SRT, e.g. observations of nearby stars, galaxies or surveys; 3) Development of a real-time KLT algorithm, suitable for SRT, GBT and the Parkes radio telescope; 4) Implementation of a pipeline for Fast Radio Burst searches using the KLT algorithm; 5) Porting of the instruments employed at GBT and the Parkes telescopes to the SRT for SETI, Fast Radio Burst and Pulsar studies; 6) Discussion about a possible participation of SRT in the Breakthrough Listen program, especially by exploiting a seven-feed S-band receiver (3 - 4.5 GHz) currently under development by the INAF team. We present the status of the aforementioned activities, a possible timeline for each of them and the future perspectives of such a collaboration.

F3.8-0003-18 THE BREAKTHROUGH LISTEN SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE: CURRENT STATUS AND FUTURE DIRECTIONS

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Breakthrough Listen is a ten-year program designed to conduct the most sensitive, comprehensive and intensive search for evidence of intelligent life beyond the Earth ever undertaken. Employing the world's largest telescopes, operating across the electromagnetic spectrum, Breakthrough Listen will survey a million nearby stars, hundreds of nearby galaxies and the Milky Way galactic plane. Future extensions to the program will bring wide-field "all-sky" survey capabilities at both radio and optical wavelengths. The program is also investigating data mining approaches using extant and forthcoming survey data, including special focus on machine learning and artificial intelligence-based techniques.

Here we will review the status of the Breakthrough Listen program, briefly discuss recent results and instrument deployments, and detail plans for the near and mid-term future of the program

F3.8-0004-18 MODELING OF FAST RADIO BURSTS WITH THE KARHUNEN-LOEVE TRANSFORM

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Fast radio bursts (FRBs) are highly energetic transient radio pulses that are believed to originate outside the Milky Way. FRBs are observed as broadband signals that only last a few milliseconds. Out of the 30 FRBs that have been observed to date, only one has been found to be "repeating", so there might be at least two classes of FRBs. By solving the mystery of their origin and progenitors, astronomers will be able to use FRBs to address a range of open questions about cosmology, intergalactic magnetic fields, and general relativity. Searching for transients such as FRBs involves the detection of dispersed pulses in noisy data. The KarhunenLoeve Transform (KLT) is a mathematical algorithm used to model stochastic processes in time. Unlike the widely used Fourier Transform (FT), the KLT is not limited to harmonic functions; it works well for both narrow and wideband signals; and it works well with both stationary and non-stationary input stochastic processes. Because of its features, the KLT has proven to be way more efficient in retrieving signals out of noise, despite being more computationally intensive and therefore slower. The KLT is therefore the most appropriate tool for modeling transient signals such as FRBs. In this work, we present the application of the relativistic KLT to a sample of FRB signals.

F3.8-0005-18 AN OPTICAL SEARCH FOR DIRECTED ENERGY SIGNATURES IN M31

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In realm of optical SETI, searches for pulsed laser signals have historically been preferred over those for continuous wave beacons. There are many valid reasons for this, namely the near elimination of false positives and simple experimental components often present in pulsed searches. However, due to significant improvements in laser technologies and light-detection systems since the mid-20th century, as well as new data from the recent Kepler mission, continuous wave searches can no longer be ignored. We propose a search for continuous wave laser beacons from an intelligent civilization in the Andromeda galaxy. Using only a 0.8 meter telescope, a standard photometric system, and an image processing pipeline, we expect to be able to detect any CW laser signal directed at us from an extraterrestrial civilization in M31, as long as the civilization is operating at a wavelength we can "see" and has left the beacon on long enough for us to detect it here on Earth. The search target is M31 due to its high stellar density relative to our own Milky Way galaxy. Andromeda is home to at least one trillion stars, and thus at least one trillion planets. This is an unprecedented number of targets relative to other past SETI searches. For this reason we call this project the Trillion Planet Survey.

F3.8-0006-18 A SEARCH FOR TECHNOSIGNATURES FROM 14 PLANETARY SYSTEMS IN THE KEPLER FIELD WITH THE GREEN BANK TELESCOPE

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Analysis of Kepler mission data suggests that the Milky Way includes billions of Earth-like planets in the habitable zone of their host star. Current technology enables the detection of technosignatures emitted from a large fraction of the Galaxy. We describe a search for technosignatures that is sensitive to Arecibo-class transmitters located within 450 ly of Earth and transmitters that are 1000 times more effective than Arecibo within 14 000 ly of Earth. Our observations focused on 14 planetary systems in the Kepler field and used the L-band receiver (1.15-1.73 GHz) of the 100 m diameter Green Bank Telescope. Each source was observed for a total integration time of 5 minutes. We obtained power spectra at a frequency resolution of 3 Hz and examined narrowband signals with Doppler drift rates between +/-9 Hz s-1. We flagged any detection with a signal-to-noise ratio in excess of 10 as a candidate signal and identified approximately 850 000 candidates. Most (99%) of these candidate signals were automatically classified as human-generated radio-frequency interference (RFI). A large fraction (>99%) of the remaining candidate signals were also flagged as anthropogenic RFI because they have frequencies that overlap those used by global navigation satellite systems, satellite downlinks, or other interferers detected in heavily polluted regions of the spectrum. All 19 remaining candidate signals were scrutinized and none could be attributed to an extraterrestrial source.

F3.8-0007-18 SEARCHING FOR DELIBERATE SIGNALS FROM RED DWARFS

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It’s been the tradition of SETI efforts to examine the vicinities of solar-type stars for radio and optical emissions that would betray the presence of intelligent beings. This conservative approach derives from the simple fact that the one example we have of intelligence orbits such a star. However, recent exoplanet discoveries suggest that red dwarf stars, despite having narrow habitable zones, also have large numbers of planets in these zones. Estimates suggest that 15

- 50 percent of these runty stars have at least one habitable planet. Additional advantages to searching red dwarfs for engineered signals include their abundance and their age.

The SETI Institute has embarked on a survey of 20,000 of the nearest red dwarf stellar systems, using its Allen Telescope Array. We report on the details of this experiment, and the results so far.

F3.8-0008-18 THE BREAKTHROUGH LISTEN SEARCH FOR INTELLIGENT LIFE: THE FIRST SETI RESULTS AND OTHER FUTURE SCIENCE.

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The Breakthrough Listen (BL) Initiative is the largest campaign in human history on the search for extraterrestrial intelligence. The work presented here is the first BL search for engineered signals. This comprises a sample of 692 nearby stars within 50 pc. We used the Green Bank Telescope (GBT) to conduct observations over 1.1-1.9 GHz (L-band). Our observing strategy allows us to reject most of the detected signals as terrestrial interference. During the analysis, eleven stars show events that passed our thresholding algorithm, but detailed analysis of their properties indicates they are consistent with known examples of anthropogenic radio frequency interference. This small number of false positives and their understood properties give confidence on the techniques used for this search. We conclude that, at the time of our observations none of the observed systems host high-duty-cycle radio transmitters emitting at the observed frequencies with an EIRP of 1013 W, readily achievable by our own civilization. We can place limits on the presence of engineered signals from putative extraterrestrial civilizations inhabiting the environs of the target stars. Our results suggest that fewer than sim 0.2% of the stellar systems within 50 pc possess the type of transmitters searched in this survey. This work provides the most stringent limit on the number of low power radio transmitters around nearby stars to date. We explored several metics to compare our results to previous SETI efforts. We developed a new figure-of-merit that can encompass a wider set of parameters and can be used on future SETI experiments for a meaningful comparison.We note that the current BL state-of-the-art digital backend installed at the Green Bank Observatory is the fastest ever used for a SETI experiment by a factor of a few. Here we will describe the potential use of the BL backend by other groups on complementary science, as well as a mention the ongoing and potential collaborations focused in particular in the study of astrophysically powered radio emission from stars targeted by our program.

F3.8-0009-18 SETI@HOME ANALYSIS OF OBSERVATIONS OF 220 NEARBY STARS

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We present the SETI@home analysis of observations of 220 nearby start and 29 non-stellar targets taken in several radio band by the Breakthrough Listen project using the Green Bank Telescope. We describe the data taking process and the analysis pipeline, which utilizes a coherent de-chirp method to search through a large range of accelerating Doppler frames to find signals that are not frequency stable in the topocentric reference frame. We find that most of the high amplitude signal we detect are stable in the topocentric frame. Many have Doppler drift rates similar to what is expected for a satellite in low Earth orbit. We find none that are indicative of a stable frequency in the frame of the barycenter of the solar system. We will show some examples of the signals we detected and discuss their properties. No signals of demonstrably extraterrestrial origin were found.

F3.8-0010-18 ON THE BREAK THROUGH LISTEN AUTOMATIC SEARCH FOR PERIODIC BROAD BAND EXTRATERRESTRIAL SIGNALS

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We report on the analysis tool to search for wide band repeating drifting signals in data of 'filterbank' format (raw radio telescope data converted in frequency channels versus time format). We test the pipeline by detecting Pulsars and FRBs using a wealth of stored Break Through Listen (BTL) data from the Green Bank BTL observational campaign in progress. We then extend the testing using BTL data from the Parkes Radio telescope for the southern hemisphere. The code will be updated to handle hd5 data format. Our final scope is to install the code widely for the BTL backend to run while data are being taken, thus contributing to the intelligent ET searching.

F3.8-0011-18 EMPIRICAL LIMITS ON THE EXISTENCE OF INTERSTELLAR PROBES IN THE SOLAR SYSTEM

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NASA has five robotic space probes on escape trajectories from the solar system (Pioneer 11, Pioneer 12, Voyager 1, Voyager 2, and New Horizons), and "interstellar probes" are among the concepts being voiced for consideration for future mission concepts. While none of these robotic probes will be operational on the time scale that it would take to reach another star, it is natural to ask whether another civilization might also be sending out interstellar probes. Serious consideration of such interstellar probes dates at least to R. Bracewell in the early 1960s, and the recent discovery of 1I/2017 'Oumuamua has rekindled some of that interest.

We consider what limits exist on interstellar probes in the solar system, using data available from planetary exploration and astronomical sky surveys. Perhaps not surprisingly, the completeness to which the solar system has been searched varies as a function of distance from the Sun. However, with notable exceptions, only extremely crude limits can be placed on the existence of interstellar probes.

Part of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

F3.8-0012-18 ARTIFACT SETI AS A FRUITFUL COMPLEMENT TO COMMUNICATION SETI

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Artifact SETI includes searches for waste heat, megastructures orbiting stars, and other evidence of engineering on large scales. Many such searches can proceed via interrogation in novel corners of parameter space of archival optical, infrared, and time domain data sets collected for other purposes. I present examples of how such searches complement communication SETI by enriching target lists, while also generating ancillary science through its false positives and detection of astrophysical exotica. I will also present the philosophy and results of a new graduate course in SETI at Penn State.

F3.8-0013-18 A REPORT ON THE IAA PERMANENT SETI COMMITTEE'S REVIEW OF THE SETI POST-DETECTION AND REPLY PROTOCOLS

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In 1989, the SETI Committee of the International Academy of Astronautics (IAA) developed the "Declaration of Principles Concerning Activities Following the Detection of Extraterrestrial Intelligence." These SETI Post-Detection Protocols provided a mechanism to guide the procedures for verification and announcement of the confirmed detection of extraterrestrial intelligence. This was followed in 1995 by the "Draft Declaration of Principles Concerning Sending Communications with Extraterrestrial Intelligence" (Proposed SETI Reply Protocols). These Protocols were presented to the United Nations Committee on the Peaceful Uses of Outer Space, and received wide international approval and endorsement from institutions and individuals engaged in or otherwise concerned with the search for extraterrestrial intelligence.

SETI as a discipline has greatly expanded in the decades since the Protocols were written, thanks to advances in instrumentation and observational techniques, more sophisticated theoretical calculations and arguments, and a growing awareness of how to exploit astronomical data from a wide range of wavelengths for signs of intelligence.

In 2010 the SETI Post-Detection Protocols were revised to update and streamline its provisions (2010 Declaration of Principles). However, the revisions have not been adequate to keep pace with SETI's recent scientific and technological advances.

Moreover, the 2010 revisions did not address the revolutionary changes that have been made in the forms of media and information dissemination since the original Protocols were written

- namely the extensive reliance on the Internet and social media, and the concomitant decline in print and other traditional forms of mass communication, which if poorly handled places the credibility of SETI at risk. Recent studies have shown there is therefore a clear need for a fresh review of the Protocols.

As members of the IAA Permanent SETI Committee, the authors were tasked with initiating this review at its meeting during the 68th International Astronautical Congress in Adelaide in September, 2017. We will discuss the current status of this review, and our plans for a wideranging consultation to engage the SETI community, the international community (including scientists in all interested fields), as well as the general public. The aim is for a frank, open dialogue, that ensures as comprehensive a review as possible. This is believed to be the best route to achieve widely accepted, clearly articulated SETI Protocols that will be abided by the community, and will ultimately serve the interests of SETI as a recognized and well-respected academic discipline.

F3.8-0014-18 BREAKTHROUGH LISTEN TARGET SELECTION AT MEERKAT

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The Breakthrough Listen Search for Extra-terrestrial Intelligence is poised to begin observations at the MeerKat Telescope in pursuit of its 1,000,000 star survey. By conducting commensal observations with other science programs on MeerKat pursuing a wide range of scientific goals and observation strategies, we plan to fully utilize the science capabilities of this next generation facility. Breakthrough Listen has previously focused on a targeted star survey of the Solar neighborhood with the Green Bank Telescope and a survey of the Galactic Plane with the Parkes Telescope. The MeerKat observations will expand the number of targeted star search by a factor of 1000, and will combine the telescope infrastructure of MeerKat with the digital instrumentation and analysis capabilities of Breakthrough Listen.

F3.8-0015-18 BEYOND INITIAL SIGNAL CATEGORIZATION AND SYNTACTIC ASSIGNMENT: THE ROLE OF METADATA IN DECODING AND INTERPRETING NONHUMAN SIGNALS

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The processes involved in detecting, verifying, and deciphering an alien signal from space are vast. Although the first two aspects have been studied and thought out over the decades, the decipherment and interpretation process for any alien signal is less explored and has mainly focused on developing methods to discover, identify, and categorize the structural and syntactic content of a signal - to confirm intelligent agent credentials, as a precursor to semantic assignment. Ways forward are suggested by anthropology and animal behavior studies. Anthropologists study and interpret human cultures in various ways. Likewise, animal behaviorists study animals in a variety of ways through signal deconstruction and interpretation.

The data an animal behaviorist analyzes can vary from a physical signal to multiple signals within a social or behavioral context, including an immense array of metadata. Each level of information allows its equal level of interpretation. When scientists observe animal societies, they are usually extracting information by passive observation that involves trying not to disturb an animal performing its natural behavior. Signals are collected and matched with metadata (age, sex, behavioral activity), to allow the interpretation of meaning of an activity.

Some animal vocalizations are discrete, others are graded. Sequences of sound types show absolute and relative changes in the spacing between signals including prosodic aspects such as rhythm and synchrony. We search for the smallest unit of information, combinatorial features of units, and grammar and structure reflecting rules of order. And although patterns of modulation and encoding of information across taxa may provide insight into the data mining of an alien signal, the true interpretation of the meaning of information may rest in the metadata and contextual details used in the society itself. Although we may be able to discern the complexity and structure of a message, interpretation of the meaning of an alien signal may be impossible without such metadata, especially if the content goes beyond a mere greeting and factual statement of their location and biology.

Assuming that an intentional signal (vs. leakage) sent by an alien civilization would include a key for deciphering message content, our job for fully understanding may include searching

for embedded metadata, allowing us to interpret meaning in the message. The assumption here is that communicated patterns and rules would be purposely infused into the message itself, to help the naive receiver interpret the message. How might an alien transmission be encoded to create metadata to help any potential receiver of the information understand its significance? How do we think like a nonhuman when we are human? Studies from both animal behavior and anthropology can inform us of potential ways to look outside ourselves for new ideas. We propose that work of this kind should be an integral part of the SETI 'post-detection' portfolio of concerns, and in turn, that 'post-detection' preparatory work must be integral to SETI as a whole.

F3.8-0017-18 NONLINEAR DYNAMICS IN A POPULATION OF COMMUNICATIVE CIVILIZATIONS THROUGH CONTACTS BY COMMUNICATION CHANNELS AND A STRATEGY OF SETI

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Nonlinear effects in a population of extraterrestrial civilizations mean generally that civilizations can influence each other by a number of various ways. In this paper we study the situation when contacts between civilizations by communication channels may influence mean lifetime of civilizations in the communicative stage and mean "communication range" - the average limiting distance at which a given civilization can establish direct contact with another civilization. As the mathematical model in the paper shows, such a mutual influence of civilizations can lead to the appearance of a positive feedback loop, due to which at some point in time a very sharp phase transition from a state in which contacts among civilizations are rare (on average the number of partners by contact for one civilization is much less than one), to a state in which each civilization has on average one or more contact partners. The same feedback loop leads to the phenomenon of bi-stability in the population of galactic civilizations, when the same average frequency of the emergence of new civilizations, depending on the prehistory of the system, may correspond to a population with a small number of civilizations and a low probability of contacts, or a population with a large number of civilizations and frequent contacts. A strategy of SETI search in this context is discussed.

F3.8-0018-18 EVO-SETI SCALE FOR EXOPLANETS WITH LIFE

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The Evo-SETI Scale (Evo-SETI stands for "Evolution and SETI") is a scale of information measured in bits.

It ranges between zero (corresponding to the time of the origin of life on Earth, 3.5 billion years ago or a little more, like 3.8 billion years ago, or so) and 25,595 bits, that is today's value of the scale.

The straight line between these two values is the Scale measuring the EvoEntropy, i.e. the Shannon Entropy of Information Theory for a family of lognormal probability densities constrained between the time axis and the exponential curve representing the number of Species living on Earth at each instant between 3.5 billion years ago and now. In reality, this exponential is rather the mean value of the number of living Species in the 3.5 billion years of time, since many Species went extinct in the past. Mathematically speaking, we thus have a stochastic process with this exponential mean value and this is called Geometric Brownian Motion (GBM). This GBM turns out to be a lognormal process, and not a Gaussian process.

The relevant mathematics is rather difficult, and was developed by this author in a series of some ten highly mathematical papers published in the International Journal of Astrobiology and in Acta Astronautica since 2010.

But the meaning of the Evo-SETI Scale is quite neat: it shows "how much evolved" a certain Species is with respect to all other Species, both of the past and of the present. And if we replace "Species" with "Complexity", the Evo-SETI Scale becomes the Complexity Scale that we can extrapolate into the future in order to find how much more complex than Humans a certain ET Civilization will turn out to be when SETI, the Search for ExtraTerrestrial Intelligence, will put us in touch with Alien Civilizations.

In conclusion, our Scale really is an Evo-SETI Scale, combining both the past (Evolution) and the future (SETI) into a unique, highly mathematical scheme.

F3.8-0019-18 A MATHEMATICAL AND SCIENTIFIC MESSAGE FOR ACTIVE SETI

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On three successive days (October 16, 17, and 18, 2017), METI (Messaging Extraterrestrial Intelligence), a nonprofit scientific and educational organization, transmitted its first interstellar message as part a project called "Sónar Calling GJ273b." The target was a potentially habitable exoplanet named GJ 273b, orbiting Luyten's star, a red dwarf 12.4 light years from Earth. The project was initiated by the Sónar music festival to commemorate its 25th anniversary, and it was a collaboration between Sónar, METI, and The Institute of Space Studies of Catalonia (IEEC). This paper discusses the mathematical and scientific tutorial created by METI for the transmission.

METI's tutorial was sent in binary code at two frequencies, 929.0 MHz and 930.2 MHz, using the 32-meter, fully steerable parabolic antenna of the (European Incoherent Scatter Scientific Association (EISCAT) in Tromsø, Norway, which has a peak power of 2 MW. The tutorial was sent three times on each of three days at 125 bits per second, for a total transmission time of 11 minutes each day. By repeating the message each day, any extraterrestrial recipients will be able to correct errors that occur as the message traverses interstellar space.

The tutorial used a minimal number of key mathematical concepts to introduce fundamental physical concepts like time, frequency, and wavelength. For example, after introducing numbers, basic arithmetic functions, and Pythagorean triples, we describe sine waves through the ratios of sides of a right triangle.

METI's mathematical and scientific tutorial includes innovative features like a "cosmic clock" that lets extraterrestrials confirm that their understanding of time from our scientific message maps onto the passage of time they can observe throughout the transmission itself. An overall design feature we emphasized is that the form of the message is linked to the contents of the message. For example, we explain the notion of radio frequency by sending signals of different frequencies, and then describing the signals in mathematical terms.

F3.8-0020-18 DEVELOPING ETHICALLY INFORMED METI PROTOCOLS

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No protocols exist to guide, prohibit, require discussion or consensus, prior to sending directed radio or optical messages intended to be intercepted or received by extraterrestrials. Thus anyone with the power and the know-how to operate radio and optical telescopes can freely send out information about our planet to potential onlookers. There is an ongoing debate within the greater SETI community regarding the concerns and risks of transmitting such messages. For example, a statement published in 2015 by the Berkeley SETI Research Center, and signed by several astrobiologists, states, "[i]ntentionally signaling other civilizations in the Milky Way Galaxy raises concerns from all the people of Earth, about both the message and the consequences of contact. A worldwide scientific, political and humanitarian discussion must occur before any message is sent." Here we present the need for ethicists, and philosophers in general, to be included in this discussion and propose a method for addressing the ethical arguments involved in transmitting intentional messages into space with the intent of supporting a cross-cultural and multidisciplinary METI protocol.

F3.8-0021-18 A THREE-STEPS ROAD MAP TO THE NEW FRONTIER: LOCATING THE NEAREST ETIS, AND THE ROLE OF ASTRONAUTS.

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An obvious New Frontier for humanity is to locate our nearest neighbors technically advanced (ETI, extra-terrestrial intelligence), in response to the question "Are we alone in the Universe?" This quest can be achieved with three steps: 1. find the nearest exoplanets in the habitable zone (HZ) of their host stars. 2. find bio-signatures in their atmospheric and surface spectra.

3. find unvolontary signs of advanced technology (city lights at night, radio signal leaks). We argue that steps 2 and 3 will require large space telescopes that need to be oriented to targets already identified in step 1 as hosting exoplanets of Earth or super Earth size in the habitable zone. We show that non-transiting planets in HZ are 3 to 9 times nearer the sun than transiting planets, the gain factor being a function of star temperature. The requirement for step 1 is within the reach of a network of 2-4 m diameter ground-based automated telescopes associated with HARPS-type spectrometers. The search should be done by increasing distance from our sun. Steps 2 and 3 will require the building in space of large size telescopes, which elements could launched separately, and be assembled in space by astronauts, in a fashion similar to the way was built the International Space Station. The telescopes could also be placed on the moon or at Lagrange L2 point. Since ETI can spot us, we must be able to spot them. Communication is an independent matter to be discussed separately. The author acknowledge support from the Russian Government Grant 14.W03.31.0017.

F3.8-0022-18 CHARLES CROS AND NIKOLA TESLA, PIONEERS OF INTERPLANETARY TELEGRAPHY

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The birth of SETI (Search for Extraterrestrial Intelligence) is usually dated from 1959 (note 1) with the famous Cocconi and Morrison publication emphasizing that microwaves frequencies were the most appropriate for interstellar communication (note 2). In 1960, American astronomer Frank Drake was the first to put this hypothesis into practice with the Project Ozma. Since then, a lot of searches have been undertaken -in radio or optical frequenciesto attempt to intercept alien signals from advanced technological civilizations. Another aspect of communication is sending messages, known as METI (note 3) (Messaging to ExtraTerrestrial Intelligence, another term is ActiveSETI), which seems to be less prevalent than SETI but perhaps even more debated. Some messages have been sent to the stars during the past decades, generally more for symbolic purposes than to start a "conversation" with other -very far and unknownplanets. Recently, however, the discovery of potentially habitable exo-Earths revived the question of messaging to alien civilizations, since these exoplanets represent now concrete targets. Considering a historical perspective, sending messages to other planets is not a new idea. Pioneering projects were proposed during the nineteenth century to communicate on an interplanetary scale. The latter half of the nineteenth and the very beginning of the twenti- eth century were particularly prolific periods on that question, and many efforts were made to elaborate schemes to contact our neighboring planets through an interplanetary telegraphy. Developments in the field of terrestrial communications (electrical telegraphy, telephone) and intense Martian observations suggested it could be achievable to "talk to other planets", especially Mars. In this paper we focus on French inventor and poet Charles Cros (1842- 1888) and Serbian-American inventor and physicist Nikola Tesla (1856-1943), who have been among the most active and convinced pioneers of interplanetary telegraphy. Their projects are discussed here, even if they have never been put into practice.

1 In fact, the acronym SETI was not used before 1975. 2 Giuseppe Cocconi and Philip Morrison, Searching for Interstellar Communications, Nature, 184 (4690) 844- 846 (1959). 3 The acronym

METI was coined by Russian scientist Alexander Zaitsev in 2005 (http://www.cplire.ru/html/rasr/irm/Dra

F3.8-0023-18 A SEARCH FOR TECHNOSIGNATURES FROM TRAPPIST-1, LHS 1140, AND

10 PLANETARY SYSTEMS IN THE KEPLER FIELD WITH THE GREEN BANK TELESCOPE AT 1.15-1.73 GHZ

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As part of our ongoing search for technosignatures, we collected over three terabytes of radio astronomy data in May 2017 using the L-band receiver (1.15-1.73 GHz) of the 100 m diameter Green Bank Telescope (GBT). These observations focused primarily on planetary systems in the Kepler field, but also included scans of the recently discovered TRAPPIST-1 and LHS 1140 systems. We will present the results of our search for narrowband signals in this data set with techniques that are generally similar to those described by Margot et al. (2018, https://arxiv.org/abs/1802.01081). We will also describe several improvements to our search algorithms that make the identification of radio-frequency interference (RFI) more robust. In particular, we describe improvements to the characterization of signals that we resolve in the frequency domain.

LIFE SCIENCES AS RELATED TO SPACE (F)

INNOVATIVE APPROACHES TO SPACE HABITATION (F4.1)

F4.1-0001-18 BIOSPHERIC LIFE SUPPORT - INTEGRATING BIOLOGICAL REGENERATION INTO PROTECTION OF HUMANS IN SPACE.

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In the nineties, the Biosphere 2 project innovated, by assembling a set of Earth biomes samplesplus an organic ag one, inside a closed Mars base-like structure, next to 1.5 ha under glass, in Arizona, US. The crew of 8 inside completed their two years contract, though facing setbacksthe system failed, e.g., to produce enough food/air supplies. But their "failures" were as meaningful as their achievements for the future of life support systems (LSS) research. By this period, the Russians had accumulated experience in extended orbital stays, achieving biological outcomes inside their stations. After reaching the Moon, the US administration put the space program as part of a "détente" policy. Alongside the US space shuttle program, the Russians were invited to join the new International Space Station (ISS), bringing to that pragmatic project their physical-chemical LSSthen a top air/water regenerative technology. Present US policy keeps the ISS operational, extending its service past its planned retirement (2016). The extension will allow partner agencies to deploy new experiments there, resuming basic research focusing more forward-looking goals. For deep-space, since consumables logistics becomes more difficultand habitability an issue, with diminishing Earth's view, further research has been recommended. Four major areas have been identified for human protection: (1) radiation mitigation; (2) highly recyclable bio-regenerative (BR) LSS; (3) micro-gravity countermeasures including artificial gravity (AG), and (4) psychological safety. To contribute to the efforts to address these issues, a basic lab/virtual iterative research has been proposed, assuming (in a worst case scenario) that: I) It won't be possible to send people to long deep space missions, safely, with the current (low quality of life) support technology (ISS micro-gravity 'up-gradings'); II) The alternative to implant a Mars surface human supportive biosphere would also not be possible either, due to evolutionary restraints (life could adapt and survive, but not necessarily to favor humans). From the above considerations arises the question: Would an average approach be possible where, by applying the artificial gravity concept to S/Cs, a fragment of Earth bioregenerative environment could be integrated inside reusable manned vehiclesthus enhancing its habitability/autonomy in long deep space missions? For this research question a provisory answer has been provided. And to test it, a small AG+BR bench simulator (plus computer methods) has been devised. Since massive AG systems aren't advisable inside ISS for stability reasons, any future AG+BR trials must be run in association, but outside ISS structure.

F4.1-0002-18 FUNCTIONAL SUBSTANCES WHICH CONTRIBUTE TO DRY HEAT TOLERANCE OF A TERRESTRIAL CYANOBACTERIUM IT NOSTOC SP. HK-01

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Terrestrial cyanobacteria can be utilized for bio-chemical circulation in closed bio-ecosystems because of their photosynthetic ability, nitrogen fixation ability, utility as food and tolerance to harsh environments. Dried colonies of a terrestrial cyanobacterium, Nostoc sp. HK-01 (hereafter HK-01), have high tolerances to vacuum, UV, gamma-rays, heavy particle beams and extreme temperatures. Environmental tolerances are important for transportation in outer space. HK-01 was adopted as a biological material for the "TANPOPO" mission (JAXA et al.,), because of their high environmental tolerances. The "TANPOPO" mission is performing space exposure experiments on the Japan Experimental Module (JEM) of the International Space Station (ISS). The results of these experiments will show the ability of HK-01 to survive in space. HK-01 has several different types of cells in its life cycle. Akinete (dormant cell) is the cell type which has a tolerance to dry heat in HK-01 (Kimura et al., Biol. Sci. Space, 2015; 2017). Some functional substances which provide tolerance against heat exist in the akinete cells. In this study, we investigated the properties of low molecule compounds which are accumulated in akinetes of HK-01, to prevent protein aggregation during exposure to heat (Kimura et al., Am. J. Plant Sci., 2017). Our results suggested that the compounds have some function as a compatible solute, which contributes to the dry heat tolerance of akinetes of HK-01.

F4.1-0003-18 BUILDING THE CONDITIONS FOR LIVING TOGETHER, A MAJOR KEY TO SUCCESSFUL SPACE HABITATION

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While a lot of research is dedicated to the material conditions to make a sustainable life possible on board of space habitation, a lot of design still has to go in building environments that will facilitate the « living-together ». Half-way between well-known Biosphere-2 and the entire Planet Earth which is the base for our primary experience, Reunion Island, a French/European community at the opposite of California with respect to the Planet, is considered as a remarkable model for good living-together. Attention may be given to an understanding of the special conditions of the environment in the island that allow for this success. What are then the possibilities of downsizing the structures involved in this environment to transfer them to the architectural design of space habitation ?

F4.1-0004-18 CHLAMYDOMONAS-COMMUNITY BIOREACTOR

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The primary requirement of a bioregenerative life support system is to handle the complexity of variable environmental conditions in an efficient and sustainable way. For an entire system design it is mandatory to understand the behavior of each subsystem under these variable conditions. In a modular approach the biochemical and physicochemical inand outputs of each subsystem need to be investigated and optimized before combining several to a more complex and bigger system.

Within the scope of ModuLES (Modular Life Support and Energy Systems), initiated and funded by the German Space Agency, DLR, a photobioreactor (PBR) with the unicellular microalgae Chlamydomonas reinhardtii was selected as the starting point of this research. The PBR and its subsystems were designed to understand the behavior and physiology of Chlamydomonas in a closed system - in regards to the production of oxygen under a given supply of carbon dioxide, nutrients and light energy.

On ground, Chlamydomonas is the most researched unicellular algae around the globe, but when considering cultivating it in a microgravity environment over a long duration of time, several areas show up, which have never been researched. In general, research on ground is conducted in an open system, but for spaceflight application, a closed system is a basic requirement. Thus, the importance to understand the general behavior and physiology is a prerequisite for successful operation of a PBR in space.

Additionally, it is important to allow a community of algae, bacteria and fungi to develop and coexist within the closed system of the PBR, because in future steps of ModuLES, the PBR will be connected to other modules to slowly build up a life support system. Latest when connecting the PBR to a second module it will not be operating under sterile conditions any longer. Thus, the ModuLES-PBR will be filled with a sterile algae solution, but under non-sterile conditions, allowing contamination to occur.

The design is based on a chemostatic process, allowing the investigation of environmental impacts on the microalgae-community, with a set of sensory devices and a sampling unit supporting the physiological research. With these results the next step to a turbidostatic performance can be completed.

As an interface to other subsystems an oxygen removal and carbon dioxide supply over a liquid to gas exchange system is implemented. To achieve the recycling of media, a filtration, analysis, and resupply unit is designed to reduce the needed resupply mass for spaceflight applications to a minimum.

To understand the required flexibility of an MRU to sustain a community-PBR, upper and lower limits of specific media components were tested and the recovery of the community documented in tests. Based on this data and the design adjustments to the media recycling system, the obtained performance data can be used to design the next ModuLES level, the next module which will couple to the PBR.

F4.1-0005-18 GENES OF TERRESTRIAL CYANOBACTERIA WHICH ARE EXPECTED TO BE USEFUL IN SPACE ENVIRONMENTS.

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Cyanobacteria are photosynthetic organisms which produce oxygen (O2) on the earth. Terrestrial cyanobacteria are living in extreme environments. Some terrestrial cyanobacteria have tolerance to desiccation and the ability of nitrogen fixation. The habitats of a terrestrial cyanobacterium, Nostoc commune, range from polar environments to desert environments. N. commune has extracellular polysaccharides, tolerance to desiccation and the ability of nitrogen fixation, and its abilities are expected to be useful for agriculture and terraforming. Recently, we analyzed the genome sequence of terrestrial cyanobacteria including Nostoc sp. HK-01 (NIES-2109, hereafter HK-01) isolated from a crust of N. commune. HK-01 survives under low atmospheric pressure such as on Mars and dried HK-01 can tolerate high temperatures and high levels of gamma radiation. Here, we are trying to analyze useful genes for extreme environments using various cyanobacterial genome sequence data, and we will discuss the genes expected to function in space environments.

F4.1-0006-18 SUITABLE UTILIZATION OF TREES AND CYANOBACTERIA WITH REGOLITH FOR HABITATION ON MARS

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We have been suggesting that woody plant materials are very useful and important for habitation on Mars. During our research, we have found that woody plants have several properties which can be utilized for therapy and materials for energy and construction on Mars. The cell wall components of woody plants can also be utilized on Mars for construction. It has been well known that cellulose is like a reinforced bar and lignin is like concrete. Hemicellulose is connected to cellulose and lignin. It has been reported that there are possibilities that the bark of tree can be used as vacuum sealant, because those substances are not soluble in water, and can be used as charcoal for the purification of various liquids. On the other hand, cyanobacteria are candidate organisms to be first introduced into Mars's environments. Both of these materials, wood and cyanobacteria, have several components which have protect against UV radiation. Here, we will show some way of using them for habitation on Mars.

F4.1-0007-18 CHLOROPHYTUM PLANTS - CARBON MONOXIDE ABSORBERS

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In previous experiments (Gitelson J.I. et.al., 2003), in the air of the habitableroom of the closed ecological system (CES), the presence of toxic impurities was revealed. In particular, carbon monoxide (CO) was discovered. The problem of air purification from harmful substances is one of the most urgent problems in the world. Carbon monoxide is the most difficult issue to deal with. The aim is to identify the ability of Chloropytum plants to absorb carbon monoxide. An answer is needed: can indoor plants growing in a sealed chamber clean the air of gaseous impurities, in particular of carbon monoxide? Blooming adult evergreen Chlorophytum plants (Chloropytum sp.) growing in terrestrial conditions were used as research objects. Research methodology. Blooming adult Chlorophytum plants grew in tightly closed glass vials of 13 and 18 liters, into which carbon dioxide was added daily. Carbon monoxide was supplied according to the scheme of the experiment. The content of carbon monoxide in the air was measured by means of a "Polar" gas analyzer.The measurement range for carbon monoxide was 0 to 5,000 mg/m3. The measurement principle was electrochemical. The content of carbon monoxide in the air of sealed chambers was measured with a "Polar" gas analyzer. 3 experiments were conducted. 26 cases were studied: The first experiment revealed the ability of Chlorophytum plants to absorb carbon monoxide. In the second experiment we found the dependence of air purification upon the volume of the studied air. The third experiment revealed a direct correlation between the mass of photosynthesizing plants and their ability to absorb carbon monoxide. We believe that Chlorophytum plants can be recommended for purifying the airfrom carbon monoxide in the habitable rooms of space and underwater stations.

F4.1-0008-18 THE POTENTIAL APPLICATIONS OF AQUAPONICS FOR BIOREGENERATIVE SPACE LIFE SUPPORT SYSTEMS

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The integration of fish and plants in a closed-loop, symbiotic system is commonly referred to as aquaponics. The sustainable design of combined food production has led to many advances and new directions during the past decade. Aquaponics presents a promising new direction for enhancing bioregenerative life support systems for space because of its recycling design and high productivity of plants and fish. Researchers around the globe are now engaged in enhancing aquaponics system sustainability, while reducing inputs (water, fish feed, energy for moving water and supplying oxygen) at the same time increasing outputs in the form of edible food. New methodologies have created advances in these integrated systems, closing the loop of sustainability even tighter. Water use efficiency and nutrient cycling are the major advantages of aquaponic food production over other methods currently used. Decoupled, or dual-loop systems, have been developed that separate the two compartments (fish and plants) for optimization of each component. Nutrient solutions derived from mineralized fish effluents can easily be tailored for specific plants with the addition of small amounts of nutrient salts. This move toward isolating each unit also provides risk-mitigation in the event one of the systems fails. New aquaponics diets are being developed that are designed not just for fish but for the fish and plants by over-fortifying fish diets with additional plant nutrients. Other new directions in fish feed formulation includes replacing fish meal and oil with other sources of protein from plants, insects or algae. Fish feeds formulated with algae have the potential to enhance the nutritional quality of the fish protein by increasing the heart-healthy omega oil content of the final product. Many fish species have now been successfully cultivated in aquaponics systems, spanning a diverse range of temperature. Warm-water fish like tilapia (Oreochromis spp.) and cold water fish such as trout, sturgeon and salmon are successfully being integrated with plants in a beneficial union. The fish provide the majority of the nutrients while the plants clean the water allowing for recycling while creating a zero-discharge facility. Proper air handling allows cycling of the CO2 rich environment created from fish respiration through the plant component, increasing the photosynthetic rate and yield of plant crops, with the added benefit of oxygen being released by the plants. This paper covers the most recent advances in aquaponics in terms of food, energy and water production and use, all critical parameters to optimize for successful adoption as bioregenerative space life support systems.

F4.1-0009-18 CARDIOVASCULAR MEDICAL DEVICES PERFORMANCE UNDER MICROGRAVITY CONDITIONS

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The occlusion performance of medical devices for congenital cardiopathies PDA-R and ASD-R were analyzed through a cardiac emulator brought under Microgravity conditions (10-6g) compared to the results obtained with Earth gravity. This experiment is mainly to comparatively determine the occlusion percentage of the aforementioned devices. Results were collected at Drop Tower of the ZARM Institute which provides the needed environment for experimentation.

F4.1-0010-18 "R-EVOLUTION OF ARCHITECTURE FROM EARTH TO SPACE

Ayşe Ören, info@ayseoren.com Turkey 1. Introduction As we embark on a journey for new homes in the new worlds to lay solid foundations, we should consider not only the survival of frontiers but also well-being of those to live in zero gravity.

As a versatile science, architecture encompasses abstract human needs as well.

On our new different direction in the course of the Homo sapiens evolution, we can do this with designs addressing both our needs and senses. Well-being of humans can be achieved by creating environments supporting the cognitive and social stages in the evolution process.

Space stations are going through their own evolution process. Any step taken can serve as a reference for further attempts. When studying the history of architecture, window designing is discussed in a later phase, which is the case for building a spaceship as well.

We lean on the places we live both physically and metaphorically. The feeling of belonging is essential here, entailing trans-humanism, which is significant since the environment therein is like a dress comfortable enough to fit in, meeting needs without any burden.

Utilizing the advent of technology, we can create moods and atmospheres to regulate night and day cycles, thus we can turn claustrophobic places into cosy or dream-like places.

Senses provoke a psychological sensation going beyond cultural codes as they are rooted within consciousness, which allows designers to create a mood within a space that tells a story and evokes an emotional impact.

Colour, amount of light, sound and odour are not superficial. As much as intangible, they are real and powerful tools with a physical presence.

Tapping into induction, we can solve a whole system based on a part thereof. Therefore, fractal designs may not yield good results unless used correctly in terms of design although they are functional, which makes geometric arrangement critical.

F4.1-0011-18 INTERACTION OF PLANTS AND ILLUMINATING ENVIRONMENT ON THE EMOTION AND SLEEP OF HUMAN IN ISOLATION ENVIRONMENT

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The emotion and sleep of the crew members in missions of deep space and deep sea exploration are topics of special interest because of the isolation environment. Variable detections have found that sleep and emotion are closely linked. And plants could significantly regulate human's psychology, emotion and sleep through their own color, smell, landscape and release of negative oxygen ions. In addition, the illuminating conditions of the environment in which people were located also had a significant influence on the human emotion and sleep. But there were few reports on the interaction of plants and light environment on human emotion and sleep. Here, we demonstrated the interaction of plants and light environment on the sleep and emotion of volunteers working in closed cabins of "Lunar Palace I", and all the volunteers had no sleep or psychological problems. In this research, three species of plants which had different characteristics in smell and color, and three color temperature levels which were commonly used in people living environment were selected. Through the orthogonal tests of plants and illuminating environment were taken out in the cabins, emotion, blood pressure, heartbeat, electrocardiogram, cortisol, alpha salivary amylase concentration and sleep conditions of volunteers were measured and analyzed. To explore the interaction and mechanism of plant and illuminating environment on human emotion and sleep in isolated environment, and provide scientific basis for improving the physiological and psychological conditions of people in the isolation environment.

F4.1-0012-18 TOLERANCE OF THE CELL LAYER OF NOSTOC SP. HK-01 AGAINST UV RADIATION

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Cyanobacteria have several abilities to qualify as candidate organisms that can grow in extreme environments, such as on Mars. Dry colonies of a cyanobacterium, Nostoc sp. HK-01, can tolerate several elements of space environments. It has been reported that cyanobacteria have the ability to produce extra-cellular substances (ES), which are protective against UV radiation. The intra-cellular substances may have the same abilities as ES. We investigated the correlation between the protective abilities of ES and intra-cellular substances against UV radiation and the cell layer. Here, we show the relationship between the thickness of the cell layer and the tolerance against UV radiation in Nostoc sp. HK-01. Detailed information about the relationship between cell layer thickness and tolerance against UV radiation would contribute to calculating the number of cells which need to be transported to extraterrestrial environments for space agriculture.

F4.1-0013-18 CHARACTERIZATION OF BACTERIAL CELLULOSE PARAMETERS FOR CLOTHES PRODUCTION IN SPACE USING KOMBUCHA MICROBIAL CONSORTIUM

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Kombucha is one of the most popular microbial consortium tested in space and simulated space conditions. It consists of multispecies bacterial component producing bacterial cellulose and multispecies fraction of yeasts producing probiotic brewing. Bacterial cellulose can be used in multiple forms such as paper, bandage, threads, electrophoretic membranes and clothes. Here we tested three different microbial consortia: native kombucha, kombucha with added purple bacteria Rhodobacter sphaeroides and kombucha with added cyanobacteria Synechocystis sp. PCC6803. Bacterial cellulose was transformed into fabric by lyophylization process or air drying. FTIR, ion leaching, membrane interaction with water and SEM methods were employed to determine biological, chemical and physical properties of obtained bacterial cellulose. We characterized and compared critical parameters for cellulose production: mass, energy, transparency, thickness, acidity, vitality and biocontamination. Obtained bacterial celluloses were tested during simulations of space missions by analog astronauts in the Lunares habitat in forms of wristand armbands. Sweat absorption and interaction with skin was analyzed.

Our results suggest that kombucha can be used for clothes production in space. Simple breeding, strong resistance for deleterious space environment and multifunctional applications of kombucha consortium make this microbial population the best candidate for in situ nanocellulose production.

LIFE SCIENCES AS RELATED TO SPACE (F)

ADVANCED LIFE SUPPORT TESTBEDS AND FACILITIES (F4.2)

F4.2-0001-18 OVERVIEW OF THE EDEN ISS PROJECT. MOBILE TEST FACILITY: ANALOGUE TESTING OF PLANT CULTIVATION

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Plant cultivation in closed environments is challenging and several key technologies necessary for space-based plant production are not yet space-qualified or remain in early stages of development. The European-funded Horizon H2020 EDEN ISS project has the goal to develop and demonstrate higher plant cultivation technologies and procedures, suitable for future deployment on the International Space Station and from a long-term perspective, within Moon and Mars habitats. Over the last four years, the EDEN ISS consortium designed and tested essential plant cultivation technologies using an International Standard Payload Rack cultivation system for potential testing on-board the International Space Station. Furthermore, a Future Exploration Greenhouse was designed with the focus on future planetary bio-regenerative life support system deployments. A dedicated greenhouse system, called the Mobile Test Facility, was designed, built and deployed to the German Neumayer III research station in Antarctica. In addition to producing biomass that will be returned to partner laboratories for analysis the facility provides the overwintering crew of 10 people with fresh vegetables during their isolation phase. The presentation gives an overview of the EDEN ISS research objectives, associated milestones and reports on the status of the analogue mission in Antarctica. In addition, the designed and implemented subsystems are described. Further, an overview of the assembly, integration, and test phase that took place in 2017 at the DLR Institute of Space Systems is given.

F4.2-0002-18 EXPERIMENTAL MODEL FOR TESTING CLOSURE TECHNOLOGIES OF MATTER TURNOVER PROCESSES

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The experimental model of closed ecosystem for testing the technologies aimed at their use in the sequel for full-scale closed ecosystems including a human has been discussed. The experimental model under study provides full closure with respect to gas exchange and water and allows utilization of human wastes and inedible plant biomass. By means of physical-chemical method, purification of gas medium from pollutants has been provided. The system allows realizing the human participation in the system gas exchange with the help of a gas contour. The results of the technologies' tests in the given system demonstrated detection possibilities of their positive and negative characteristics in the process of durational many months'experiments in the conditions of full airtightness. The experimental model of closed ecosystem developed can be used at the testing and modifying stages of new technologies for their further use in future stations of space application. The study was supported by the Russian Science Foundation (Project no.14-14-00599).

F4.2-0003-18 TIME SCALE: TOWARDS THE NEXT GENERATION RESEARCH AND TECHNOLOGY DEMONSTRATION PLATFORM FOR LIFE SUPPORT SYSTEMS ON THE INTERNATIONAL SPACE STATION

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As part of the EU Horizon 2020 project TIME SCALE, a flight concept for cultivation of higher plants and algae platform has been developed. This will allow life scientific research and technology demonstration on the International Space Station to benefit future closed regenerative life support system as part of human space exploration. The concept consists of several subsystems that allow environmental control, plant health monitoring and water and nutrient management. It is modular with possibility to exchange of e.g. a Plant cultivation chamber with an Alga cultivation chamber. The main focus in the project has been on the Crop cultivation system. Particular emphasize has been on the water and nutrient system and the Plant cultivation chamber since lesson learned from previous space experiments show that these subsystems are challenging under reduced gravity conditions, i.e. there is a knowledge and technology gap in this area. To demonstrate this flight concept on ground a Crop cultivation system prototype has been designed and developed. The system has an automated recycling of water and nutrients in a closed water loop, including a gradual increase of the nutrient concentration corresponding to the plant life cycles and nutrient demand. As part of the prototype verification tests, lettuce will be cultivated for 20 days. During the final test eight individual macro-nutrients (ions) will be automatically monitored via the new and state of the art CleanGrow multiion-sensor system. This presentation will outline the TIME SCALE Crop cultivation system prototype functionalities, the final test results with lettuce, as well as, the future potential utilization in flight operations.

F4.2-0004-18 IMPORTANCE OF AIR MOVEMENTS FOR PROPERLY CONTROLLING GAS AND HEAT EXCHANGES BETWEEN PLANTS AND THE ATMOSPHERE UNDER ALTERED GRAVITY CONDITIONS

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Free convection can effortlessly occur with uneven temperature distribution and air movements are induced by convection even in a closed chamber with no forced ventilation system on Earth. However, very little free convection would occur under a microgravity condition in space. The limited free convection would reduce plant growth by limiting heat and gas exchanges on plant leaves. Plant growth facilities in space require being highly reliable for long durations over multiple plant life cycles with little manual control. Restricted free air convection under microgravity conditions in space would limit plant growth by retarding heat and gas exchanges between leaves and the ambient air. Proper air movement is essential for promoting plant growth not only in the vegetative growth stages but also in the reproductive growth stages, especially in space. Considerable effort must be directed toward the development for controlling air movement and for enhancing the heat and gas exchanges between plants and the ambient air, and consequently promoting the growth of healthy plants and normal reproduction in a closed plant production system under altered gravity conditions in space.

F4.2-0005-18 WATER CYCLING FOR REGENERATIVE LIFE SUPPORT SYSTEMS: MELISSA'S DEVELOPMENT OF AN INTEGRATED BIOPHYSICOCHEMICAL APPROACH

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The increased public and private attention for long-term human spaceflight missions to the Moon or Mars stimulates the development of robust regenerative life support systems (RLSS). With a primary focus to minimize the mass of the crew's metabolic consumables, water is the foremost candidate for recycling. In the international Space station (ISS), a physico-chemical system is in place to recovering water from urine and condensate. This system has a relatively high demand for energy and chemicals, only achieves around 70-80% water recovery, and does not allow for the treatment of grey water (e.g. from a shower). To improve these aspects, a novel integration of biological, physical and chemical unit processes was developed within the framework of ESA's RLSS programme MELiSSA (micro-ecological life support system alternative).

First, a grey water treatment system was developed reaching up to 95% water recovery, based on ultrafiltration and reverse osmosis. This system was subsequently upscaled, incorporating also a nanofiltration stage, and validated on the antarctic station Concordia, recovering 75% of the water at ESA hygiene standards. Second, a urine treatment system was conceived, using nitrification as core process. Initial process development was with a packed-bed reactor at MELiSSA's pilot plant in Barcelona on synthetic medium. The process was subsequently optimized to treat urine at maximum conversion efficiencies and rates (up to 1 g N/L/d). Third, an integrated water treatment unit breadboard (WTUB) was established to treat a flow of urine, condensate and shower water generated by one person. The previously validated membrane filtration and nitrification processes were complemented with precipitation, avoiding scaling, and electrodialysis, facilitating the filtration stages. Continuous operation for 3 months showed a total water recovery of around 86%, respecting main ESA hygiene standards. Current research efforts are mainly oriented to adapt the biological process (nitrification) to Space conditions, for instance at the level of defining the microbial consortium, investigating the effects of radiation and implementing a bubble-less aeration system.

MELiSSA's integrated biophysicochemical system WTUB was demonstrated to reach technology readiness level (TRL) 4. This opens up opportunities for more efficient water recovery in future spaceflights, while being compatible with strategies to recover and reuse nutrients from the concentrated and precipitated streams for food production.

F4.2-0006-18 EVALUATION OF A SIMULTANEOUS NITRIFICATION-DENITRIFICATION AND A TWO STAGE MEMBRANE-AERATED BIOLOGICAL REACTOR FOR PRE-TREATMENT OF HABITATION WASTE STREAMS IN SUPPORT OF CLOSED LOOP RECYCLING SYSTEMS

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Biological stabilization of habitation waste streams has successfully been demonstrated in membrane aerated biological reactors (R-CoMANDAR) for multiyear periods. These systems have demonstrated biological pre-treatment of a variety of waste streams ranging from an ISS composition (urine + flush and humidity condensate) to a possible Early Planetary Base wastewater (urine, flush water, hygiene wastewater, and laundry). Biological pre-treatment can be used to reduce organic matter and convert organic N to NOxor N2. These conversions stabilize the waste stream, reducing downstream growth potential, lower the pH to prevent ammo- nia volatilization and scaling, and can be used to produce N2 for resupply of a habitation atmosphere. The use of biological treatment can also allow for elimination of hazardous pretreat, reducing consumables. As part of our ongoing work, we designed and operated two micro-gravity compatible systems to evaluate the benefit of incorporating denitrification into biological processing of habitation waste streams. We evaluated two systems, a single stage MABR and dual stage MABR-Packed Bed. The single stage system was operated to achieve simultaneous nitrification-denitrification (SNDN) by controlling bulk DO while the dual stage system maintained fully aerobic conditions in the MABR and anoxic conditions in the packed bed. Each system has been operating for over 2 years. We report on an overall comparison of treatment using single stage aerobic conditions, SNDN operational regime, and two stage aerobic-anoxic operation to evaluate the system with the best overall attributes to support recycling of space habitation waste streams. We present rates and overall conversion efficiencies of carbon oxidation, nitrification, and denitrification. We also report on effluent pH, off gas composition, and effluent stability as measured by distillation quality, biological stability, and effluent pH.

F4.2-0007-18 INTEGRATION OF NITRIFYING, PHOTOSYNTHETIC AND ANIMAL COMPARTMENTS AT THE MELISSA PILOT PLANT

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MELiSSA project is developing regenerative Life Support technologies for long-term Space missions. It is conceived as a series of compartments, each one performing a specific function, forming a complete cycle, inspired in the terrestrial ecological systems, providing the main functionalities of food production, atmosphere regeneration, water recovery and including as well waste treatment. Each one of the compartments is colonized with specific bacteria or higher plants depending on its dedicated function. The MELiSSA Pilot Plant is a facility conceived for the demonstration of this concept, using laboratory rats as a demonstrator of the crew. In an initial phase, the individual compartments of the MELiSSA Pilot Plant were designed, manufactured, installed, characterized and operated in continuous mode during longterm series of experiments. This has also allowed developing the corresponding mathematical models and control loops, these being intrinsic components of the approach followed within MELiSSA. Following this, the connection of compartments has become the main target of the facility.

The gas phase connection of the photobioreactor based on the culture of the cyanobacteria Arthrospira platensis, producing oxygen, and the animal isolator with rats (mock crew) as oxygen consumers was tested in several experiments of continuous connection with duration of 4-5 weeks. It has demonstrated

good robustness and the ability of the control system to adjust the dynamics of the oxygen production compartment to that of the oxygen consumption compartment, while maintaining a desired percentage of oxygen in the gas phase of the animal compartment. The key variable used to adjust the production of the photosynthetic compartment to the consumer's compartment is the illumination intensity in the photobioreactor, governed by the control system of the MELiSSA Pilot Plant. To note, the demand of oxygen by the consumers is changing following 12 hours day/night periods. The results show a very precise adjustment of the operation of the integrated system and a fast capacity of the control system to drive the oxygen level to a given set point. The evolution of the different variables of the integration, such as oxygen production and CO2 consumption in the photobioreactor, the oxygen consumption and CO2 production in the animal compartment, the illumination intensity, percentage of oxygen in the gas phase and operational conditions of the system at several experimental conditions will be discussed.

The liquid phase connection of the previously described photobioreactor and the nitrifying packed-bed bioreactor based on the co-culture of Nitrosomonas winogradsky and Nitrobacter europaea immobilized on a polystyrene support was tested for a period of six months of continuous operation at different experimental conditions. The experiments provided a validation of the oxygen production in the photosynthetic bioreactor being fed by the outlet of the nitrifying bioreactor. Several residence times have been tested including different inlet flows and light intensity levels in the photosynthetic bioreactor and nitrifying compartment loads. It is also demonstrated that the nitrifying bioreactor can meet the nitrate requirements of the cyanobacteria Arthrospira platensis.

Keywords: MELiSSA, Pilot Plant, Integration, continuous operation, bioreactors, control, Arthrospira platensis, Nitrosomonas europaea, Nitrobacter winogradskyi

F4.2-0008-18 ARTHROSPIRA SP. GROWTH IN PHOTOBIOREACTOR: MODEL AND SIMULATION OF THE ISS AND GROUND EXPERIMENTS

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The Arthrospira-B experiment is the first experiment in space ever allowing the online measurements of both oxygen production rate and growth rate of Arthrospira sp. in batch photobioreactors running in ISS. A 4 bioreactors system was integrated in the ISS Biolab incubator. Each reactor is composed of two chambers (gas/liquid) separated by a PTFE membrane and have been running in batch conditions. Oxygen production is measured by online measurement of the pressure increase in the gas chamber. The experiments are composed of several successive batch cultures for each reactor, performed in parallel on ISS and on ground. In this work, a model for the growth of Arthrospira sp in these membrane photobioreactors is proposed and the simulations results obtained are compared to the experimental results gathered in microgravity and on ground. The photobioreactor model is based on a light transfer limitation model, already used to describe and predict the growth and oxygen production in small to large scale ground photobioreactors. This approach is completed by a model for pH in the liquid phase. This permits to consider the pH increase associated to the bicarbonate consumption for the biomass growth. A membrane gas-liquid transfer model is used to predict the gas pressure increase in the gas chamber. Substrate limitation, pH inhibition, as well as oxygen inhibition must be considered in the biological model. A good fitting is achieved between experimental and simulation results when a good mixing of the liquid phase is maintained. These data show that microgravity has no first order effect on Arthrospira growth rate in a photobioreactor operating in space in ISS. Keywords: MELiSSA, Arthrospira sp., photobiobioreactors, model, flight experiment

F4.2-0009-18 LONG-TERM LIFE SUPPORT EXPERIMENT FOR SURVIVAL ON THE MOON: 'LUNAR PALACE 365'

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A 365-day bioregenerative life support experiment 'Lunar Palace 365', was carried out in the upgraded closed integrative experimental facility, Lunar Palace-1, facing the long-term autonomous survival of humans in the future lunar base. The completed Lunar Palace-1 contains two plant cabins and one comprehensive cabin with a total area of 500m3. It comprises a series of modules with different functions such as higher plant cultivation, insect rearing, waste treatment, crew living and material storage. In the higher plant cultivation module, 35 species of crops including wheat, soybean, chufa, potato, carrot and leafy vegetables have been cultivated to achieve the complete recycling of vegetarian food, water and oxygen for four crew members. In the insect rearing module, yellow mealworms were fed with fermented inedible biomass to provide animal proteins for the crew. Waste treatment module consists of two sub-modules: solid waste treatment and wastewater treatment. In the solid waste treatment module, parts of the inedible plant biomass and the crew's feces were mingled and fermented in the solid waste bio-convertor to produce soil-like substrate and CO2. Thus, the gas balance could be maintained and the system closure could be increased. Sanitary kitchen wastewater and urine were treated by biological methods in respective circulation. Moreover, the stability of the artificial closed ecosystem with four biological links, 'human-plant-animal-microorganisms', were tested in various circumstances such as the crew shifts and the loss of power. The experiment 'Lunar Palace 365' has achieved a higher degree of food supply and system closure than the previous research. In addition, we also studied the psychological changes of crew members with different combinations during the long-term bioregenerative life support experiment and the interaction with gut microbiome, the developmental succession of environmental microorganisms, the impact of light environment and plant environment on human beings.

F4.2-0010-18 CHALLENGES OF ANTARCTIC PLANT PRODUCTION. LESSONS LEARNED FROM THE DEPLOYMENT AND PRELIMINARY OPERATIONAL RESULTS FROM THE EDEN ISS PROJECT

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Dating back as far as the early 1900s, people have been constructing plant production systems in Antarctica. In the early years, these plant production systems were typically small and expeditioner driven. Current systems, such as the EDEN ISS Mobile Test Facility are more complex, use the latest in controlled environment agriculture technology and begin to provide non-negligible impact on overwintering crew diets while minimizing their environmental footprint. Although EDEN ISS, like other Antarctic greenhouse projects focuses on providing fresh food to overwintering crewmembers, it differs from the bulk of these projects in that it has the primary focus of taking advantage of Antarctica's remoteness, extreme environment and stringent environmental regulations to advance space-based production systems. The EDEN ISS project also distinguishes itself from many other Antarctic greenhouse projects in that its development involved several years of planning and design mirroring space system development pathways. This includes a space systems engineering focused process throughout its design, testing and then subsequent deployment and operational phase. This work presents a number of the key lessons learned from the EDEN ISS design phase; assembly, integration and test phase; two month field team deployment phase and from the facility's first few months of operation. Preliminary results from the facility, including leakage, crew time requirements, water use, acoustic tests and power requirements are also presented. These and the results of an assessment of the implemented space system design process are described so as to help future Antarctic greenhouse developers and those using Antarctica as a space analogue site for this purpose, to refine their initial assumptions and improve their overall designs.

F4.2-0011-18 ADAPTIVE LIGHTING SYSTEM FOR SPACE PLANT GROWTH

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Currently, optimal LED lighting inside plant growth facilities (PGF) is considered constant during plant growth period. However, there is evidence of drift of photosynthesis under constant lighting and various crop demands of lighting with plant age. It follows that the optimal lighting mode can drift along with advancing plant age. Adaptive control procedure involves continuous automatic search of current lighting parameters which provides optimal plant growth ability. Adaptive Lighting System (ALS) for space PGF includes closed plant growth chamber with red and white LEDs luminary and CO2 gas analyzer (GA). PPFD from every type of the LEDs can be controlled by microprocessor (MP) independently of one another. Periodically, the infrared GA measures the decrease in the concentration of CO2 associated with the crop apparent photosynthesis (AF). The MP collects signals from the GA and calculates the crop photosynthetic rate and then merit functional during measurement time. In the capacity of merit functional for space PGF we have taken a product of the crop photosynthetic rate by current photosynthetic efficiency in the time. Gradient and simplex algorithms have been effectively used for search of current optimal lighting parameters. ALS has been tested with Chinese cabbage (Brassica chinensis L.). Total photosynthetic photon flux density (PPFD) and red/white light ratio (X1 and X2, correspondingly) have been used as optimization factors. The factor X1 can be changed from 100 µmol/(m2s) to 900 µmol/(m2s), factor X2 - from 0 to 1.5. Also, we have investigated the crop apparent photosynthesis response on abrupt changes in the level of PPFD (500 µmol/(m2s) to 900 µmol/(m2s) and back) or light wavelength (440 nm to 660 nm and back). It has been shown that transients are non-periodic and last less than 1.5 minutes. At the same level of PPFD, AF of the crop under red light was about 1.5 times higher than under blue one, regardless of the age of the plant. The crop AF reaction on simultaneous alteration of total PPFD and light wave length has been nonlinear. It was shown that ALS can't track exactly a maximum of the merit functional because of time drift during vegetation. So search algorithm's parameters should be justified experimentally to come close to optimal lighting regime during plant growth. The ALS efficiency could be estimated by comparison of plant growth results with ALS and under the best continuous LED lighting.

F4.2-0012-18 APPROBATION OF A PHYSICAL-CHEMICAL METHOD OF ATMOSPHERE PURIFICATION IN CLSS EXPERIMENTAL MODEL

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In the experimental CLSS model a multi-month experiment was developed at the Institute of Biophysics SB RAS to grow higher plants (models of the phototrophic link CLSS) using biological and physical-chemical products for processing organic waste (human exometabolites and inedible plant biomass). This model is closed and has a unique atmosphere that simulates the composition of the CLSS gas medium equipped with methods of engaging in intrasystem mass turnover of organic waste. As such methods were considered technologies of the soil-like substrate (SLS) and the reactor of "wet" combustion in hydrogen peroxide. The presence of volatile organic compounds - gas products formed during the "wet" incineration of waste - requires the use of any methods of cleaning the atmosphere. As such, a method for high-temperature cat- alytic oxidation was developed. The developed method for high-temperature purification on a platinum catalyst differs from the previously optimized heating system (presented at IAC 2016), which allows reaching higher temperatures (up to 900 ° C and above) and obtaining a gas purged of organic compounds from the wet-combustion reactor, which is confirmed massspectrometric method of analysis. The increased temperature and capacity of the catalytic chamber also make it possible to obtain purified gas at higher flow rates. The presence of this system of catalytic atmosphere purification opens the possibility of a full-scale inclusion of the "wet" combustion reactor in mass-transfer processes of CLSS. This paper presents the results of experiments to test the physical-chemical method for cleaning the atmosphere of a hermetic chamber with plants (representatives of the phototrophic link of CLSS) during different periods of time - from several days to several weeks. This study was carried out in the IBP SB RAS and supported by the grant of the Russian Science Foundation (Project No. 14-14-00599).

F4.2-0013-18 UNRESOLVED PROBLEMS IDENTIFIED IN CLASSICAL STUDIES

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At least three issues were identified but not resolved in the early studies of biological life support systems. (1) Jack Myers and colleagues developed algal-mouse O2/CO2 exchange systems that required volume adjustments because a liquid-gas system has very different pressure responses than a gaseous system. (2) Many of the early nutritional studies were badly flawed and better techniques are now being used. If single cells are to be a significant part of a diet, nucleic acids and chlorophyll degradation products were identified as potential problems. (3) Can the chemical energy of waste products be re-introduced into the food cycle or must they be completely oxidized and then re-energized via photosynthesis? Fish (Tilapia) have been raised on human fecal material. These issues may still deserve study.

F4.2-0014-18 BREADBOARD VERIFICATION OF A NOVEL TECHNOLOGY TRAIN TO RECYCLE NUTRIENTS AND WATER FROM URINE FOR HUMAN SPACEFLIGHT

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One of the major challenges for long-term Space exploration and habitation is the requirement of a regenerative life support system (RLSS) to provide food, water and oxygen for astronauts, since missions over long distances cannot rely on extensive resupply (Lasseur et al. 2010). Urine, one of the main waste streams in a RLSS, is an important water recovery target, since urine consists for more than 90% out of water, and water supply is responsible for over 90% of the mass of the life support consumables (Tamponnet et al. 1999). Additionally, urine presents the major flux of nitrogen in a RLSS and is rich in other macroand micronutrients (Clauwaert et al. 2017). Currently, on board of the International Space Station (ISS), vapour compression distillation (VCD) is used to recover water from urine, yielding a water recovery percentage of only ~74%, while consuming hazardous and toxic chemicals (chromium trioxide and sulfuric acid) to prevent fouling, and requiring ~315 W (Carter 2009). Moreover, the VCD unit faces severe scaling problems due to uncontrolled calcium sulphate precipitation, which requires extensive maintenance, and the nutrients end up in a toxic brine, limiting nutrient recycling in the RLSS.

Within the framework of MELiSSA (Micro-Ecological Life Support System Alternative), a breadboard installation has been developed to recover water and nutrients from urine, by combining biological

and physicochemical unit processes. First, crystallization removed 93% of the calcium and 82% of the magnesium from the urine, safeguarding the downstream processes from scaling. Second, a moving bed biofilm reactor oxidized >90% of the organics (COD, chemical oxygen demand), preventing biofouling in the electrodialysis (ED) unit. In addition,

>90% of total Kjeldahl nitrogen (mainly present as the uncharged molecule urea) was converted into nitrate by means of nitrification in order to stabilise the urine and to be able to capture the nitrogen in a non-volatile form in ED, avoiding the risk that ammonia volatilisation can pose to the crew. Third, ED was used to extract nutrients from the filtered (0.1 μm) effluent of the bioreactor. Approximately 70% of the nutrients were concentrated in 15% of the ED feed stream. The precipitates, rich in phosphorus, and the ED concentrate, rich in nitrogen and potassium, can be recovered as fertilizers for crop production. Due to nitrification, nitrogen is present in the ED concentrate as nitrate, which is, in most cases, the preferred nitrogen source for plants. The ED diluate is low in nutrients and salts, which makes it a suitable stream for water recovery through membrane filtration.

This novel technology train opens up opportunities for efficient water and nutrient recovery from urine during long-term Space missions through smartly integrating chemical, biological and physical/electrical separation and conversion mechanisms. The testbed facility, sized for one crew member, has been successfully operated in a laboratory environment, corresponding to level 4 on the technology readiness level (TRL) scale. Implementation in Space, however, requires improvement of the long-term stability and performance, and adaptation to the Space conditions.

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F4.2-0015-18 PBR@LSR: A HYBRID LIFE SUPPORT SYSTEM EXPERIMENT AT THE ISS

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Space Agencies' human spaceflight plans include as possible future destinations the Moon, asteroids and Mars. The long duration of these missions and its further distance to Earth will require reducing the dependence on Earth's resources as much as possible. A potential solution is the use of a hybrid Life Support System (LSS), combining physico-chemical and biological technologies. The experiment PBR@LSR (Photobioreactor at the Life Support Rack) will be launched to the International Space Station in November 2018 to demonstrate the functionality of such a hybrid life support system. A second objective is to prove the feasibility of nonaxenic long-term cultivation of microalgae (Chlorella vulgaris) for up to 180 days under space conditions. The experiment and development of the µg adapted photobioreactor was initiated in 2014 by DLR and the Institute of Space Systems (IRS) of the University of Stuttgart with Airbus Defence and Space as prime for the flight hardware. The hybrid approach will be demonstrated by the connection of the photobioreactor to the European Life Support Rack (LSR, also known as ACLS - Advanced Closed Loop System). The LSR uses physico-chemical technologies to collect and process the carbon dioxide produced by the astronauts into oxygen, by using a solidamine absorber, a Sabatier reactor and water electrolysis. A highly concentrated CO_2 surplus from the LSR will be fed to the biological component, the PBR, which will produce oxygen and biomass. Every two weeks a partial liquid exchange will allow harvesting biomass and providing fresh nutrients. Relevant sensors (CO_2, O_2, pH, cell density, etc.) will allow evaluating the performance and stability of the experiment and several algae suspension samples will be taken at different intervals and returned to Earth to evaluate the radiation and µg influence on the algal cells. Various experiments were carried out in three breadboards on ground to investigate both biological and technical aspects, in order to design the flight experiment. This presentation gives an overview of the knowledge gained in ground experiments, the design and construction of the flight experiment and the planned operations.

F4.2-0016-18 ADVANCED CANDIDATE CROP ANALYSIS CAPABILITIES AT THE UNIVERSITY OF GUELPH'S CONTROLLED ENVIRONMENT SYSTEMS RESEARCH FACILITY

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Understanding how candidate crops respond to the variety of interacting and variable environmental parameters that govern growth and development is critical for optimizing life-support services; it is also critical to ensuring resiliency in the face of inevitable perturbations within the overall life-support system. The Controlled Environment Systems Research Facility at the University of Guelph (Guelph, Ontario, Canada) is home to an extensive suite of whole plant and canopy-scale controlled environment chambers designed to evaluate variable light intensity and spectra (including ultraviolet and far red), atmospheric pressures, atmospheric gas compositions, vapour pressure deficits, carbon dioxide concentrations, and temperature profiles, etc. The net whole plant effect (e.g., net carbon exchange rate) of interactions between these variables, or isolated responses to single environmental parameters, are measured in real time. The range of capabilities will be discussed as they pertain to crop performance in bioregenerative life-support scenarios.

F4.3-0001-18 INTEND TO MASTER THE SOLAR SYSTEM? TAKE CARE OF THE RELIABILITY OF BIOLOGICAL LIFE SUPPORT SYSTEMS

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The statement that the key purpose of space LSS is to ensure the safety of the crew and preserve its health and performance can be considered as trivial. But then it follows logically that the reliable functioning of the LSS should be chosen as the key parameter of any LSS optimization criteria. Between 1996 (Bartsev et al., 1996) and 2003 (Gitelson et al., 2003), a number of papers were published on the problems of ensuring the reliability of the BLSS for long-term missions. At the same time there was practically no substantive discussion of the problem. Sometimes the attitude towards the reliability of the BLSS becomes curious. For example, in the ESA document (Dussap CG TN3: Definition of the Ideal Facility for Life Support Issues, REGLISSE-2003), the statement "Safety is the number one priority of all flight hardware systems" is located in paragraph number 14 (page 22). Recently, a number of papers devoted to the problem of reliability of BLSS have appeared (Holubnyak, Rygalov, 2009, Jones, 2009, Jones, Kliss, 2010; Jones, Ewert, 2010; Jones, 2012). At last, it was noted that studies on the reliability of the BLSS for long-term missions should be started as early as possible. Why? According to well-known formulae for estimating the mean time between failures (MTBF) of technical ssystems it follows that in order to guarantee sure operation of the BLSS for 2 years (the lower confidence limit of MTBF) with a reliability of 99.5%, it is necessary that during a 10-year test of one experimental BLSS there should not be a single failure (15 years in the case of one failure and 25 years in the case of 4 failures). There are no established methods of assessing BLSS reliability due to their hybrid construction - the availability of technical and biological parts. So the reliability of a BLSS depends both on the reliability of the engineering units and on the stability of the ecological component with respect to the failures of technical units considering as perturbations of ecological regeneration unit. In addition, the ecosystem can be disturbed by the appearance of mutants, which can be considered as the introduction of a new species. The evaluation of the reliability of the BLSS with respect to external disturbing (destructive) impacts presupposes conducting critical experiments leading to the destruction of ecological part of BLSS. The problem is that experiments on the destruction of manned BLSS are unacceptable, but similar experiments are necessary to create a technology for building reliable BLSS. Possible approaches to solving this problem are discussed. However it has to be stated that the lack of interest in the search for effective solutions to the mentioned above problems, which is also indicated by the low activity of researchers in F4.3 Event, manifests the lack of a true intention to master outer space.

F4.3-0002-18 DYNAMIC SYSTEM MODELING AND STABILITY ANALYSIS OF ELEMENT CYCLING IN BIOREGENERATIVE LIFE SUPPORT SYSTEM

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Establishing bioregenerative life support system (BLSS) is crucial for building bases on the moon and mars as well as the long-term deep space exploration. To ensure the system run steadily for long time, it is important to notice the process of elements cycling and analyze the stability of the system. The purpose of this work is to establish a dynamic system mathematical differential equations model for the elements cycling process of the 4-biological-link complex system which consists of plants, animal, human and microorganism, called LUNAR PALACE

365. Plant module, animal module and microorganism module were in the dynamic change, and the life activities like photosynthesis of plants and respiration of animal (which we selected yellow mealworm as animal module) drived the vital elements (C, H, O, N) to flow within the system. The crew was in a stable state, and it drived the C, N element in the food to the other modules. Meanwhile, we also integrated the effect of non-biological factors such as temperature, light intensity etc. on the flow of elements in this mathematical model. The interaction of all the biological modules in the 4-biological-link system was able to maintain the balance of the oxygen and carbon dioxide. Based on the establishment of a valid mathematical models by principles of physiology and ecology and the data we collected, we simulated and analyzed the stability of the system in MATLAB/ Simulink. By observing the process of the elements cycling in 4-biological-link, the methods to improve the stability of BLSS and to optimize the design are put forward in theory. The results of the two crew exchange experiments and the simulation demonstrate that feedback characteristics of the biology in this system could eliminate external disturbances and restore the system to be relatively stable state.

F4.3-0003-18 ANALYSIS OF THE KEY FACTORS AFFECTING THE RELIABILITY OF BIOLOGICAL REGENERATION LIFE SUPPORT SYSTEM

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Abstract:The Bioregenerative life support system(BLSS) is the key technology for long-term manned deep space exploration. BLSS includes units of plant cultivation, animal breeding, microbial treatment solid waste, water treatment cycle utilization, air management and temperature and humidity control subsystems. Hence BLSS involves not only complex mechanical and electrical subsystems but also more complicated biological subsystems. It is a necessary for BLSS to maintain long-term stable and efficient operation for the safety of crew. Once a certain unit fails and cannot be dealt with timely and effectively, it may cause catastrophe for crewmember and the overall system.In the research,analysis of the key factors that affect the reliability of biological regeneration system is quite significant for system operation continuously.Based on the " Lunar Palace 365" experiment, the key factors affecting the reliability of BLSS will be comprehensively investigated and analyzed in order to lay a foundation for further development and improvement of BLSS.

Keywords: BLSS; reliability analysis;mathematical modeling; computer simulation.

F4.3-0004-18 A HEURISTIC METHOD OF FINDING STABILITY-INCREASE FUNCTIONS

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Adequate assessment of the dynamic behavior of Closed Ecological Life Support Systems (CELSS) is a prerequisite for effective environmental management in general. Apparently, the only tool for obtaining such an assessment is mathematical modeling of ecosystems. However, in order to constitute tools for obtaining adequate forecasts, ecosystem models have to demonstrate general properties that do not contradict the properties of natural ecosystems. Traditional ecosystem models show that increased complexity of an ecosystem leads to its decreased stability. However it contradicts typical patterns observed for real ecosystems. Possible explanation of this contradiction is that these models are built by analogy with models of chemical kinetics; each species is considered as an auto-catalyst consuming nutrients at a strictly fixed ratio, similar to rate coefficients of chemical reactions. Previous research showed that models with non-fixed ratios of nutrient consumption (or "flexible" metabolism models) can demonstrate a positive relationship between complexity and stability. At the same time it remains unclear what kind of "flexibility" is sufficient to provide similar to natural biodiversitystability dependence. Another "complementary" objective is to determine conditions that lead to negative diversity-stability dependence. Reproducing this feature in models is important since this negative dependence sometimes appears in nature and has to be demonstrated by models. An analytical approach to selecting that kind of modifications which increase Lyapunov's stability of traditional models is suggested. Quantitative estimation of stability for different models at different numbers of species was conducted. It was analytically shown that "flexible" metabolism models can be considered as modifications of traditional models with increased stability. A computer-based experiment with "flexible" models also demonstrates increased Lyapunov's stability with an increasing number of species. However, "flexible" ecosystem models can be unstable ecologically: some species can be eliminated due to increased lack of resources with an increasing number of species.

F4.3-0005-18 ELISSA: A LIFE SUPPORT SYSTEM (LSS) TECHNOLOGY SELECTION, MODELLING AND SIMULATION TOOL FOR HUMAN SPACEFLIGHT MISSIONS

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The LabVIEW-based simulation tool ELISSA (Environment for Life-Support Systems Simulation and Analysis) allows analysis and comparison of different Life Support System (LSS) designs and optimization. The tool development started in the mid-90's at the Institute of Space Systems (IRS), University of Stuttgart and is continuously being upgraded. The simulation tool, based on a time-discrete method, includes a wide library of LSS potential components for future long duration missions, including technologies currently in use and in development. Both regenerative physico-chemical and biological components are included in the four defined subsystems: air, water, food and waste management. Each component is modeled according to available reference data: from specifications for existing technologies or experimental data or physical and chemical fundamentals for those in development. Special focus is set on updating the components with experimental data from the research carried out at the IRS lab, for example for fuel cell or photobioreactor models. A user-friendly interface allows the selection of the LSS components and other mission specific parameters such as size of the crew, mission duration, initial consumables or tank sizes. Depending on the computer capability, a simulation of 500 days can last a couple of hours, with a time step of 60 seconds. The result of the simulation is the evolution of the system over the mission time, which enables an adapted sizing of the system: the components, tanks and required consumables. To compare different LSS designs, ELISSA generates as an output parameter the Equivalent System Mass (ESM). Complementary, two extra tools were developed in the last decade: PreLISSA (Preparation Tool for Life Support System Simulation and Analysis), designed to carry out trade-offs based on time-averaged operation and ReLISSA (Reliability tool for Life Support System Simulation and Analysis) for a reliability analysis. This poster presents an overview of the current status of ELISSA, PreLISSA and ReLISSA. An example of a Mars Mission system study and future development possibilities are presented.

F4.3-0006-18 MODELING OF SOLID WASTE TREATMENT UNIT IN BLSS

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A bioregenerative life support system (BLSS) is an artificial closed ecosystem which provides basic human life support for long-duration and far-distance space activities such as lunar bases. Solid waste treatment unit is an important part of BLSS. It plays a vital role in the gas and material cycle of the whole system. From May 2017 to May 2018Lunar Palace 365 Experiment was conducted in Lunar Palace 1, an integrative experimental facility for Permanent Astrobase Life-Support Artificial Closed Ecosystem. In the experiment, solid wastes such as plant straws and human feces were treated with microbial aerobic fermentation in a bio-convertor. Dynamic model and parameters of the microorganism and substrate balance, water balance and heat balance process was determined. And the integral model of solid waste treatment unit was developed. CO2 production rate, water content, microorganism and substrate weight in Lunar Palace 365 Experiment were predicted using the model. The predicted results and actual test results were compared and analyzed. This research result has an important significance in effectively improving the predictability and controllability of BLSS.

F4.3-0007-18 DESIGN AND IMPLEMENTATION OF SOFTWARE FOR DIETARY MANAGEMENT IN SPACE PERMANENT BASE

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Controlled Ecological Life Support System (CELSS) is one of key technologies for establishment of permanent base on the surface of the Moon or Mars. The configuration and closure of CELSS largely depends on the astronaut's diet. Thus, it is necessary to set up a dietary management system for astronauts in the CELSS.

In this paper a dietary management system was especially designed for CELSS. Through this dietary management system a more reasonable and comprehensive recipe for astronauts could be obtained so that reasonable configuration and closure of CELSS would be gained as well. Database was used to store the biochemical data of Chinese daily edible vegetables. The dietary reference intakes for astronauts were developed according to nutritional recommendations of Chinese Nutrition Society, as well as considering the effects of the space environment on human's diet and physiology. The integrated criteria for plant screening were summarized, which were employed as constraints of the optimization process along with the nutritional requirements.

Optimal results of a more reasonable and comprehensive recipe for astronauts in CELSS could be obtained by means of the multi-objective programming method. It could be used to provide assistant decision support for the CELSS designers.

F4.4-0001-18 HISTORICAL PARALLELS OF BIOLOGICAL SPACE FLIGHT EXPERIMENTS ON SOYUZ, SALYUT, MIR AND SHENZHOU

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Human exploitation of space is a great achievement of our civilization. After the first space flights a development of artificial biological environment in space systems is a second big step. First successful biological experiments on a board of space station were performed on Salyut and Mir stations in 70-90th of last century such as - first long time cultivation of plants in space (wheat, linen, lettuce, crepis); - first flowers in space (Arabidopsis); - first harvesting of seeds in space (Arabidopsis); - first harvesting of roots (radish); - first full life cycle from seeds to seeds in space (wheat), Guinness recorded; - first tissue culture experiments (Panax ginseng L, Crocus sativus L, Stevia rebaundiana B; - first tree growing in space for 2 years (Limonia acidissima), Guinness recorded. As a new wave, the modern experiments on a board of Shenzhou Chinese space ships are performed with plants and tissue culture. The space flight experiments are now focused on applications of the space biology results to Earth technologies. In particular, the tomato seeds exposed 6 years in space are used in pharmacy industry in more then 10 pharmaceutical products. Tissue culture experiments are performed on the board of Shenzhou spaceship for creation of new bioproducts including Space Panax ginseng, Space Spirulina, Space Stetatin, Space Tomato and others products with unique properties. Space investments come back.

F4.4-0002-18 SPACE FLIGHT SURVIVAL OF NITROGEN-CYCLE MICROORGANISMS

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To sustain human Space exploration missions where no resupply from Earth or other planets is possible, adequate life support systems need to be developed. The recycling of water and nutrient, combined with in-situ production of oxygen and food can be achieved thanks to the metabolic capabilities of living organisms, including bacteria. Nitrogen is an element of key importance to produce food that meets the nutritional requirements of the crew, and several biotechnological processes for its recovery have been proposed. The European Space Agency's Life Support System (MELiSSA) for instance, houses nitrogen conversions in the CI thermophilic anaerobic hydrolytic compartment and in the CIII nitrifying compartment, to recover a nitrified stream for cyanobacteria (CIVa) or edible higher plant (CIVb) production. But Space is a challenging environment for life: microgravity, temperature, UV and cosmic radiation can affect survival, health and functionality of humans, microorganisms, animals and plants. To validate nitrogen recovery bioprocess for Space application, ammonia oxidizing bacteria (Nitrosomonas europeae ATCC 19718 and Nitrosomonas ureae nm10), nitrite oxidizing bacteria (Nitrobacter winogradskyi ATCC 2539 and Nitrospira moscoviensis M1) and a ureolytic heterotroph (Cupriavidus pinatubonensis 1245) were exposed to the Lower Earth Orbit conditions of the International Space Station (ISS) for 7 days. Additionally, Nitrosomonas europeae ATCC 19718, Nitrobacter winogradskyi ATCC 2539, Cupriavidus pinatubonensis 1245, and three mixed communities (one for urine nitrification, one containing anammox and one containing ammonia-oxidizing archaea, AOA) were exposed to 20 ± 4°C, hyper and -gravity and between ca. 20 and ca. 40 mGy of radiation over 44 days FOTON-M4 flight, obtaining a radiation dosage which is about the double as inside the International Space Station (ISS) for the corresponding period. Our results shows that temperature control during storage influence is more important than LEO/radiation-exposure, since the activities observed after the Space flights were generally comparable to the control exposed to similar storage conditions on Earth. The mixed microbial communities were more rapidly (3 days) reactivated compared to the pure cultures and the synthetic microbial communities (10 days), however their nitrifying activity show greater variability following LEO exposure. No clear influence of the key ammonia/nitrite oxidizing genera and community eveness/diversity was found.

Our results indicate not only that the bacteria involved in these conversions can withstand Space travel and storage under space flight conditions, but also be reactivated efficiently after space flight for application in a regenerative life support system. Overall, successful preservation of all the key metabolic nitrogen conversion functions was achieved. For the first time, the potential of ureolysis, nitrification, denitrification and anammox is validated after flight exposure, encouraging future Space applications for N-related microorganisms.

F4.4-0003-18 MOLECULAR BIOLOGY OF BACTERIAL BIOFILMS IN THE HUMAN SPACEFLIGHT ENVIRONMENT

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An important microbiological issue which has emerged during long-duration human spaceflight is the interaction of resident microbes with various materials, leading to biocorrosion and biodeterioration in space habitats. Notably, bacterial biofilms have been implicated in contamination and biofouling of potable water systems in long-duration spacecraft such as the Space Shuttles, space station Mir, and the International Space Station (ISS). Recent results from ISS experiments indicate that spaceflight can promote biofilm formation in it Pseudomonas aeruginosa and it Escherichia coli, and can promote invasive growth of the yeasts it Saccharomyces cerevisieae and it Candida albicans. It is thus important to understand how exposure to the spaceflight environment influences biofilm formation in microbes.

The well-studied Gram-positive bacterium it Bacillus subtilis has long served as a model organism for studies in space biology and astrobiology. it B. subtilis is a frequent isolate from ISS surfaces, and biofilms containing it B. subtilis were reported from the Space Shuttle water system. In two recent missions to the ISS (BRIC-21 and BRIC-23), we measured transcriptomic responses of it B. subtilis to the spaceflight environment. In both experiments we observed significant up-regulation of transcripts associated with biofilm formation in flight (FL) samples when compared to matched ground control (GC) samples. Specifically up-regulated in FL samples were transcripts originating from: (i) the it epsABCDEFGHIJKLMNO operon, which encodes the extracellular polysaccharide (EPS) biofilm component poly-N-acetylglucosamine;

(ii) the it tapAsipWtasA operon, encoding major protein components (TasA and TapA) of biofilms, and (iii) it bslA, encoding the hydrophobic surface layer protein BslA. In addition, transcripts of the biofilm regulatory genes it slrA and it kinD were also consistently up-regulated in FL samples. These results represent the first molecular evidence from any bacterial species for up-regulation of biofilm gene expression under microgravity conditions.

The results above strongly suggest that it B. subtilis may preferentially form biofilms under spaceflight conditions. Unfortunately, the standard laboratory strain of it B. subtilis used in the spaceflight transcriptome studies, strain 168, has lost the capacity to form robust biofilms during the course of its >60-year history of laboratory domestication. We therefore propose to investigate biofilm formation in spaceflight using the “wild” ancestral it B. subtilis strain NCIB3610. The molecular aspects of biofilm formation in this strain have been studied intensively and its genome has been completely sequenced and annotated. We will present an update on our plans for investigating NCIB3610 biofilm formation in matched FL vs. GC samples on ISS and results from pre-launch experiments. Supported by NASA Space Biology grant NNX14AT38G.

F4.4-0004-18 EFFECTS OF SIMULATED MICROGRAVITY ON GROWTH, PHYSIOLOGY AND PHOTOSYNTHETIC MACHINERY IN SYNECHOCYSTIS SP. PCC 6803

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Use of plants as a bioregenerative life support system has been widely accepted and envisaged in space research. However, very little information has been explored using unicellular photosynthetic cyanobacteria as a promising component of life support system. Cyanobacteria offer several advantages like increased metabolic adaptability, reduced payload, simpler nutritional requirements, less space and are good source of nutritious food, therefore serving themselves as an organism of choice for space research. In the present work, Synechocystis sp. PCC 6803 was used as a model organism for photosynthetic study in simulated microgravity condition. Briefly, the actively grown culture of Synechocystis was exposed on 1-D clinostat for five days continuously at 25° C. Control (1 g) was kept next to the clinostat with all environmental conditions same as for microgravity. The obtained result showed a significant alteration in protein profile as well as biochemical changes in microgravity grown culture compared with the control. However, there was no significant difference in growth in control and microgravity grown culture. Simulated microgravity promoted the synthesis of photosynthetic pigments compared to control. Further, the effects of simulated microgravity on the phycobilisome complex, the principle photosynthetic machinery will be discussed. Finding of this study would give insight into the current challenges and improvement in cyanobacterial studies in space.

F4.4-0005-18 ABILITIES OF A CYANOBACTERIUM, NOSTOC SP.HK.01, TO UTILIZE ITS OWN CELLS IN DEFENCE AGAINST UV RADIATION

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We have been studying the tolerances to space-environments of a cyanobacterium, Nostoc sp. HK-01 (hereafter referred to as HK-01), for over ten years. We have already found that dry colonies of HK-01 had high tolerance to UV. It has been reported that some components in extracellular polysaccharide (EPS) have been tolerant to UV, but more details were not deeply investigated. There is a possibility that there is a relationship between the number of cells and defense against exposure to UV. The thickness of cell layers may be related to tolerance to UV radiation. Several dry colonies of HK-01 were investigated after exposure to UV radiation. Cells with and without EPS were also tested after exposure to UV radiation. In the results of tested colonies of HK-01 under several condition after the UV radiation. The results obtained after exposure to UV radiation showed that there is a correlation between the thickness of layers of cells and their survival rates. We will discuss those results and future space agriculture using HK-01 on Mars.

F4.4-0006-18 BIOFILM IN SPACE (BFS): DESIGNING A SPACEFLIGHT EXPERIMENT

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Fungal growth has been detected aboard the Russian Space Station (Mir) and the International Space Station (ISS), promoting biodegradation of the spacecraft materials and compromising life-support systems [1-2]. Defining filamentous fungi biofilms is currently in debate among the scientific community. Nevertheless these are indeed associated with higher tolerance and resistance to adverse conditions [3-5]. To better monitor and control fungal contamination during long duration spaceflight missions, the NASA-funded project "Biofilm in Space (BFS)" comprises a spaceflight experiment aboard the ISS, planned to be launched late 2018/early 2019 on a SpaceX flight. It will study growth and biofilm formation in microgravity also testing coupons of different materials (such as quartz, aluminum silicone, and polycarbonate developed by the Saarland University), in the search for spaceflight-relevant antimicrobial surfaces.

To mature the experimental design to be spaceflight ready, several pre-flight tests need to be performed. For this, one of the tasks of the German Aerospace Center (Institute of Aerospace Medicine, Cologne) is to define and optimize the culturing conditions for the fungus Penicillium rubens on the space hardware: the 12-well BioCell (developed by BioServe Space Technologies). Because growth in the BioCell will inevitably differ from common laboratory containers (such as flasks or multi-well plates), it is important to assess: i) growth and biofilm formation in the BioCell; ii) growth and adherence to coupons compared with planktonic growth iii) needed adaptations for the space-proven culturing system. An initial approach tested P. rubens growth in the 12-well BioCells, both in simulated microgravity provided by clinorotation (µ x g) and in ground static control (1 x g), as well as its adherence to two different material coupons - cellulose membrane and aluminum.

Results revealed fungal growth on all the 12-wells of the BioCell culturing system, within the tested 48h and 96h of incubation in both µ x g and 1 x g conditions. Biomass measurements showed more adhered biomass in cellulose membrane coupons (average 100% increase) than in aluminum coupons (average 3% increase). Additionally, fluorescence microscopy of couponattached biomass disclosed their hyphal structure and surrounding matrix. The 12-well BioCell was established as an adequate culturing system for growth of P. rubens in the upcoming spaceflight experiment aboard the ISS. This marks an important step in having new methodologies to study filamentous fungi biofilms that will help to develop the appropriate contamination-control measures, both on Earth and in space.

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F4.4-0007-18 RESPONSE OF ARABIDOPSIS THALIANA SEEDS TO SIMULATED GALACTIC COSMIC RAYS

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One of the major concerns for long-term exploration missions beyond the Earth's magnetosphere, is radiation risks. These risks arise primarily from solar energetic particles (SEPs) and galactic cosmic rays (GCRs). With the goal of manned Mars exploration, the production of fresh food during long duration space missions is critical for meeting astronauts' nutritional and psychological needs. However, the biological effects of space radiation on plants have not been sufficiently investigated and characterized. This comprises a significant knowledge gap in terms of future NASA interplanetary missions and for establishing permanent inhabited bases.

This pilot study is to evaluate the effect of simulated GCRs on Arabidopsis thaliana seeds using the NASA Space Radiation Laboratory (NSRL) facility at Brookhaven National Lab (BNL). The imbibed Arabidopsis seeds were exposed to two simulated GCR scenarios of combined ions including protons, helium, oxygen, titanium, and/or iron ions. The exposures were conducted acutely or at a low dose rate over a 4 hr time period. Some seeds were also exposed to individual high-LET ions (protons, helium, or titanium ions). Control and irradiated seeds were then transferred to a hydroponic system for growth within an environmentally controlled chamber with light intensity at 150 mol·m-2·s-1. Six days after planting, morphological parameters were measured to evaluate radiation induced damage in the seedlings. Simulated GCR induced transcriptomic changes in 10 day Arabidopsis seedlings were also investigated using the same

GCR scenarios mentioned above.

Exposure to simulated GCRs or individual high-LET ions had no impact on the germination rate of both control and irradiated seeds. However, the morphological changes of the seedlings cultured from irradiated seeds were found to be doseand ion quality-dependent, with heavier ions causing more severe damages. Transcriptomic profiles were significantly altered in the seedlings exposed to charged particles. Estimate hits/tracks per imbibed seed, root meristem and shoot meristem regions in a mature Arabidopsis embryo were also determined. More experiments need to be performed to complete the study using more doseand time-points and to explore the mechanisms underlying heavy ions induced damage in Arabidopsis and other model plant organisms, especially those that have been identified as potential candidate crops for astronaut consumption and have been or will be grown on ISS.

F4.4-0008-18 TOWARD BIOTECHNOLOGY IN SPACE: HIGH-THROUGHPUT INSTRUMENTS FOR IN SITU BIOLOGICAL RESEARCH BEYOND EARTH

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Over the last two decades high throughput methods have revolutionized the field of biology. The key components of this new approach are genomics, proteomics and metabolomics, collectively known as "omics". They are aimed at studying content and activity of the full complement of genes, proteins and metabolites, respectively, in an organism or a consortium of organisms. Even though omics approaches are relatively new, they are already widely used and have yielded many important insights to biology and medicine. In the half-century of space exploration multiple lines of evidence have accumulated to state with near-certainty that effects of space environments are not limited to a single gene or even a small number of genes, or a single subcellular component, but instead influence many genes and cell functions. This implies that they should be studied using global, integrative methods. This, in turn, means, that omics approaches are not only helpful, but are indispensable for space biology. To achieve the expected advances from omics technologies, the current paradigm of performing data analyses post-flight should change to include omics tools for in situ research. However, developing omics instruments for space applications remains a challenge even in the case of mature methods. Among contributing factors are the need for substantial miniaturization and automation, compatibility of all protocols and materials with conditions in space, safety issues and the requirements for low power and operation independent of the direction of the gravity vector. We will discuss which omics technologies are currently amenable to adaptations for space applications and how these adaptations can be achieved. We will review ongoing efforts aimed in this direction and discuss scientific benefits that they might bring. In this context, we will argue that, with sufficient commitment, at least some instruments for high-throughput measurements could be ready for deployment on-board spacecraft in the next 2-3 years. Once developed and deployed, omics tools can be used for a wide variety of high-value studies on biological systems ranging from microorganisms to humans that hold significant potential for discoveries in space biology, biotechnology, pharmacology and medicine.

F4.4-0009-18 STUDIES OF PLANT GENE EXPRESSION AND FUNCTION STIMULATED BY SPACE MICROGRAVITY

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One of the important questions in space biology is how plants respond to an outer space environment i.e., how genetic expression is altered in space microgravity. In this study, the transcriptome of Arabidopsis thaliana seedlings was analyzed as part of the Germany SIMBOX (Science in Microgravity Box) spaceflight experiment on Shenzhou 8. A gene chip was used to screen gene expression differences in Arabidopsis thaliana seedlings between microgravity and 1g centrifugal force in space. Microarray analysis revealed that 368 genes were differentially expressed. Gene Ontology (GO) analysis indicated that these genes were involved in the plant's response to stress, secondary metabolism, hormone metabolism, transcription, protein phosphorylation, lipid metabolism, transport and cell wall metabolism processes. Real time PCR was used to analyzed the miRNA expression including Arabidopsis miR160,miR161, miR394, miR402, miR403, and miR408. MiR408 was significantly upregulated. An overexpression vector of Arabidopsis miR408 was constructed and transferred to Arabidopsis plant. The roots of plants over expressing miR408 exhibited a slower reorientation upon gravistimulation in comparison with those of wild-type. This result indicated that miR408 could play a role in root gravitropic response.

F4.4-0010-18 SURVIVAL OF BACTERIA IN ALTERED GRAVITY: ADAPTATION STRATEGIES AND IMPLICATIONS IN PLANETARY PROTECTION

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Gravity is a major parameter for the survival of micro-organisms in space. Micro-organisms need to evolve complex adaptation strategies to survive in hyper gravity stress. Organisms experience altered gravity in space and when spacecrafts or rockets eject or land on surfaces. For validating the ability of interplanetary travel or survival in Space, the survival of micro-organisms in altered gravity is imperative. These organisms' micro-organisms can stay dormant during stress or adapt to the stress and revert to their metabolically active state when they encounter favourable environment. The study of such survival in altered gravity also is important while devising planetary protection strategies as ejection of microflora from Earth in outer space is a major concern. The present investigation focused on studying the growth and physiology of bacteria and its antimicrobial resistance pattern in hypergravity of 223 g. The effect of hypergravity on cell membrane integrity and permeability and cellular stress was studied by using membrane leakage assays. The survival strategies of bacteria in inhabitable environment are useful to device an appropriate measures to reduce the contamination from spaceflights and spacecrafts and to strengthen Planetary protection.

F4.4-0011-18 STUDY ON THE SPATIAL CULTURE APPARATUS OF HIGHER PLANTS

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China Space laboratory TianGong No.2 is a very good platform for space science research as a long time orbiting spacecraft. A long period of growth and development of higher plants was studied by using its microgravity environment to understand and elucidate the role of gravity in the whole process of plant growth and development. In this paper, a space experiment devicethe spatial culture apparatus of higher plants was developed. According to the experimental design, Arabidopsis seeds and rice seeds began to germinate in space until the flowered and fruited for the whole life cycle. Some of them were brought back to the ground by the astronauts. The device is designed as the main box and return unit. The main box contains enclosed culture space and electrical control part, and the return unit is attached to the main body. The main box and the return unit have the environment monitoring, liquid management and illumination function adapting to the space environment; The main box of the length of sunshine and short sunshine culture area, respectively, two sterile culture units and color camera for observation, the design of a fluorescent camera to observe the gene expression of the sample. 2016 MidAutumn Festival, the experimental device with TianGong No.2 launch, and successfully carried out the experiment, the return unit with sample returned according to plan. The researchers got a lot of valuable data.

F4.4-0012-18 LIVE IMAGING TECHNIQUE AND ITS APPLICATION TO INVESTIGATE FOR THE GROWTH AND DEVELOPMENT OF ADVANCED PLANT IN CHINESE SPACECRAFT

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In order to study the growth and development of advanced plants under microgravity conditions, the live imaging technique and advanced plant culture device have been developed. This paper will introduce the live imaging technique and the device used in the Tiangong-2 spacecraft and SJ-10 recoverable satellite. These experiments focus the influence of plant behaviors in space environments. The experiment samples were Arabidopsis and Rice. There were two cameras and one fluorescence camera in the advanced plant device. The flowering gene expression was investigated with transgenic GFP through the fluorescence camera. When the devices were carried in space, the pump put water into culture unit and the life support were controlled well, such as the temperature, humidity, light intensity. The experiment in space has been carried out more than 1 year. In the process of seed germination, seedling growth, flower and fruit, serial real-time images were successfully obtained. The experimental results in space were concluded.

F4.4-0013-18 GENOMIC CHARACTERIZATION AND VIRULENCE POTENTIAL OF TWO FUSARIUM OXYSPORUM ISOLATES CULTURED FROM THE INTERNATIONAL SPACE STATION

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Fusarium oxysporum is a filamentous asexual ascomycete that is ubiquitous in soil and notorious for fusarium wilt, a deadly vascular wilting syndrome in plants. Strains are classified into formae speciales “special forms” based on the host it can infect and at present, there are over 100 formae speciales that have been classified. While well known for its pathogenicity in plants, oxysporum extends beyond plants to infect humans as well. It is an emerging opportunistic pathogen that is the leading cause of invasive fungal infections in immunocompromised patients.

Two F. oxysporum isolates (denoted F3 and F4) were cultured from the dining table of the US segment of the International Space Station during an ongoing Microbial Tracking study, the first time this species has been isolated from a built environment and from the space environment. The genome was paired-end sequenced on the Illumina Hi-Seq platform and assembled de novo with AbySS. The genomes of F3 and F4 were compared to 100 formae speciales using (i) EF1 alpha sequence typing and (ii) the presence/absence of 100 effector genes that are unique to different formae speciales. Single nucleotide polymorphism analysis was also performed using

PhaMe to assess how similar F3 and F4 were to their closest neighbors on the phylogenic tree. The genomic characterization

shows that F3 and F4 are the same strain but are distinct from the 100 strains that they were compared against, and possibly represent a novel strain.

A recent study published by our group comparing the virulence of Aspergillus fumigatus ISS isolates to that of ground isolates showed ISS isolates to be more virulent in a zebrafish model. That study prompted the examination of the virulence potential of F3 and F4 and an F. oxysporum isolate collected in the aftermath of the Chernobyl disaster. Immunocompromised Caenorhabditis elegans strains, AU1 (sek-1) and AU37 (glp-4;sek-1) were exposed to fungal conidia for 40 hours. Results demonstrated that ISS isolates displayed higher lethal phenotype compared to the ground control. The Chernobyl isolates consisted of the ground isolate (Gr) and its derivative exposed to space flight (Sp). The Sp strain demonstrated significantly higher killing ability suggesting that this strain was effected by microgravity exposure.

This study highlights the importance of further analysis of Fusarium and other fungal strains that have been exposed to the space environment as the biology of these isolates may have important implications in the medical, pharmaceutical and agricultural fields.

F4.4-0014-18 "WELLBEING IN LONG DURATION SPACE TRAVELS

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Introduction As we embark on a journey for new homes in the new worlds to lay solid foundations, we should consider not only the survival of frontiers but also well-being of those to live in zero gravity.

As a versatile science, architecture encompasses abstract human needs as well.

On our new different direction in the course of the Homo sapiens evolution, we can do this with designs addressing both our needs and senses. Well-being of humans can be achieved by creating environments supporting the cognitive and social stages in the evolution process.

Space stations are going through their own evolution process. Any step taken can serve as a reference for further attempts. When studying the history of architecture, window designing is discussed in a later phase, which is the case for building a spaceship as well.

We lean on the places we live both physically and metaphorically. The feeling of belonging is essential here, entailing trans-humanism, which is significant since the environment therein is like a dress comfortable enough to fit in, meeting needs without any burden.

Utilizing the advent of technology, we can create moods and atmospheres to regulate night and day cycles, thus we can turn claustrophobic places into cosy or dream-like places.

Senses provoke a psychological sensation going beyond cultural codes as they are rooted within consciousness, which allows designers to create a mood within a space that tells a story and evokes an emotional impact.

Colour, amount of light, sound and odour are not superficial. As much as intangible, they are real and powerful tools with a physical presence.

Tapping into induction, we can solve a whole system based on a part thereof. Therefore, fractal designs may not yield good results unless used correctly in terms of design although they are functional, which makes geometric arrangement critical.

F4.4-0015-18 BIOREACTOR WITH REMOTE SCIENCE OPERATING MODE PIGGYBACKED ON TIANZHOU-1 CARGO TRANSPORT SPACECRAFT

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Tianzhou-1 Cargo Transport Spacecraft is the first unmanned cargo transfer vehicle developed by China for manned spacestation. The system composition and main function of the bioreactor are introduced briefly in the paper.Because the biological samples in the bioreactor will not be returned to the ground from space,some special space experiment technologies which are suitable for the bioreactor are described in detail,including multi-channel liquid transportion and management,multi-type animal cells circuit testing,dynamic targets microscopic (fluorescence) observation in situ,experiment remote operations based on realtime data of the biological samples in space etc.The technical function and main parameters of the bioreactor are verified in space flight experiment successfully,and the main experimental results in space are concluded.

F4.4-0016-18 PARAMETERS OF PEPPER PLANTS FOR CULTIVATION IN SPACEFLIGHT GROWN ON NUTRIENT MEDIUM WITH NANOPARTICLES

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For successful work and life of astronauts, researchers, etc. in space flights, long stay at space stations and space settlements, optimal engineering systems for life support are needed, allowing to solve technical and psychological problems. In this respect, it is worth to consider plants in cosmos as one of the units in a life-support system. Modern development of biotechnologies makes it feasible to receive materials with new improved properties for plants growing. Formulation and components proportions changes in nutrient medium are capable to modify plant properties considerably. We have devised a nutrient medium in which essential metals such as iron, zinc and copper were added as electro neutral nanoparticles instead of metal salts. Such replacement is appropriate through unique nanoparticles properties: metal nanoparticles are less toxic than metal ionic forms; produce prolonged effects, serving as a depot of elements; nanoparticles introduced in biotic doses stimulate metabolic processes of the organism; nanoparticles action is multifunctional. LJ-king pepper was used for cultivation on a nutrient medium with iron, zinc and copper nanoparticles in different concentrations. Pepper plants grown on the nutrient medium with metal nanoparticles showed better morphometrical and physiological characteristics than controls: seedlings and plants were compact with the developed and active root system.

F4.4-0017-18 CELL GROWTH AND DIFFERENTIATION ASSOCIATED WITH MASS TRANSPORTATION UNDER MICROGRAVITY

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Cells are able to sense gravity change through different mechanisms. It is hypothesized that cells possess the specialized structures for gravity perception (direct mechanism), are affected by the changes in physical features of gravity-dependent microenvironment (indirect mechanism), or work in a cooperative way from both mechanisms. To address the issue, we develop a novel space cell culture system (SCCS), mainly consisting of precisely-controlled flow chamber and gas exchange unit, to elucidate the responses of endothelial cells and mesenchymal stem cells (MSCs) under microgravity environment in SJ-10 recoverable satellite. Our data indicate that different mass transport patterns could alter cellular metabolism. Moreover, endothelial cells and MSCs are regulated by microgravity and respond differentially in initiating cytoskeletal remodeling, dysregulating signaling pathways relevant to cell adhesion, or directing hepatic differentiation. These results provide an insight in understanding the mechanosensing and mechanotransduction of mammalian cells under space microgravity.

F4.4-0018-18 SPACE SHIP WITH LARGE SELF-REGULATED ECOLOGICAL SYSTEM FOR DEEP SPACE FLIGHTS

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Future long term space activity with human crew requires self-regulated ecological system to provide water, air and food for crew. Modern theoretical and experimental investigation results show that a sustainable ecological system can be made, but it requires large enough area and volume, which cannot be provided with modern space ship and space station technologies. The large volume frame can be created with using of inflatable construction, which can be directly cured in space environment. Large size space ship with self-ecological system is proposed and discussed.

The study was supported by Humboldt Foundation, ESA (contract 17083/03/NL/SFe), NASA program of the stratospheric balloons and RFBR grants (05-08-18277, 12-08-00970 and 14-08- 96011).

F4.4-0019-18 INFLUENCE OF MAGNETIC VACUUM ON THE LIVING CYCLE AND SURVIVAL OF DROSOPHYLA MELANOGASTER

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Not only the absence of gravity takes place in space flight but the magnetic field is also changes. Sometimes it is very small. So the experiments in magnetic vacuum are needed. All experiments were fulfilled in the artificial magnetic field inductance of which was equal to 20 nT - 3 µT. The artificial magnetic field was created in µ-metal shield with the reminded magnetic field 20 nT. The direction of the artificial magnetic field was vertical. The samples were the pure lines of Drosophila MelanogasterCantonese -S and Muller-5 and the line of wild type Wild. Under standard conditions the living cycle for Cantonese -S was equal to 12 days and for Muller-5 - 16 days. It was revealed that for pure lines the living cycles slowed down on 3 days while treating in magnetic fields under 3 µT. The first generation didn't give the posterity, i.e. perished. For Wild type the cycle slowing was equal to 2 days. The imago emerges on the 17-th day after laying. The second generation of Wild also perished on the stage of the third generation development. The results obtained correlate to the ones obtained by other authors under the conditions of zero gravity.

F4.4-0020-18 GENOMICS OF A MICROGRAVITY-EXPOSED STRAIN OF CLADOSPORIDIUM CLADOSPORIOIDES - A RADIATION-TOLERANT FUNGUS ISOLATED FROM THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

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A radiation-tolerant strain of Cladosporidium cladosporioides isolated from the failed block of the Chernobyl nuclear power plant and flown on the International Space Station was characterized and compared with control specimens kept on the ground. This radiation-tolerant fungus was selected for this study to ascertain the effects of microgravity and the space environment on the growth and physiological responses of this organism to spaceflight. Fungi are known to produce many secondary-metabolites, especially when stressed. Some of these secondarymetabolites have become medically important drugs. Differences detected in genomic content between flightand ground-control specimens allude to adaptations that may be important for survival in space, and may provide the opportunity for novel drug discovery. Changes detected in transcriptomic content between flightand ground-control specimens indicated acclimatization responses that may be important for survival in space, and provided evidence that these potentially important secondary-metabolites were being produced in the space environment. The characterization and comparison of both flightand ground-control specimens demonstrated differences in this radiation-tolerant fungal strain that may lead to the discovery of useful natural compounds.

F4.4-0021-18 SEROTONIN METABOLISM UNDER EFFECT OF IONIZING RADIATION AND HYPOGRAVITY

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Central nervous system dysfunctions caused by ionizing radiation and hypogravity are a key factor hindering deep space missions (Kokhan et al., 2016). For the ground-based modeling of space flight factors, male Wistar rats were exposed to ionizing radiation (heavy charged particles and γ-quanta in combination; R) and hypogravity (in the antiorthostatic suspension model; AS). Several groups of animals were subjected to both single exposure to R or AS factor, and their combinations. The obtained data indicate that effects of AS and R factors in combination demonstrate synergetic and antagonistic effects on psychoemotional status, cognitive abilities and monoamine metabolism. Surprisingly, the combined effects of these factors lead to the neutralization of the negative effects (hypolocomotion, decreased orientation and exploratory behavior, cognitive impairments) arising from the separate action of R and AS factors. The effect of the AS factor led to a limited activation of the serotoninergic system. Whereas addition of the R factor led to the spread of activation on all the studied brain structures. We have obtained the first evidence that 5-HT2a receptor in the prefrontal cortex and D2 receptor in the hippocampus can be involved in the aforementioned neutralization effect. We suggest that these biomolecules can be potential targets for pharmacological correction of the pathophysiological effects of R and AS factors during deep-space missions.

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F4.4-0022-18 THE BEHAVIOR OF THICK-TOED GECKOS DURING THE FLOTATION IN WEIGHTLESSNESS.

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The purpose of the research was to study the behavior of 15 female Turner's Thick-toed Geckos (Chondrodactylus turneri GRAY 1864) during a 30-day orbital experiment on the unmanned spacecraft "BION-M" No. 1. In weightlessness, geckos maintained their ability to attach to the surfaces using the subdigital pads of their toes. On average, geckos spent in the attached position 99.91% of the video recorded flight time, and only 0.09% accounted for the flotations. In quiescent geckos, spontaneous detachments of some limbs (hanging) were also observed. The detachments of hind limbs occurred in 52.3% of cases, more often than all other possible detachments taken together. Upon detachment from the surface of all four limbs without the immediate recovery of attachment, the geckos started to float, while continuing to be motionless, perhaps being asleep or dormant. That is why all flotations were divided into 2 main groups: 1 - active (flotation begins in moving and exactly awake gecko); 2 - passive (flotation begins in quiescent, possibly sleeping gecko - PF). The PF group in turn was subdivided into: 1 - short flotation (SF), when the gecko drifted from the surface to a distance of no more than 2.5 cm, and 2 - long flotations (LF, the distance was more, than 2.5 cm). SFs were more frequent and accounted for 262 cases (58.2%) of the total number of flotations (450 cases). The active geckos, when starting to float, and the floating quiescent geckos, when resuming their active condition, immediately restored the attachment by a number of behavioral responses. The discovered geckos' responses to PF were similar to the behavioral reflexes triggered by a fall under terrestrial conditions: 1 - the ventral extension of the limbs, 2 - the skydiving posture, and 3 - postural righting reflex. Ventral extension of limbs was described in weightlessness for the first time. In SF it was enough to restore the attachment, but in LF we observed all 3 reactions with high frequency (91.5, 95.7 and 82.4% of all cases of LF of quiescent geckos correspondingly), although they did not lead to quick restoration of attachment. It is known from literature, that the skydiving posture in ground-based conditions creates useful aerodynamic forces, making gliding or directed aerial descent possible and reducing the impact force when landing. In

weightlessness the dilated limbs increase the likelihood of contact of the flotating gecko with any surface and restore the attachment. This reflex actuated regularly after the activation of geckos in long flotations during the entire orbital flight. The righting reflex in thick-toed geckos in the flight experiment was manifested in incomplete (by 90°) or exaggerated (up to 270-360°) forms. The duration of turns calculated for 31 instances of rotation by 180° in geckos varied from 0.08 seconds to 0.64 seconds; with an average of 0.325±0.099 seconds. It is almost 3 times more slowly, than it was described in Earth conditions for flat-tailed house geckos by Jusufi et al. (2008). These differences can possibly be caused by both the species-specific features of animals and the effect of weightlessness on thick-toed geckos. It is known that, in terrestrial conditions, the postural righting reflex is stimulated by the signals from the vestibular apparatus about the incorrect position of the body relative to the gravity vector. The obtained data suggest that in animals, as in humans, in zero gravity spatial orientation illusions are possible. The number and frequency of individual flotations during the flight did not depend on the size and weight of the geckos. There were no animals without a single flotation episode, but the frequency of flotations varied both individually and depending on the condition of the geckos. The number of flotations in the quiescent geckos was 4.5 times higher than that of the same animals in an active state. Consequently, an active control of the attachment could become weaker or inexistent in animals in quiescent states or in a sleeping state. In active geckos the number of flotations during the flight was decreased compared to the first week of the flight. Hence, it is possible, that in weightlessness, geckos adapt to changes in environmental conditions by learning from their own experiences, and strengthening the active control of the attachment. In quiescent geckos the number of flotations did not change significantly during the flight. Individual variability in the frequency of flotations was found in the active and quiescent geckos during the flight. The findings show that the ability to attach to the surfaces is an important factor in the geckos' adaptation to the conditions of orbital flight. The behavioral responses that originated under terrestrial conditions can also be adapted to weightlessness and remain partially effective.

F4.4-0023-18 PROBLEM OF HYPOMAGNETIC CONDITIONS AT THE MOON, MARS AND AT MANNED FLIGHTS IN DEEP SPACE

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The problem has already been discussed in our reports at COSPAR 37, 39, 40. It is shown that the absence of the usual geomagnetic field (GMF) will lead, as a rule, to undesirable consequences for astronauts at the near-moon station, during long-range space missions and at future lunar and Martian bases. Hypomagnetic conditions (HMC) will also adversely affect the biological elements of life support systems. HMC should be considered along with the weightlessness, cosmic radiationand other factors of the flight and outer space. Recently, various aspects of this problem have been discussed at conferences of different direction (for example, [1]) and in the literature (for example, [2]). In our recent studies it was shown that the germination of lettuce seeds irradiated with ions with high values of linear energy transfer in GMF weakened in 2.5•103 times leads to increasing of the percentage of cells with chromosomal aberrations and multiple aberrations more than twice compared with the irradiated seeds germinating under normal conditions. Therefore, there is a synergistic effect of these factors. Synergism of combined exposure of HMC and a very weak alternating (50 Hz) magnetic field (i.e., the factor is radically different from radiation) has also been revealed in our studies of the HMC effects on the growth of Japanese quail embryos. Accelerated loss of mineral matter from the animal (rat) bone tissue under the influence of simulated weightlessness and HMC was discovered by Chinese researchers [3]. This is an alarming phenomenon for manned astronautics. Probably we should expect the possible synergy of the impact of HMC and some other factors of flight

and outer space, which will need to be taken into account when norming board conditions. Questions of creations of collective analogue of GMF in the habitable volume of future spacecraft and on lunar and Martian bases by means of electromagnetic systems are considered in this report. This fundamentally solves the problem. The real possibility is also shown of creating individual analog of GMF (jacket, jumpsuit and cap [4]), including for work in spacesuits on the surface of the Moon and Mars.

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F4.4-0024-18 SURVIVAL AND PHYSIOLOGICAL ADAPTATION OF EXTREMOPHILES IN RESPONSE TO HYPERGRAVITY STRESS

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Life on other planets and the survival strategies of the organisms on the other planets is a subject of speculation. Hypergravity is a major aspect when survival of micro-organisms in space and other planets is concerned. The more the survival strategies of micro-organisms in hypergravity stress are studied, the more the enigma of the origin of life unfolds. Hypergravity is also related to ejection and travel of micro-organisms from one planet to other planet. The micro-organisms can stay dormant and travel from one place to other and again become active when they encounter a favourable environment. When the survival strategies in such inhabitable environment are studied, it is also possible to device an appropriate method to reduce the contamination from spaceflights and spacecrafts. The present investigation focuses on the survival of extremophilic organism to hypergravity. The adaptation strategies, intracellular ion sequestration and production of compatible solutes in altered gravity are reported herewith.

F4.4-0025-18 CREATION OF NUTRIENT MEDIUM USING NANOTECHNOLOIGY FOR PLANTS GROWING IN SPACEFLIGHTS

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Quality life and fruitful activity of astronauts and researchers in conditions of spaceflights and prolonged work at space stations are only possible with life zone providing fresh air, natural food, comfortable psychological conditions, etc. The solution of that problem in cosmos is possible by use of high nanoand biotechnologies for plants growth. A priority should be given not only to a choice of species of plants able to grow in cosmos, but also optimization of cultivation conditions, including modifications of nutrient mediums, illumination and temperature. We are deeply convinced that just manipulations with growing conditions are a guarantee of success in the decision of this problem. To improve the method of plants growing on the artificial nutrient medium with balanced composition of elements necessary for growth and development of plants, we added essential metals Fe, Zn, Cu - in an electroneutral form as nanoparticles (NPs) instead of sulfates or other easily dissolving salts. Metal nanoparticles have some advantages in comparison with salts: NPs are characterized by prolonged and multifunctional actions; NPs are less toxic compared with salts; NPs are able to penetrate in plants tissues and stimulate vital processes in biotic dozes. A high reactivity of NPs, their active interactions with nutrient medium components, requires development of certain technological solutions for conservation of activity potential of nanoparticles in nutrient mediums. We developed an artificial nutrient medium with a balanced composition, including metal NPs for the efficient cultivation of plants in space flight conditions.

F4.5-0001-18 30 YEARS OF ACTIVITIES, AN OVERVIEW OF MELISSA PROJECT

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Seeded in 1987 with a precursor flight experiment on board the Chinese rocket longue Marche, conceptualized and published in October 1988, and initiated in March 1989, the European project of regenerative life support, from its early days has followed a very progressive approach. Today, after almost 30 years of activities. The project gather a very large community from scientists to engineers, from universities to spin-off companies, from industry to space companies, from students to European civil servants. This large community distributed over 15 European countries is pursuing two main objectives: - Space life support system and - Terrestrial circular economy. It is correct to state that the key challenge of MELiSSA is: how to select, to assemble and to demonstrate processes and technologies to reach the highest degree of closure within the ALISSE criteria set: Mass, Energy, Efficiency, Safety, Reliability and Crew Time. Mainly due to these final objectives, the overall project is structured in a very progressive approach. Within Phase 1, Basic RD, the processes and technologies, generally at low TRL are characterize a stoichiometry's level, energy and safety, then static and dynamics models are elaborated for an integration in the overall system. After this intensive characterization, within phase 2 called: Preliminary Flight experiments, the critical space issues are identified (e.g. reduced gravity, multi-phases processes, radiations,.) and propose for flight experiment, generally in LEO. So far, the main part of the flight s experiments were done via International competition of the ILSRA ISS. From this already solid information the selected processes and technologies are integrated and demonstrated over a long period and with a living consumer, human but potentially animals too. The core of this activity is performed at the MELiSSA Pilot plant in Spain. In parallel, of these 3 phases run as well the Phase 4: Technology transfer, where already 3 spin-off company have been created. Initiated to transfer space technology to Earth, this phase is becoming more and more a platform of collaboration for join RD efforts. Phase 5, which has taken a reasonable amplitude over the last years: Education and Communication is led by the MELiSSA foundation and support Students and STEM activity (e.g. AstroPlants).

F4.5-0002-18 CLOSING NUTRIENT LOOPS FOR BIOREGENERATIVE LIFE SUPPORT SYSTEMS

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Estimates from Russian Bios-3 studies in the 1980s and NASA studies in the 1990s suggest that about 125 kg of fertilizer and acid (for pH control) would be required to grow enough plants to support one person for one year. About 90 kg of this total was fertilizer. These studies used hydroponic approaches and likely supplied excess nutrients to the plants to avoid stress, nonetheless, they provide a good reference point planning bioregenerative life support systems. For a crew of four for a 3-year Mars mission, this would amount to 125 kg person-1 yr-1 X 4 persons X 3 years, or 1500 kg of fertilizer and acid. Waste processing studies with inedible plant biomass have demonstrated that many nutrients can be recycled to grow more plants. Assuming 50% of the biomass is inedible and that you could recycle 50% of the nutrients from this biomass, this could reduce the fertilizer mass by 25%. This assumes the nutrient content of the inedible biomass is similar to the edible biomass, but many nutrients like N and K are often higher in the inedible leaves and stems, and hence the savings could be even greater. Likewise, more intensive treatment of inedible waste could increase recovery rates to 90% for many elements. Recycling human metabolic wastes, especially urine, could reduce fertilizer import costs even further. In addition, recovery of any nutrients from in situ regolith could further reduce imported fertilizer, and more studies are needed in this area. Strategies for reducing acid or base needed for pH control would also help, and using mixtures of nitrate and ammonium nitrogen fertilizer are one classic approach to mitigate pH changes.

F4.5-0003-18 FORMATION OF TURNOVER PROCEDURES IN A TENTATIVE MODEL OF AN ARTIFICIAL ECOSYSTEM

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Under creation of turnover processes, 2 concentration in the system atmosphere was succeeded to maintain at the level not limiting photosynthetic processes and being not harmful to a human (800 - 2000 ppm). The total 2 content in ECES was in average 344, the average daily 2 consumption equaled to 1309 and the time of one 2 turnover (cycle) was 6.3 h. 2 concentration did not lower than 20.8% and did not grow higher than 22.6%. The air breathed out by a human entered the system and the system air was consumed by a human. Thus, CO_2 and O_2 concentrations were maintained in the system in the specified limits simulating approximately 0.06 of human respiratory needs. Assimilating coefficient calculated equaled to 0.83. Considering O_2 concentration in the system to be a limiting factor for calculation 'a part of a human' then the ECES created corresponded to the estimated 'part of a human' varying in the limits of 5.4% ÷ 6,5%. Plants grown in ECES compartments could provide the daily human requirements with carbohydrates on 1.7 %, with vegetable oils on 5.5 % and with vegetable proteins on 6.4 %. Periodicity of the human involvement in a gas contour was determined according to the limits of 2 concentration inside the system, fluctuation of which were searched out in the diapason of 900 ppm - 2500 ppm. At the expense of the human periodic involvement into the system's gas contour both 2 and 2 concentrations were adjusted in the determined limits, and the latter remained in the limits of 21%-22.6% at that. Change dynamics in the mineral solution for plants of the following fundamental elements Ca, K, Na, N; Mg, P, S was investigated. Mineralized organic wastes of animal and vegetable origins were the sources of their supply. Considerable decrease of phosphorus content in the nutrient solution was discovered within one-month observations that demanded that biogen introduction from the stock to compensate mineral elements withdrawn with edible biomass from the SLS the inedible biomass of the plants grown by the hydroponics method on the expanded clay aggregate and by the water culture method in the amount necessary for K content restoration was inserted into the SLS. Solid and liquid human wastes also were the mineral elements' sources. These metabolites entered the reactor for physical-chemical oxidation from where the reactor gas after its purification came in the ECES,

and the liquid oxidized products were used to correct the nutrient solutions for irrigation of the plants cultivated by the hydroponics method on the expanded clay aggregate thus restoring the nutrient elements' concentration in the solution up to a necessary level. The edible biomass grown in the ECES could supply the human daily needs in a vegetable diet part approximately on 6%. The principal summands of the water cycle emerging in the ECES were 250ml of the correcting solution resulting in the process of physical-chemical oxidation of solid and liquid human wastes and 250ml of the extraction after the wheat straw watering. The rest of water generally contained in the nutrient solution for plants and in the plants' biomass. The daily water cycle was 12.9 l, and the time of one water cycle was 11.7 days. The chemical elements' content (, As, B, Be, Cd, Cu, Fe, Mn, Zn, etc.) in the intersystem water amounted either the tenth-hundredth parts of their MPC. It was established that the closure of more than 90% corresponded to Ca, Mg, S, N, and to 2 and

The lower closure (84%) was registered for, and the lowest (60%) - for. The ECES created let to raise and to solve a wide range of problems with respect to investigating the functioning mechanisms of matter turnover processes concerning terrestrial and space applications. The perfection of a deeper purification technology of the system gas composition, a total chemical and microbiological monitoring of nutrient solutions, and a technologies' creation for a higher closure level of the biogen sets should be noted in particular. The work has been performed under financial support of RSF grant (project 14-14-00599) at IBP SB RAS

F4.5-0004-18 RESEARCH ON SOLID WASTE TREATMENT AND REUSE IN LUNAR 365

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Abstract: Bio-regenerative Life Support System (BLSS) is essential in human long-term space exploration, which could provide oxygen, food, water and other survival essentials. In addition, solid waste produced could be reutilized through fermentation treatment in this system. Solid waste treatment was considered as one of the most important rate-limiting steps in terms of material circulation and energy flow of BLSS. Solid waste including wheat straw, human and yellow mealworm feces were disposed in the continuous aerobic fermentation bio-convertor in "Lunar Palace 1" for 365 days of closed experiment with crews. During the fermentation process, the microbial diversity and compost putrescibility were demonstrated. Then the decomposed compost was used as fertilizer for wheat with Hoagland nutrient solution as the control. Meanwhile, the optimal planting way was selected through the solid waste treatment experiment. The evolvement process of microbial community were demonstrated and the feasibility of using the disposed solid waste as fertilizer for wheat was verified. The study reused the solid waste and improved the closure level of the BLSS. It is of great significance for the solid waste management for long-term space exploration.

F4.5-0005-18 NITROGEN CYCLING IN REGENERATIVE LIFE SUPPORT SYSTEMS: CHALLENGES FOR WASTE REFINERY AND FOOD PRODUCTION PROCESSES

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In order to sustain human life in an isolated environment, an efficient conversion of wasted nutrients to food might become mandatory. This is particularly the case for space missions where resupply from earth or in-situ resource utilization is not possible or desirable. A combination of different technologies is needed to allow full recycling of e.g. nitrogenous compounds in space. In this presentation, an overview is given of the different essential processes and technologies that enable closure of the nitrogen cycle in Regenerative Life Support Systems (RLSS). Primary waste material is first refined through a set of biological and physicochemical stages to ensure efficient conversion of waste products into secondary building blocks, followed by the production of food through select biological methods. For each technology, bottlenecks are identified. Furthermore, challenges and outlooks are presented at the integrated system level. Space adaptation and integration deserve key attention to enable recovery of nitrogen for the production of nutritional food in space, but also in closed loop systems on earth.

F4.5-0006-18 DEVELOPMENT OF THE ATMOSPHERIC SYSTEM OF THE MELISSA PLANT COMPARTMENT BASED ON A MECHANISTIC MODEL OF PLANT GROWTH AND GAS EXCHANGES

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The growth and development of higher plants are strongly influenced by environmental conditions (e.g. gravity, pressure, temperature, relative humidity, partial pressure of O2 or CO2) so that their use within bio-regenerative life support systems requires a thorough understanding of their growth mechanisms and behaviors for a wide range of environmental conditions. This is achieved within the frame of the MELiSSA (Micro-Ecological Life Support System Alternative) project led by the European Space Agency (ESA), with the design of the atmospheric system of the plant compartment alongside the development of a mechanistic physical model of plant growth and plant gas exchanges. This approach is based on the understanding of elementary phenomena and using the atmospheric system to validate the model, instead of following an empirical approach to build a mathematical description. Therefore, essential plant growth parameters are defined and a modular approach is followed to define essential sub-systems, whose sizes are based on mass balance related to plant growth. This includes elements balances, i.e. both carbon and oxygen balances. The system is designed to host plant shoots until harvest in a closed, controlled and automated environment, in which CO2 uptake and water vapor release are measured on-line, giving the clue for assessing uptake and production rates on the basis of conservation constraints, more than global quantities that are uncorrelated in terms of mass balances. The aim of this atmospheric plant growth system is to gain insight with respect to modelling, engineering and control aspects of the MELiSSA plant compartment and to improve the understanding of the processes. It is demonstrated how the selected design will be used for leading to knowledge modeling and understanding purposes of growth mechanisms of higher plants in close chambers, accounting for process parameters such as pressure, temperature, relative humidity, partial pressure of O2 and CO2, gas velocity and ultimately gravity.

F4.5-0007-18 STUDY ON THE APPLICATION EFFECT OF COLD TOLERANT BIOCONTROL AGENT PSEUDOCHROBACTRUM KIREDJIANIAE A4 IN BLSS

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Bioregenerative Life Support System (BLSS) is an indispensable key technology for manned deep space exploration, such as lunar or martial base. The plant unit is the key unit of the BLSS, providing food for the crew, regenerating air through the photosynthetic CO2 absorption and O2 emission and preserving the crew's wellbeing. Wheat, as a staple food crop, plays a very important role in BLSS, because of its high nutritional value of seeds, richness in carbohydrates, and ability to produce further food products. The level of wheat crop production directly affects the amount of food in the BLSS. In order to ensure the healthy growth and of wheat and increase its yield, experiments were conducted to promote the growth of wheat by applying the low temperature-resistant biocontrol strain A4, which isolated and pre-selected during the experiment of "Lunar Palace 365" according to the special requirements of BLSS. During the experiment, the photosynthesis, chlorophyll content, superoxide dismutase activity, malondialdehyde (MDA) content in leaves, other physiological indexes and harvesting indexes were measured and analyzed. Microbial communities of wheat leaf surface and rhizosphere were determined to study the application of biocontrol agent A4 on wheat growth and yield promotion. The research is mainly focused on the regulation of microbial communities to ensure the healthy growth of wheat, and will provide a reference strategy for pathogen biocontrol and growth promotion of wheat in BLSS.

F4.5-0008-18 WHY DID CARBON BECOME THE PSEUDO-LIMITING FACTOR IN AQUATIC CLOSED ECOLOGICAL SYSTEMS?

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Closure from the atmosphere forces us to observe processes that we would overlook in an open system where CO2 and O2 exchanges are unlimited. Our early Closed Ecological Systems (CESs) with a C:N ratio of 26.4 were not intended to become carbon limited with pH values in excess of 11, but that was the result, with a mixture of green algae (Ankistrodesmus, Scenedesmus, and Selenastrum) and associated bacteria. Those with grazers (Daphnia) developed pH values in excess of 10. The C:N ratio of 105 was more satisfactory. C:N ratio of 422 did not result in more algal in vivo fluorescence, and resulted in shorter survival of Daphnia populations than 105. Reasons for the high C:N ratio may include the ability of one of our species, Scenedesmus to form high lipid cells with a C:N ratio of 51, but other mechanisms may also be involved. Our CESs do not receive CO2 gas from an external source, as is common in many sub-system experiments, which would control pH and obscure unexpected CO2 uptake.

F4.5-0009-18 BIO-ELECTROCHEMICAL OXIDATION FOR CO2 RECOVERY IN REGENERATIVE LIFE SUPPORT SYSTEMS

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Long term manned space missions or extraterrestrial habitation will require a regenerative means of supplying the basic resources (i.e., food, water, oxygen) necessary to support human life. The MELiSSA concept established within the European space agency is a closed loop compartmentalized artificial ecosystem designed to recycle solid organic wastes (e.g., inedible food waste and feces) for the regeneration of food, water, and oxygen for human consumption. Carbon recycling in this loop depends on decomposition of organically bound carbon to CO2 followed by fixation of CO2 by phototrophic microorganisms and higher plants that serve to provide the food and oxygen. A challenge at this moment for the MELiSSA-loop is closing the carbon cycle, by completely oxidizing the carbon in the organic waste and non-edible parts of the plant into CO2. Optimization of a thermophilic membrane fermentation reactor for primary waste treatment has been demonstrated to achieve organic matter degradation efficiencies up to 65%, but with a maximum of 15% carbon recovery as CO2. The balance of carbon remains as soluble organic compounds (mainly volatile fatty acids; VFAs), biomass, and undigested solids. In this study we demonstrate the feasibility of coupling thermophilic fermentation to bio-anodic oxidation in a microbial electrolysis cell (MEC) to drive carbon recovery towards CO2. Bioanodic oxidation has the potential to favor CO2 production over methane, and provide in-situ pH control by electro-migration of hydroxyl ions produced at the cathode across an anion exchange membrane. A five liter fermentation reactor treating a standardized waste composed of red beets, lettuce, wheat straw, toilet paper, and feces was operated continuously for over two years to produce realistic effluents for MEC experiments. The fermentation achieved similar performance to past experiments with an organic matter degradation efficiency of 50% and a VFA production efficiency of approximately 35%. Lab scale MEC batch tests on the permeate showed high removal efficiencies for all VFAs (80-100%) after 7 days with COD and carbon

removal efficiencies of 72% achieved. Further tests with synthetic feed were performed to test bio-anode acclimation and stability, and to quantify carbon flow through the reactor. Columbic efficiencies indicate 70% conversion of carbon from acetate and butyrate to CO_2 at this stage, though higher conversion may be possible with further process development and optimization. This coupled process could increase CO_2 recovery from 15% to 40% on total carbon input in these tests. Additional integration of thermal chemical treatment of the remaining biomass and undigested solids CO_2 recovery has the potential to reach at least 85%.

F4.5-0010-18 EXPERIMENTAL ASSESSMENT OF PHYTOPATHOLOGICAL RISKS IN CELSS

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Year-long experiment with non-sterile CELSS conducted in the Laboratory of controlled biosynthesis of phototrophs revealed the following phytopathological risks for higher plants based life support system. The major risk is contamination of CELLS by phythopathogenic fungi of Fusarium species causing root rot of cereals. In our experiments it was estimated that one infected plant produces about 1500 conidia of Fusarium per day, and these conidia are ready to infect new plants in 6-8 hours after formation. In the system based on conveyor cropping this leads to fast spreading of disease via nutrient solution and accumulation of newly formed conidia in the substrate. No other soil borne pathogens were observed during all the time of experiment. Another risk is associated with previously undescribed bacterial stalk rot of wheat. The disease affects weakened plants and seems to be non-dangerous for plants growing under optimal condition. At least one case of mass death of plants was associated with poisoning plants by cyanobacterial toxins. Among agriculturally significant insect pests only thrips were found. Unexpectedly no phytopathogenic nematodes were observed despite on the fact that free living nematodes colonized the CELSS from the very beginning of the experiment. We assume that predatory fungi Arthrobotrys oligospora developed in the rhizosphere and feeding on the free living nematodes created a biological barrier to phytopathogenic nematodes.

The study was supported by the Russian Science Foundation (Project no.14-14-00599)

F4.5-0011-18 ABIOGENIC O2 CYCLE LOOP IN BTLSS

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An experimental model with a purpose to test links compatibility and material flows closure of a new generation Bio Technical Life Support Systems' (BTLSS) technologies combined together prior to a manned experiment, is being developed at the Institute of Biophysics SB RAS. One of its aims is to verify and analyze the atmosphere composition safety for crew of the new closed ecosystem in a cycling period longer than several months. In the model, excess oxygen resulting from the process of organic wastes' "wet incineration" in hydrogen peroxide, is being removed by burning it in hydrogen obtained by an extra-system water electrolysis to compensate the model gas balance. In the model, hydrogen is being obtained by water electrolysis and is turning back into water after burning with atmospheric excess O2. An automation system to control the gases flow rates' balance and to prevent explosions is developed. In the planned full-scale experiment BIOS-4 with a crew of 3-4 people, the excess oxygen resulting from H2O2 decomposition in "wet incineration" reactor, will be used on H2O2 recovery. The processes of H2O2 synthesis most suitable for the BTLSS material cycle closure and gas requirements for the crew cabin atmosphere are being under study. The processes must be ecologically safe, energy efficient, adding minimal mass to the BTLSS, reliable and as simple as possible.

F4.5-0012-18 RELEVANCE OF LEDS LIGHTING OPTIMIZATION FOR SPACE PGF IN THE CONTEXT OF CELSS CLOSURE INCREASE

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One essential way of CELSS closure increasing is to use plant growth facilities (PGFs) for space crew food production. At the present time the first biological component of a space LSS is small PGFs, aimed at supplying the crew with fresh vegetables and creating psychological comfort inside the cabin. Now all plant-growth projects for space PGFs include LEDs lighting. It was calculated that conveyor-type cylindrical PGF with 3 m3 of total volume and about 10 kW of energy consumption could provide of full CELSS closure concerning A and C vitamins for crew of 6. The results can be accomplished when crops lighting inside the PGF is strictly optimized. This work presents the procedure and results of lighting optimization for red (660 nm) and white (4000K) LEDs in respect to Chinese cabbage (Brassica chinensis L.) crop. An average photosynthetic photon flux density (PPFD), light spectral composition (red/white ratio) and pulsed light effect on the ascorbic acid yield and the plant physiological status were examined in the fractional 3-factor experiment. The lighting optimization criterion (Qv) was designed for the vitamin PGF as the maximum of squared crop biomass on its ascorbic acid concentration, divided by the light energy consumption. Maximal Qv ensures both high ascorbic acid yield and

LED luminary high functional efficiency. The regression model of optimization criterion was constructed based on the experimental

data. The analysis of the model allowed to determine the optimal lighting regime: 500 μmol/(m2s) time-averaged total PPFD; 1.5 red/white ratio and 30 μs light pulse duration with pulse repetition cycle 501 μs. This lighting regime has kept high level of the crop gas exchange, normal leaves structure, proper chlorophyll a and b content and sugar concentration favorable for the plant growth.

F4.5-0013-18 RESULTS OF TESTING OF THE IMPROVED EXPERIMENTAL MODEL OF THE BTLSS WITH PLANT WASTES AND HUMAN WASTES INCLUDED IN THE MASS EXCHANGE

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Mass exchange processes in the new experimental model of the biotechnical life support system (BTLSS) constructed at the Institute of Biophysics SB RAS have a higher degree of closure than in the previous BTLSS, and, thus, the technologies employed in the new system are more complex. Therefore, before closing the loops of mass exchange processes for several months, the new model of the BTLSS was run to match the technologies employed to cultivate plants and the methods used to involve inedible plant parts and human wastes into the mass exchange with the CO2 absorption rate and the amount of the resulting O2. The plant compartment included vegetables grown on the soil-like substrate (SLS) (chufa, beet, carrot, radish, and lettuce), plants hydroponically grown on expanded clay aggregate (wheat, soybean, watercress), and plants grown in aquaculture (common glasswort and watercress). Nutrient solutions for hydroponically grown plants were prepared by using products of physicochemical mineralization of human wastes. Growing the plants in aquaculture enabled maintaining NaCl concentration in the irrigation solution for hydroponically grown plants at a level safe for the plants. Inedible plant biomass was added to the SLS. Three cycles of closing the system by gas were run, which lasted 7, 7, and 10 days. The comparison of the amount of CO2 fed into the system over 24 h (simulating human respiration) and the amount of CO2 daily exhaled by a 70-kg middle-aged human showed that between 1% and 4% of the daily emissions of CO2 were assimilated in the system, and about 3% of the average human daily O2 requirement accumulated in the system. Plant productivity was between 4 and 4.7% of the human daily vegetable requirement, or between 3 and 3.5% of the total human daily food requirement. Assessment of the level of essential for growth and development of plants macronutrients involvement into mass exchange processes was carried out. It

was shown that addition of gas from reactor of physical-chemical incineration of exometabolites during 10 days did not affect plants growth. Thus, testing of the BTLSS showed a match between the technologies employed to arrange mass exchange processes. This study was supported by the grant of the Russian Science Foundation (Project No. 14-14- 00599).

F4.5-0014-18 ESTIMATING FOOD SETS IN VIEW OF NASA'S NUTRITION REQUIREMENTS FOR LONG-DURATION MISSIONS

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Prior to making a space menu, it is necessary to estimate the suitability of food candidates (FCs) intended for Bioregenerative Life Support Systems. In our computer model FCs were represented as column vectors. Each column vector member represented the mass of nutrients in 100 g of FCs. A set of column vectors formed the "nutrient-FCs" matrix with the size 30x46, where "30" is the number of monitored nutrients and "46" is the number of FCs. FCs masses were considered as independent continuous variables with lower and upper bounds. FCs were programmatically selected from "nutrient-FCs" matrix according to the nutritional requirements stated in the NASA Constellation Program (C×P), document 70024 "HumanSystems Integration Requirements", section 3.5.1.3.1 (Cooper et al., 2011). Calculations were carried out in Matlab using the knitromatlab function. The best fit to the NASA's nutrition requirements was obtained after selecting nineteen FCs, i.e.: sodium chloride, water, rice, white potato, beet, cabbage, squash, sufflower oil, soybeans, chickpeas, cowpea, strawberries, onion, garlic, poultry, snail, tilapia, goat milk, and sugar. The total calculated masses of magnesium, potassium, thiamin, riboflavin, niacin, vitamin B12, vitamin E, vitamin K and omega 6 fatty acids in the set of selected FCs exceeded the corresponding normative daily intakes. However, we could not approve these results because the upper bounds for these nutrients are not established. The calculated masses of iron and phosphorus also exceeded the upper bounds designated for these nutrients. Conversely, we revealed the deficiency of pantothenic acid and vitamin D. Changing the number of selected FCs within 10-46 did not eliminate the nutrient misbalances. Implementation of NASA's nutrition requirement "2/3 of total protein should be in the form of animal protein" was a sufficient condition to support the scores above 100 for all indispensable amino acids.

F4.6-0001-18 VIABILITY AND BIOLOGICAL PROPERTIES OF BARLEY SEEDS UNDER SPACE AND MARS ENVIRONMENTS

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Plants play an important role in supplying nutrients and oxygen to human under material recycle system in space as well as on earth, therefore, seed storage in space should be necessary to self-supply foods when number of astronauts would stay and investigate for a long-term habitation of orbit and the bases of the Moon and Mars. In order to understand the effect of real space environments on the preservation of seeds, the seeds of malting barley, "Haruna Nijo", were exposed to outside of the Russian Zvezda module of International Space Station. After 15-month exposure on-board the EXPOSE-R2 space platform, the seeds were transported to Earth, soaked in water, and germinated on the filter paper filled with water. The germination percentage of the seeds (SS) exposed under space vacuum and solar UV radiation (> 120 nm) was 67%, while that of the seeds (MS) exposed under Mars gas (95.55% CO_2, 2.70% N_2, 1.60% Ar, 0.15% O_2) at 1,000 Pa pressure and solar UV radiation (> 200 nm) was 100%. The surface color of SS seemed brown as it burned, compared with MS and ground control seeds (GS). The germinated seeds of SS, MS, and GS were transplanted to the Wagner pot filled with soil and cultivated for 5 months in the greenhouse. The agronomic properties of SS and MS, such as culm length, plant weight, 1,000 grain weight, number of main stem leaf, number of ear, or ripening ratio, were not different significantly from those of GS. From these results, barley seeds could survive space and Mars environments for the long-term habitation.

F4.6-0002-18 OPERATION OF AN ENCLOSED AQUATIC ECOSYSTEM IN THE SHENZHOU8 MISSION

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Longterm spaceflight needs reliable Biological life support systems (BLSS) to supply astronauts with enough food, fresh air and recycle wasters, but the knowledge about the operation pattern and controlling strategy is rear. For this purpose, a miniaturized enclosed aquatic ecosystem was developed and flown on the Chinese spaceship Shenzhou-8. The system with a total volume of about 60 mL was separated into two chambers by means of a gas transparent membrane. The lower chamber was inoculated with Euglena gracilis cells, and the upper chamber was cultured with Chlorella cells and three snails. After 17.5 days flight, the samples were analyzed. It was found that all snails in the ground module (GM) were alive, while in the flight module (FM) only one snail survived. The total cell numbers, assimilation of nutrients like nitrogen and phosphorus, soluble proteins and carbohydrate contents showed a decrease in FM than in GM. The correlation analysis showed upper chambers of both FM and GM had the same positive and negative correlation factors, while differential correlation was found in lower chambers. These results suggested primary productivity in the enclosed system decreased in microgravity, accompanied with nutrients assimilation. The FM chamber endured lacking of domination species to sustain the system development and GM chamber endured richness in population abundance. These results implied photosynthesis intensity should be reduced to keep the system healthy. More Chlorella but less Euglena might be a useful strategy to sustain system stability. It is the first systematic analysis of enclosed systems in microgravity.

F4.6-0003-18 THE TECHNOLOGY OF INSTRUMENT FOR DETECTING MICROORGANISMS IN SPACECRAFT

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Space life facilities

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The occurrence of microorganisms in spacecraft due to contamination is a health risk to the astronauts and spacecraft. Therefore, certain microorganisms in spacecraft should be monitored and the abundance should be in the security line. Conventional detection methods may be not sensitive or do not provide rapid results allowing for immediate action. The quantitative realtime polymerase chain reaction (qPCR) technique has proven to be an effective method to detect and quantify microorganisms in a few minutes. The technique is highly sensitive and able to detect low numbers of microorganisms. However the traditional instrument for PCR does not meet the space requirements that are rapid, portable, and fully automated.In this study, a combined approach of PCR biochip and fluorescence detection camera is developed to isolate and identify the target microorganism. Microorganism in air is collected into an injector by an air pump automatically. Then nucleic acid is extracted in a liquid-tight system. PCR biochip is used to complete the PCR reaction while the camera monitors the product. Finally fluorescent probes are used in the PCR reaction to hybridize with the target sequence to generate a fluorescent signal detected by the camera whose core is an EMCCD, and quantify the amount of PCR product. This system is fully automatic and liquid-tight, which is required in the space science experimental facilities.

F4.6-0004-18 TRADE-OFF OF AGROFORESTRY PARKLAND TREE CONSERVATION AND CROPS PRODUCTION ACROSS THREE CLIMATIC ZONES IN BURKINA FASO

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The exponential grow of population couple to food demand made land for agriculture more scarcely and oblige farmer to use the small area it can be for crop production. The trade-off between crop production and tree conservation in the farm was assessed across BouroumBourmoum, Sapouy and Ouahigouya municipalities in Burkina Faso. More than 3000 trees with 1154 trees in Bouroum-Bourom, 884 trees in Ouahigouya and 1054 trees in Sapouy were used. The mean tree canopy cover and tree cover in the farm were calculated. The three principal crop cropped (millet, red sorghum and white sorghum) yield were used to estimate the trade-off considering that the mean tree canopy cover constitute the potential no cropping area. The results revealed 66.25±12 (m2), 59.92±12(m2) and 42.1±12 (m2) Tree crown cover respectively in Bouroum-Bourom, Sapouy and Ouahigouya communes. The tree cover was 23.99±3.61% in Bouroum-Bouroum, 18.23±3.61 in Sapouy and 14.88±3.61 in Ouahigouya and the trade-off resulting to tree cover were 109.5 (kg), 247.6 (kg) and 252.8 (kg). Tree cover in the agroforestry system is higher and can be consider such as forest according to the definition of forest by (FAO 2012). The higher tree cover implying the higher trade-off in the agroforestry parkland should be mean causes by tree density reduction. There is urgent need to see how smallholders farmer can continuous to maintain tree diversity in there farm by carbon payment promotion. Keyword: smallholders, Trade-off, tree conservation, crop production, Burkina Faso

F4.6-0005-18 THE IMPACT OF HYPER-GRAVITY AND GAMMA-IRRADIATION ON PHYSIOLOGY OF WHEAT SEEDLINGS

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Exposing plants to altered gravity and gamma radiation can provide us with a fundamental knowledge of plant behavior in such conditions, since the mechanisms involved in response of plants to these stresses is still unclear. The more we understand these mechanisms the more we can apply this information to take the journey of life beyond the boundaries of earth. Hence many experiments were performed on pre-imbibed wheat seeds (Lok-1 variety), wherein they were exposed to hyper-gravity stress (300g-1500g) and gamma-irradiation (Dose 20Gy-100Gy) separately. After exposure these seeds were grown in normal conditions and their growth, fluorescence parameters, and total proline content were observed on the 5th day of their growth. A gradual decline in overall growth and fluorescence parameters, with increase in hyper-gravity stress value (300g-1500g) or gamma-irradiation dose (20Gy-100Gy) was observed. Interestingly in the hyper-gravity studies a consistent increase in the total proline content was observed only till 1200g but the total proline content deteriorated thereafter for higher 'g' values. On the other hand gamma irradiation studies revealed that the total proline content continuously increased with increase in the gamma radiation dose (20Gy-100Gy). Later, pre-imbibed seeds were exposed to both stresses (combined as hyper-gravity (300g-1500g) + gamma-irradiation (40Gy)) and same parameters were studied revealing that there was comparatively greater decline in overall growth and fluorescence parameters of wheat seedlings. Also the total proline content gradually increased (from 300g+40Gy-900g+40Gy) with 900g+40Gy stress value having highest value of total proline content but the total proline content decreased subsequently for higher stress values (1200g+40Gy, 1500g+40Gy). Results obtained in the current research showed that exposing pre-imbibed wheat seeds to hyper-gravity stress, gamma radiation or both combined together may affect the proline biosynthesis and metabolism and also the photosynthetic process of wheat seedlings. Supported by Indian Space Research Organization (ISRO) and Board of Colleges University Development (BCUD), SPPU, Pune.

F4.6-0006-18 SPACE LIFE SCIENCE MULTI-COMPONENT GAS COMPOSITION TESTING EQUIPMENT

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In the space life science experiment, the presence and concentration of carbon dioxide, ethylene and other gas components have an important influence on the process and result of the experiment. In this paper, a multi-component gas detection device based on Fourier transform infrared spectroscopy is introduced. The spectrometer uses a wide-band infrared light source, an improved Michelson interferometer and a DTGS infrared detector. A long pathlength gas pool based on plane mirror reflection was designed. Compared with the traditional white cell, the gas pool has a smaller volume and the same optical path, which meets the volume constraint of the device. At present, the device has completed the prototype Set up, is carrying out relevant verification experiments. In the future, the device is expected to detect a variety of gases to meet the needs of fine control of the experimental process.

F4.7-0001-18 USING OF THE HERB IN SPACE FOODS

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The astronaut must do much work in a short time. The astronaut is exposed to much stress.For examples; Break of the hormone balance, Inappetence, Sleep shortage. Therefore the role that the meal serves as becomes big.It greatly participates in not only the health maintenance but also the mental health to consume a meal. Most of space foods are freeze dry, and the mineral is abundant, but it is necessary for the vitamins to add it particularly. When I think about it, the cultivation of the fresh vegetables with the spaceship is necessary. The Asian project team suggested cultivation of the herb in the space.The herbs were sweet basil, Dukung Abak, Hempedu Bumi and Chinese holly basil. Each herb has a fragrance ingredient.The fragrance ingredient stimulates human sense of smell. The fragrance ingredient increases an appetite. The good fragrance derives a good sleep. I can feel passage of time by observing a plant being brought up. It helps mental health to bring up a plant. We try that we bring up herb under a condition of the space. Because an experiment on the ground was over, we report it. The sweet basil which a germination rate has good is the rst candidate when we think about temperature and light quantity in the space. Three kinds of other herbs are slow-growing and germination-rate is lower than sweet basil. We think that probably we will send a sweet basil to the spaceship in space. After a sweet basil grew up in a spaceship, we analyze a fragrance ingredient. We will cook the sweeter basil and want to eat.

F4.7-0002-18 MONITORING OF AFTEREFFECT OF PROLONGED SPACE FLIGHT FACTORS ON SEEDS AND PLANTS OF LYCOPERSICON ESCULENTUM MILL

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There is a growing interest in space food and plant growing. Tomatoes (Lycopersicon esculentum Mill.) - one of the most popular vegetables in Ukraine, they are a valuable product of therapeutic and dietetic foods because they contain a significant amount of nutrients and essential to the human body minerals and vitamins, but by the content of carotenoids - lycopene and -carotene - is a powerful antioxidant. Therefore, tomato plants can be used successfully to astronauts on long space flights. We aftereffect was studied factors of space flight on the variety of tomato seeds Mir-1, which lasted (6 years) were on an orbital space station "Mir". Then, also after long-term of storage in 2011, seeds were sown in the laboratory and received seedlings grown in field conditions of Kyiv and Poltava regions of Ukraine. We have constantly monitored the observations of plants that have grown from this experimental "cosmic" seeds. Because plants grown constantly in the field natural infectious background, there was a high probability of their defeat pathogens of different nature, including viruses. The works of many authors proved reduce the concentration of carotene and lycopene in tomatoes with the defeat of viruses (Raithak, 2012). In addition, the control plants were observed symptoms of such that is a viral infection, namely in 2011 - leaves curl in 2012 - except leaves curl and even mosaics. The research results were confirmed in 2013, namely on the plants of "space" seed no symptoms of, and in control - detection of potato virus Y (method RT-PCR) and symptoms of leaf curl and mosaic. But then in 2016 in the conditions of the Kyiv region the control variant was identified by PVM (M-potato virus, tomato isolate) and TMV (tobacco mosaic virus). Earlier, in 2014, the MVP was detected in the Poltava region. For the first time in the period of long-term studies of the nature of twisting leafs of tomatoes in Ukraine, TMV has been detected in co-infection with PVM. The received sequences of the site of the gene of the capsid protein of tomato isolates PVM K-16 and Pol-14 are deposited in the Gene Bank under the numbers MF998090 and MF998089, respectively. It should be emphasized that in plant research, "economic" version seen much earlier (8 days) and mass flowering 4-5 days - ripening, compared with the control. Found that tomato plants of the variety Mir-1, which were grown under conditions of space flight aftereffect content of photosynthetic pigments exceeded under control, chlorophyll - 1.3 times, chlorophyll b - 1.5 times the amount of carotenoids was higher in 1,2 times. Chlorophyll ratio of the sum of carotenoids was 5.8 for research and version 5.1 in control. The ratio of chlorophyll a and b as in research form, and in the control has changed.

Solids content in the fruits of research exceeded option up to 0,6% of the total number of sugar at 0,67% phenolic compounds and 14 mg% control (p0.01). But resistance to disease, including late blight (on a scale SEV) according Ustymivsky research station in Poltava region. made in 2014 and 2015 - 9 points of control options and 5 and 7 in "Space" in 2014 and 2015, respectively. Year 2015 was favorable for the growth and development of vegetables, especially tomatoes, which showed a high yield. Harsh (severe) symptoms of viral infections in plants in 2017 was observed.In 2017, we observed, as in previous years, the earlier attainment of the fruits in the "space" variants, compared with the control. The average weight of the fetus was higher by 14% in the experimental version. Notably already in July, noticed lightweight twisting of the leaves and the mosaic in control. Our studies have showen no harmful aftereffects on seeds (Lycopersicon esculentum Mill.) under factors of long orbital space flight and the possibility of obtaining a quality crop of tomatoes grown from space seeds on Earth. These results can be used in modern biotechnologies and breeding.

F4.7-0003-18 DESIGNING AN ARTIFICIAL ECOSYSTEM DURING ANALOG LUNAR MISSIONS

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Future manned missions associated with colonization of Moon or Mars will be designed with accompanying organisms building stabilized artificial ecosystem to provide healthy food, optimal recycling of wastes and biological balance. During two analog Lunar Missions we designed and tested experimental artificial ecosystem based on algae, plants, insects and snails. We used two species of snails: Helix pomatia and Capea nemoralis; three species of insects: Gromphadorhina portentosa (Cockroaches), Hermetia illucens (Hermetia larvae) and Tenebrio molitor (Tenebrio larvae); five species of plants: Vigna radiata (Mung bean), Raphanus sativus (Radish), Glycine max (Soya bean), Allium cepa (Onion) and Petroselinum crispum (Persley), algae: Spirulina and photosynthetic cyanobacteria Synechocystis.

Animals, plants and photosynthetic microorganisms were selected considering their ecological relations between each other. The main aim was to close biomass cycle within selected group including analog astronauts on the top of designed ecological chain. Biological wastes generated by tested organisms were used as regolith soil fertilizer. Plants, insects and snails were used as food.

Experiments were performed during analog Lunar Test Simulation 0 in August 2016 at Queen Jadwiga Astronomical Observatory in Rzepiennik Biskupi, Poland, and during Lunar Expedition I in August 2017 at Analog Research Station in Pila, Poland. Procedures were performed at stable air temperature, air humidity, light intensity and atmospheric pressure. Body mass and food consumption of experimental species were measured and analyzed. We observed significant increase of plant growth in regolith simulants enriched with insect feaces. For snails and insects we observed, that more diverse food should be provided to sustain balanced growth and healthy populations. This result suggests that additional plant species should be incorporated into analyzed artificial ecosystem.

F4.7-0004-18 JOINT BIOCONVERSION OF PLANT INEDIBLE BIOMASS WITH MUSHROOM CULTIVATION AND YELLOW MEALWORM REARING WITHIN BIOREGENERATIVE LIFE SUPPORT SYSTEM

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Long-term deep space activities for the future of mankind, such as the establishment of the Lunar or Martial base, the construction of bioregenerative life support system (BLSS) is crucial. In BLSS, it is expected recycle plant inedible biomass and produce animal protein as much as possible within the system to reduce external material supply. Yellow mealworm (Tenebrio molitor) is the best edible insect selected by the Food and Agriculture Organization (FAO). Its advantages include suitable nutrition composition, fast growth rate, high bioconversion efficiency, easy feeding and less occupied space. Our previous studies confirmed the feasibility of T. molitor as the animal link in BLSS to provide animal proteins for the crew by bioconversion of plant straws. However, the straws must be pretreated by microbial fermentation to be used as

T. molitor's feed. Oyster mushroom (Pleurotus ostreatus) is rich in cellulases and lignocellulases that efficiently degrade straws and provide people with abundant amino acids. In this study, we established a new method that combines mushroom cultivation with T. molitor rearing for bioconversion of plant inedible biomass (PIB). We cultivated P. ostreatus by using plant straws. After harvest, we fed T. molitor larvae (divided by group) in LUNAR PALACE 1 with mushroom residues (MR), while adding other PIB, such as leaves of strawberry, cucumber or carrot as supplements to stimulate and increase T. molitor's consumption of MR. We determined molitor's growth curves, MR digestion efficiency, immune properties and gut microbiota, analyzed the data above to determine the key nutrients that favor T. molitor's consumption of MR, major bacterial genus involved in the MR digestion, and the principal growth limit factor. Based on these results, we optimized the feed composition and verified it by experiments. This study has for the first time achieved to acquire animal proteins and amino acids by bioconversion of PIB, which further improved the system closure.

F4.7-0005-18 STUDY OF AMINO ACIDS COMPOSITION IN A TERRESTRIAL CYANOBACTERIUM NOSTOC SP. HK-01 IN ORDER TO INVESTIGATE ITS USEFULNESS AS A SPACE FOOD MATERIAL.

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A terrestrial cyanobacterium, Nostoc sp. HK-01, is a photosynthetic and Nitrogen-fixing microorganism which can tolerate harsh environmental conditions, and it has attracted attention as a candidate microorganism for initial introduction to Mars. Nostoc sp. HK-01 has four types of cell morphologies: akinetes, vegetative cells, hormogonia and heterocysts. It also has extracellular substances (ES). We have indicated that Nostoc sp. HK-01 is rich in nutrients such as protein, carbohydrates and lipids, and it has been shown to be useful as a food resource. Nostoc sp. HK-01 produces a high level of protein but it has not yet been analyzed how much of each free amino acid it produces. In this study, we analyzed free the amino acids in Nostoc sp. HK-01, which are required by the human body. We investigated the amount of free amino acids of intercellular and extracellular of Nostoc sp. HK-01 which have different akinete ratios. We also investigated the amount of free amino acids after UV exposure to consider whether UV radiation can be used for cooking. As a result, colonies of Nostoc sp. HK-01 with a high amount of akinete cells have a higher amount of amino acid than colonies of Nostoc sp. HK-01 with a low amount of akinete cells. In the case of a low amount of akinete cells, the amount of extracellular free amino acids increased after UV exposure. We discussed the possibility of the function and usefulness of Nostoc sp. HK-01 as a space food material by considering the content of free amino acids.

F4.7-0006-18 APPLICATION TO SPACE FOODS OF THE DISASTER FOOD

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A long-term stay in the space of the human was enabled.The astronaut became able to stay in the long-term space for 1 from a half year.One of the pleasure in the space of the astronaut has a meal.The astronaut is chosen from each country.Therefore the space foods are full of variety.It wants to make the meal a universal meal to be able to do it.In addition, the space foods think about health and want to make a low salt diet.Nourishment balance of the meal eaten in space is regulated now.However, the meal which a hyperglycosemia level after a meal does not happen more than now is necessary.In addition, a low salt diet is necessary for hypertensive prevention.This accords with disaster food in the ground.The nutrient which is enough to take in the disaster foods for a long term is necessary.We need a meal suppressing the hyperglycosemia after a meal in a low salt diet as a disaster meal.Therefore I thought that we applied a disaster meal to space foods.We can store the disaster food at normal temperature for 3-5 years.It is necessary to be able to store the space foods at normal temperature more than three years.The nutrient that both the space foods and the disaster meal are short includes vitamins. We think that it is necessary to supplement it with a supplement about the intake of vitamins.This accords with disaster food in the ground.I thought about space foods menu with commercially available disaster food now in Japan.After all salt to take in per day increases.Most of the energy from carbohydrates is taken in.It is necessary to have vegetables.I think that it can make up for part of vitamins if I can make fresh vegetables in space. A supplement is necessary for the supply of vitamins.I think that multivitamin is good if possible.

F4.7-0007-18 KIBO INDUSTRY, INNOVATES IN AEROSPACE

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The conquest of space is a true inspiration. Imagine a long-duration mission to a distant destination. What shall we take to produce our food? A cow, sh, chicken, or just eggs. In the current state of the animal production technologies are complicated and expensive to implement, except perhaps one: the breeding of edible insects. Based on industry KIBO is postulated in partnership with Space Agriculture Task Force and the university's department of Nutrition Nagoya most innovative research program is created in modern nutrition. This program is called Pegasus. Pegasus research program aims to develop food productions and modules applicable to the aerospace conquest. Kibo entomocole industry is the rst production company in Europe to human food, it aims to become the world leader by 2020. Kibo industry is particularly specialized in producing entomosource (products with insects). The rst phase of the program is to achieve an outcome cereal bar edible insect to aerospace. So we will present the issues and objectives of the project, for aerospace and us. Jean-Philippe Paillard is the KIBO industry CEO and Vice President of the FFPIDI insects farms federation. He is also the co computer alone authorization dossier on the market in Europe and therefore the privileged interlocutor of the General Directorate for Health and Customer Review on this topic. He intervened at the last conference on the insect organized by FAO in Wageningen and in the universities of Angers, Nantes, Lille.

F4.7-0008-18 AQUAPONICS INTEGRATED BY LETTUCE HYDROPONICS AND LOACH AQUACULTURE IN CELSS

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In aquaponics systems integrated by hydroponics and aquaculture, re-use of water and balance of nutrient elements are sustained between both cultures, using dissolved elements in feces from fish for plant growth. In order to operate aquaponics (lettuce hydroponics and loach aquaculture) in Controlled Ecological Life Support Systems, we evaluated possibility that dissolved elements in excretion from loach substitute nutrient elements for lettuce plants. We analyzed growth performances of lettuce and loach, and balance of nutrient elements especially for nitrogen between input and output of the whole system and nitrogen flow in the system. As a result, lettuce grew in aquaponics with a standard solution $\times$ 0.5 as well as hydroponics with standard solution. In nitrogen balance, almost all nitrogen supplied to the system was used by growing lettuce and about quarter nitrogen contained in the feed was accumulated in loach. However, some elements from feces didn't contain completely all required elements for lettuce growth.

F4.7-0009-18 USEFULNESS OF THE INSECT FOOD IN THE LONG-TERM SPACE STAY

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The meal is important in life in the space. The importance of space foods is not only health maintenance. The space foods are one of the Life-support system for a space trip. Time for meal is time of the relaxation of home life of the astronaut. However, the breeding of the large animal is still impossible in the spaceship now narrowly. If it is sh and an insect, the breeding in the spaceship is possible. We recognize an insect as ingredients on the earth. As for the insect, possibility to save a food shortage of the earth is expected in future. We suggested the space foods using the insect for 12 years. The cultivation of the insect is pushed forward now in Europe. We suggest a menu to have you know the space foods which took in an insect more. The insect which we used for this menu is silkworm-pupa, a grasshopper, a larva of a wasp and apple snail. The Japanese foods were registered with world's cultural heritage. Therefore we used an insect to make our Japanese foods. Space foods must be universal food. This is because the astronauts are recruited from the whole world. Space foods that a world astronaut eats and thinks to be delicious are necessary. We want to take in an insect in world cooking in future. The insect food includes essential amino acids and essential fatty acid. The insect is superior nutritionally. We will think that insect food is necessary more and more on both the space and the earth in future. The insect is precious ingredients relieving a food shortage for the human.

F5.1-0001-18 STATUS OF ANIMAL EXPERIMENTS ON INTERNATIONAL SPACE STATION AND ANIMAL CARE ACTIVITIES IN JAPAN

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We would like to introduce status of Japanese animal experiments on International Space Station (ISS) in recent four years. Mouse Habitat Unit (MHU) was launched in August 2015, by the H-II Transfer Vehicle (HTV or 'Kounotori') 5 from Tanegashima island in Japan, which could house mice at most six months, both conditions of microgravity and 1 G on board with a short-arm centrifuge. The first experiment using MHU was started in 2016. The mice returned on earth in living condition, and the effect of space environment, including microgravity and cosmic radiation were investigated. Aside from MHU, some experiments were conducted only using germline cell or ES cell on ISS, for investigating the effect of space environment to these cells and their offspring. For Aquatic Habitat (AQH) experiments, 'Zebrafish muscle 2' was finished at December 2017 in Kibo module successfully. For animal care activities, a thirdparty inspection against JAXA IACUC activities and animal experiment status in JAXA was conducted at 2016.

F5.1-0002-18 GROUND BASED PARADIGMS TO INVESTIGATE THE NEUROBEHAVIOURAL EFFECTS OF ALTERED GRAVITATIONAL ENVIRONMENT IN RODENTS

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The effects of spaceflight on the nervous system physiology could have important implications for the prolonged stay outside Earth's gravitational field. In this view, both ground-based and space research using animal models represent useful tools to investigate the impact of gravity (hypergravity, microgravity and weightlessness) on the nervous system and behaviour. Data coming from these studies, besides acquisition of knowledge relevant for spaceflights and prolonged permanence of both humans and animals in space, could provide insight into basic biological phenomena underlying the plasticity of the nervous system and its adaptive responses to a changing environment. Most ground experiments employing animal models use the paradigm of hypergravity exposure with the expectation that behavioural and physiological reactions to this environment might help to explain reactions to the microgravity challenge faced by orbiting animals. An overview and perspective of ground-based experiments set up to investigate the effects of changes of gravitational environment on the neurobehavioural responses of CD-1 mouse will be reported and the short-, mediumand long-term behavioural and neurobiological consequences of hypergravity exposure both at adulthood and during early and late postnatal development discussed.

F5.1-0003-18 WHICH PRECOCIAL RODENT SPECIES IS MORE APPROPRIATE AS EXPERIMENTAL MODEL TO INVESTIGATE INFLUNCE OF ALTERED GRAVITATIONAL REGIME ON DEVELOPMENT OF THE HUMAN FETUS?

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Precocial rodents as a new experimental model to study the effects of altered gravitational condition on fetal development.

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Previously published article reported that precocial rodents are more appropriate experimental model than altricial rodents for investigation of the influence of altered gravitational regime on development of the human fetus. Influence of altered gravity on depends on stadium of maturation of the bone, muscle and nervous system. Maturity of human fetus at birth is more similar to guinea pig than to altricial rodents such as rat, mouse or hamster. Also, precocial rodent species provide possibility for the first successful mammal reproduction in space because their mature visual and locomotor system alleviates breastfeeding immediately after birth (Sekulic SR et al. Precocial rodents as a new experimental model to study the effects of altered gravitational condition on fetal development. Microgravity, Science and Technology 2006; 18: 223-5.). Precocial rodents are different species with different taxonomy background. Question is which precocial species is more appropriate for experimental model. We considered species which are maximal weight is approximately 1kg. Comparison in relation to husbandary is possible for guinea pig and chinchilla. Chinchilla is less prone to negative stress reaction, have longer average duration of pregnancy than guinea pig (110 vs 63 days), and although have same range of the number of fetuses (1-6) it has in average lower number of fetuses compared to guinea pig (2 vs 3). Newborn mortality rate is similar in both species and largely depends on correct housing conditions (10-25%). Sand bath is necessary for hygiene of chinchillas to remove excess of the oil, keep its coat and skin clean, preventing infections. For sand bath necessary condition is gravity. Therefore experiments with hypergravity (rotating platform on Earth) and hypogravity condition (rotating platform in low Earth orbit) could be more appropriate for chinchilla. Experiments in microgravity conditions could be more appropriate with guinea pig. Disadvantages of lower number of fetuses in chinchilla could be overcome with ultrasound examination of the number of embryos/fetuses prior to start of the experiment, while alternative solution for sand bath could candidate this species for experiments in microgravity conditions. Using specimens for investigation before birth could be a solution to obtain more samples in spite of high neonatal death. Prenatal development of muscle, bone and nervous system

of the guinea pig is well described in published literature while data are largely missing for chinchilla. Up to date no experiments were done using precocial rodents to examine influence of altered gravitational regime to fetal development.

F5.1-0004-18 EFFECTS OF SPACE ENVIRONMENT ON SILKWORM EMBYRO DEVELOPMENT AND MUTAGENESIS MECHANISM

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The silkworm, Bombyx mori, is a lepidopteran model insect with economic importance. The silkworm is originated from China and has been cultivated for thousands of years as the contributor of sericulture. During the long-term domestication, the silkworm has acquired many unique characteristics such as short life cycle, high fecundity, moderate sizes which are suitable for rearing in a limited area such as space environment. We participated in the project of SJ-10 recoverable satellite which carried silkworm embryos as one of 19 scientific experiments in 2016.Silkworm embryos have been were recovered from space successfully and preliminary experiments have been done to investigate influence of space environment on silkworm embryonic and post-embryonic development. Using the embryos carried by SJ-10 satellite, we plan to investigate difference of embryos between space environment and ground control groups at genomic, transcriptional and translational levels. Furthermore, using the genetic manipulation technologies such as transposon-based transgenesis and the CRISPR/Cas9 system, we will perform functional analysis on selected key genes to exploit their functions in silkworm embryonic and post-embryonic development. These studies will not only contribute to modern sericulture, but also exploit how space environment affects silkworm embryonic development and provides fundamental knowledge and experimental approaches for future space life science.

F5.1-0005-18 MICROGRAVITY INFLUENCES SHELL CALCIFICATION IN YOUNG MOLLUSK BULINUS AUSTRALIANUS

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Abstract Calcified structures can be found in many living organisms, they take important part in gravitational sensing, organs supporting and soft tissues protecting. The calcification process changes in microgravity, but the mechanism is still to be disclosed. We used young mollusk Bulinus australianus to investigate shell calcification in microgravity. 6 snails at age of 1-2 months were randomly selected for flight and ground parallel experiments. After 17.5 days, we found shell from spaceflight reduced weight, accompanied with the changes of shell fine structures, microchemistry and polymorphism. The organic matrices secretion was decreased. The interlamella in nacreous layer disappeared and amorphous calcium carbonate deposited. Based on these findings, we proposed that the deficiency in organic matrices and unformed organic spatial structures caused uncontrolled mineral nucleation and transient amorphous calcium carbonate deposition. The amorphous tablets developed in a "twodimensiongrowth" mode, prevented calcium from further incorporation. Our findings provide new sights to calcification in microgravity, especially bone loss and relevant countermeasure.

Keyword: Microgravity. Calcification. Mollusk Shell. Amorphous Calcium Carbonate

F5.1-0006-18 POLYHYDRAMNIOS AS A EXPERIMENTAL MODEL FOR DECREASING MECHANICAL STRESS ON BONE AND MUSCLE DEVELOPMENT DURING SECOND HALF OF GESTATION

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Fetus spontaneously moves from 7th week of gestation week until end of pregnancy. Absent fetal movements in neuromuscular diseases as well as in Fetal Akinesia Deformation Sequence are accompanied with hypomineralized and hypoplastic long bones. During last trimester of gestation fetus has outgrow intrauterine environment, buoyant forces only partially express effect, and fetus has 60-80% of its actual weight. During this period total amount of calcium in bone increase from 5g to 30g. The primary ossification centers in the diaphyses of the major long bones, shoulder, pelvic girdle, and phalanges of the hands and feet appear before the last trimester of gestation. The secondary ossification center in the distal diaphysis of the femur is present from the 33rd week of gestation onward. Before the thirtieth week of gestation in human fetus muscles comprised a great number of smaller type IIC fibers and scattered large type I fibers. After the thirtieth week, the percentage of type I fibers increased greatly to about 23%-50% at term. After the 24th week of gestation, the main factor in the increase in muscle cross-section area is the hypertrophy of muscle fibers. Polyhydramnios represents the excess of amniotic fluid, increase influence of buoyant force on fetus, and decrease mechanical stress on bone and muscle development during last trimester of gestation. While bone condition could be examined in noninvasive manner, investigations of the muscle condition include the biopsy. Experimental models could provide additional data. Altricial mammals are born with the myotubular stadium of muscle development of the extremities, contrary to precocial mammals, which have both types of muscle fibers mature at birth. Also altricial mammals at birth have only primary ossification centers, while precocial mammals have primary as well as secondary ossification centers. Chronic intravenous infusion of angiotensin 1 into fetal lambs (precocial mammal) caused polyhydramnios. Aquaporin 1 knockout mice could be model for polyhydramnios in altricial mammal. Comparison of the muscle and bone development in altricial and precocial mammals in polyhydramnios will provide comparative data related to influence of decreasing mechanical stress during fetal development. In literature there is no data about bone and muscle development in fetuses exposed to chronic polyhydramnios.

F5.1-0007-18 DIFFERENTIAL EXPRESSION OF HOMER SPECIFIC ISOFORMS AT THE NEUROMUSCULAR JUNCTION SUGGEST KEY MECHANISM RESPONSIBLE FOR SKELETAL MUSCLE ATROPHY DURING EXPOSURE TO MICROGRAVITY

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Introduction | The molecular mechanisms regulating skeletal muscle plasticity under extended period of disuse or exposure to microgravity (μG) are not yet fully understood. With the aim to further elucidate such mechanisms we have investigated Homer specific isoforms expression and subcellular localization in skeletal muscle soleus (SOL) and extensor digitorum longus (EDL) of adult rat and mice exposed to chronic disuse by hind limb unloading (HU) and of space-flown adult mice for 30 days in microgravity (Bion-M1, 2013). Hypothesis | Homer specific isoforms play key roles in disuse-induced neuromuscular junction (NMJ) remodeling and plasticity responsible for skeletal muscle atrophy following chronic unloading on Earth and under μG exposure. Methods | Muscle SOL and EDL from 3-weeks HU rats (n=4) and 30 days space-flown C57/black mice were used. In spaceflown animals, three different groups were investigated: The Bion-flight (BF) group (n=5), Bion-ground control (BG) and vivarium control (VC) group. Homer expression and subcellular localization was performed by using laser confocal microscopy, biochemical and Real Time-PCR (RT-PCR) analysis. Results | The immunohistochemical analysis of Homers at the NMJ of HU and Bion-M1 flown animals showed decreased of Homer fluorescence pixel intensity signals in SOL that were not seen in EDL of space-flown and ground control groups. Biochemical analysis in SOL of HU rats further support such results. Notably, by gene array analysis Homer1a, the dominant negative short Homer isoform, was up regulated after 30 days of exposure to μG whereas Homer2, the long

Homer isoform, was down regulated in muscle SOL but not in EDL. These results were further validated by RT-PCR analysis. Discussion | The results indicate that Homer specific isoforms are highly regulated at the skeletal muscle NMJ by muscle unloading conditions and that Homers are sensitive to μG in a muscle specific way.

F5.1-0008-18 STUDY OF P-GLYCOSIDE INTERACTION PROTEINS IN RAT BRAIN UNDER SIMULATED MICROGRAVITY-LABELED FREE COMPARATIVE PROTEOMICS APPROACH

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Microgravity is responsible for redistribution of fluids in the body when in space that may lead to pharmacokinetic (PK) changes. PK change could occur at absorption, distribution, metabolism or excretion processes within the body. It may cause unexpected results regarding efficacy or toxicity of the administered drugs. The altered penetration of drugs in brain could threaten lives of astronauts. P-glycoprotein (P-gp) plays a very important role in drug disposition and maintaining stability of nervous system by effluxing toxics out of blood-brain barrier (BBB). Hence, the proteins interacting with P-gp are of utmost importance. The present study is aimed to investigate interaction proteins with P-gp in rat brain under simulated microgravity by using comparative proteomics approach. Rats were tail-suspended to simulate short (7-day) and long term (21-day) microgravity effect. Non-labeling proteomics strategy was employed to observe significantly differential expression of proteins interacting with P-gp in rat brain under simulated microgravity. The significant differential expression of proteins interacting with P-gp were elucidated by HPLCQ-TOF. Twenty-six (26) of common proteins were chosen from two groups. It was found that 20 proteins were continuously down-regulated, and two proteins showed continuous up-regulation respectively in 7 and 21-day microgravity exposed rats. Bioinformatics analysis revealed that all significantly differentially expressed proteins mainly participated in regulation of 13 kinds of biological process, including ATP hydrolysis coupled proton transport, ATP hydrolysis coupled transmembrane transport and so on. These proteins are found involved pathways including P-gp synthesis, transportation and degradation in cell, APT energy supply, and phosphorylation of P-gp mediated by CAMP/PKA pathways. Atp1b1 was identified by western blot to verify MS results. These findings provide clues for understanding the relation between interaction and changed function of P-gp in rat BBB under microgravity, which might be useful for stability of nerve system and safety of medication use in space travel.

F5.1-0009-18 PROTEOMIC CHANGES RELATED TO ENERGY METABOLISM AND OXIDATIVE STRESS IN THE LIVER OF RATS EXPOSED TO SIMULATED MICROGRAVITY

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The aim of current study was to investigate proteomic changes in liver of rats under short-term simulated microgravity using the Morey-Holton model. After 3 days, strong oxidative stress was observed through the accumulation of hydrogen peroxide and malonaldehyde in rats' liver. 215 proteins particularly those related to energy metabolism pathways were differentially regulated. Processes for oxidating nutriments, such as glycolysis, -oxidation and tricarboxylic acid cycle were greatly enhanced and thus glucose and non-ester fatty acid were heavily consumed. Mitochondrial oxidative phosphorylation was significantly disrupted and thereby, the vast electrons generated from oxygenolysis might not be fully transferred to dioxygen. The enhanced utilization of glucose and non-ester fatty acid coupled with impaired electron transfer chain might contribute to oxidative stress in rats 'liver under simulated microgravity. The proteomic changes support the usage of drugs regulating carbohydrate/lipid metabolism and anti-oxidant in manned space missions.

F5.2-0001-18 PSYCHOLOGICAL AND PSYCHIATRIC ASPECTS OF A MANNED MISSION TO MARS

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Introduction: Based on past studies of astronauts and cosmonauts participating in on-orbit space missions, much has been learned about important psychological, psychiatric, and interpersonal issues that affect crewmembers involved with near-Earth space activities. However, the extreme distances that will characterize a manned mission to Mars will introduce additional psychosocial stressors never before experienced. Methods: A review was made of psychosocial studies involving crewmembers who worked in on-orbit space missions, including the presenter's own work. Also included were studies in high-fidelity space simulation environments, such as the Mars 500 simulator in Russia. Results: Based on this review, a number of psychological, psychiatric, and interpersonal issues were identified and will be discussed. But a mission to Mars will involve unique stressors, such as increased crewmember autonomy, communication delays with the Earth, and the Earth-out-of-view phenomenon. Ideas will be presented for developing research that will help us deal with such issues. Conclusions: As we progress on to Mars, the lessons learned from on-orbit space missions will help up plan ways of dealing with new psychosocial stressors that will affect crewmembers. More research in the space environment is needed to better understand these stressors and to develop ways of coping with them to ensure the accomplishment of mission goals.

F5.2-0002-18 HUMAN NATURE IN LONG DURATION SPACE TRAVELS

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Introduction As we embark on a journey for new homes in the new worlds to lay solid foundations, we should consider not only the survival of frontiers but also well-being of those to live in zero gravity.

As a versatile science, architecture encompasses abstract human needs as well.

On our new different direction in the course of the Homo sapiens evolution, we can do this with designs addressing both our needs and senses. Well-being of humans can be achieved by creating environments supporting the cognitive and social stages in the evolution process.

Space stations are going through their own evolution process. Any step taken can serve as a reference for further attempts. When studying the history of architecture, window designing is discussed in a later phase, which is the case for building a spaceship as well.

We lean on the places we live both physically and metaphorically. The feeling of belonging is essential here, entailing trans-humanism, which is significant since the environment therein is like a dress comfortable enough to fit in, meeting needs without any burden.

Utilizing the advent of technology, we can create moods and atmospheres to regulate night and day cycles, thus we can turn claustrophobic places into cosy or dream-like places.

Senses provoke a psychological sensation going beyond cultural codes as they are rooted within consciousness, which allows designers to create a mood within a space that tells a story and evokes an emotional impact.

Colour, amount of light, sound and odour are not superficial. As much as intangible, they are real and powerful tools with a physical presence.

Tapping into induction, we can solve a whole system based on a part thereof. Therefore, fractal designs may not yield good results unless used correctly in terms of design although they are functional, which makes geometric arrangement critical.

F5.2-0003-18 NEW PROBIOTICS FOR ENHANCEMENT OF HUMAN COLONIAL RESISTANCE IN ARTIFICIAL ENVIRONMENT: ACHIEVEMENTS AND PROSPECTIVE

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Planned interplanetary missions require elaboration of sufficient means to enhance colonial resistance of space crew members. Previous studies reveal decrease of protection activity of indigenous microflora of cosmonauts, thus exogenous contamination could be dramatically easified. Today there are at least four main microbial risk factors 1. Risk of autoand cross infections 2. Risk of sapronose-like infection from alternative sources in confined habitat (e.g. contaminated surfaces and LSS elements) 3. Risk of microbial contamination from outer space during EVA 4. Risk of contamination by microbial community, formed on visiting planet. To avoid microbial risks reliable and fit prophylactic means should be elaborated. Among broad range of ecologically compatible means aimed to improve colonial resistance, autoprobiotics seem to be one of the most perspective groups. We have successfully tested several kinds of probiotics, based on autochthonous bifidobacteria, lactobacilli and enterococci strains in different experiments in long-term isolation, including "Mars-500". The tremendous advantage of autoprobiotics is that there is no problem for adhesion in the biotope, and that it has no allergic impact on human organism. The form of consumption is different: tablets, collagen stripes, ampoules, sour milk products, sprays. Other perspective group of probiotics are based on collection strains, which are well known as protective strains, but still never used as probiotic medicines. For example Corynebacterium pseudodyphteriticum for treatment of high respiratory tract, was tested in different dry immersion studies to decrease or to eradicate Staphtlococcus aureus, Veillonella parvula is a good antagonist versus periodontial pathogens. The third group of prospective means form combined preparates containing probiotics together with other substances. For example, simulator of nasal secretion, containing bacterial substance together with hyaluronic acid and lysozyme was successfully tested in dry immersion studies. The list of the these latter means will be expanded in our future studies.

F5.2-0004-18 EFFECTS OF A NUTRITIONAL COCKTAIL CONSISTING OF ANTI-OXIDANT AND ANTI-INFLAMMATORY SUPPLEMENTS TO PREVENT ECTOPIC FAT STORAGE AND CARBOHYDRATE AND LIPID METABOLISM ADAPTATIONS INDUCED BY 60 DAYS OF ANTIORTHOSTATIC BED REST.

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CNRS - Université de Strasbourg -IPHC - UMR 7178, STRASBOURG, France COSPAR2018

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PURPOSE: In the perspective of the foreseen space missions to Mars and Moon, space agencies aim to understand the mechanisms leading to space deconditioning and develop countermeasure programs. A recent observation during bed-rest studies is the general storage of fat in tissues not specialized in fat storage, i.e. muscle, bone, liver, and whose function is altered because of this lipid accumulation. This general ectopic fat storage is thought to contribute to the development of metabolic syndrome in astronauts, which would jeopardize their health over the long-run. Recent studies conducted in the general population showed several nutrients taken individually, i.e. resveratrol, quercitin, -3 fatty acids, vitamins and others, partially prevent the development of metabolic features associated with metabolic diseases. In a feasibility study, we showed that a cocktail of natural antioxidants XXS-2A (741mg), coupled with both omega-3 fatty acids (1g), vitamin E (168mg) and selenium (80µg) fully prevented the hypertriglyceridemia, the drop in fasting HDL and total fat oxidation as well as the increase in de novo lipogenesis induced by low levels of physical inactivity. The objective is to investigate whether this same nutritional supplementation helps to prevent and/or reduce the deleterious effects induced by simulated microgravity.

METHODS: Twenty healthy male volunteers were randomly assigned to dietary antioxidant cocktail countermeasure (n=10) or isocaloric control diet (n=10) during a 60-day bed rest. Before and at the end of the bed-rest, we measured body composition (DXA), ectopic fat storage (MRI), total energy expenditure and substrate oxidation (indirect calorimetry) and blood chemistry. Exogenous glucose oxidation and liver de novo lipogenesis (GC-MS) were measured by using a glucose tracer, (U-13C) glucose, mixed in standard meals. Analyses used linear mixed models taking into account repeated measures.

RESULTS: Data has been completed in December 2017 and samples and data are under analysis. We hypothesize that sixty days of antiorthostatic bed-rest induce an increased ectopic fat storage in both intra-muscular, intra-hepatic abdominal, abdominal, leg and belly subcutaneous fat based on MRI data. We also expect that physical inactivity trigger exogenous glucose oxidation. Bed-ridden enforced physical inactivity induces a hyperlipemia and a drop in total lipid oxidation. As well, the circulating anti-oxidant capacity could be altered by sixty days of bed rest. We hope to show that nutrition countermeasure can play a central role for the future space missions by counteracting metabolic alterations while not having adverse effects on other system, being easy to implement and inexpensive.

F5.2-0005-18 NEUROMUSCULAR AND CARDIOVASCULAR ALTERATIONS IN ORTHOSTATIC HYPOTENSION AND POSTURAL INSTABILITY INDUCED BY MICROGRAVITY

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Alterations of postural and orthostatic tolerance are the constant consequence of space flights [Kakurin, 1972; Kozlovskaya et al., 1981; Charles, 1991; Paloski et al., 1992; Black et al., 1995;

Egorov, 1996; Buckey et al., 1996; Reschke et al., 1998, 2009; Convertino, 2002; Custaud et al., 2002; Fomina et al., 2007; Coupé et al., 2009; Jain et al., 2010; Saenko et al., 2011; Kotovskaya, 2013]. Muscle tone is considered as one of the mechanisms which play the important role in providing both orthostatic and postural tolerance. Decrease of muscle tone which is observed starting from the first minutes of exposure to weightlessness can contribute to development of both phenomena [Gevlich et al., 1984; Miller et al., 2010; Fomina et al., 2008; Kotovskaya, 2013]. In spite of the number of studies of cardiovascular and postural effects of microgravity the role of neuromuscular and vascular disorders in development of orthostatic and postural intolerance is not clear yet. The results of the study have shown that microgravity is followed by decrease of systolic arterial pressure and heart stroke volume, heart rate increase and deterioration of cardiac activity autonomic regulation during transition from supine position to vertical stance. Comparative analysis of cardiovascular parameters after 21-days of Bedrest and 3-days Dry Immersion has revealed the largest changes after Dry immersion. The changes observed after Bedrest have the same direction but less expressed. The deep alterations in postural control system such as multiple increase of amplitude and velocity of center of pressure fluctuations are observed during first hours after space flights accomplishment. The changes of these parameters after onground model experiments have the same direction but less evident. Support withdrawal is followed by postural muscles atonia. Results of our study revealed strong negative correlation between the changes of muscle tone and heart rate before and after Dry Immersion as well as correlation after exposure to Dry Immersion between parameters of postural stability and muscle tone which was not revealed under normal conditions. The study is supported by Russian Academy of Sciences, CNES and RFBR project 16-29-08320 ofim.

F5.2-0006-18 FAST TRACK MYOMETRIC ANALYSIS OF MUSCLE STATUS TO COMPLEMENT FUNCTIONAL NEUROMUSCULAR TESTS IN HUMAN ANALOG STUDIES AND SPACEFLIGHT

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Background | Neuromuscular tests are routinely used to document functional changes in skeletal muscle and tendon for example in human analog studies or during spaceflight missions. Due to the unique body positioning (usually supine in bed rest) or relaxed state of the free floating body in spaceflight, both training regimen and functional tests may not be always well tolerated due to the uncomfortable transition from relaxed state to maximal power output which is however required to maintain performance and health of astronauts in spaceflight. Thus, alternative tests for functional assessment are needed for monitoring muscle status and health under conditions of extended disuse and exercise on Earth and in Space. Hypotheses | Non-invasive myometry may be a reliable tool for monitoring of neuromuscular status in disuse and, for example, can be applied in bed rest without and with exercise (reactive jumps) as countermeasure (60 days RSL-study, DLR:envihab, Cologne, 2016). Methods | We used a hand-held MyotonPRO digital palpation device to collect biomechanical parameters, tone [Hz], stiffness [N/m], and viscoelastic properties, elasticity (log decrement) and relaxation time [ms] from surface soft tissue (muscle, tendon and fascia) at predefined body skin marks in two bed rest groups (control and exercise, n=8 each). Data collection included the shoulder/neck, back and legs of bed rest participants before (BDC-10), during (HDT+1 to HDT+58, approx.10 days increment), and after bed rest (R+10). Results | We defined a set of biomechanical property changes (vs. baseline) as key to negative bed rest effects, training effects in bed rest, and reconditioning effects (R+10 vs HDT+58) after bed rest (return to habitual activities). Functional neuromuscular tests (i.e., left leg hops linked to surface EMGs) before and after bed rest only showed trends in relevant muscular and myofascial structures of the leg. Discussion and Conclusion | The MyotonPRO technology turned out to be an easy and quick method for muscle status assessment in long-term bed rest. In thigh and calf muscle biomechanical and viscoelastic property changes preceded the functional changes. We propose non-invasive myometry as a fast track analysis protocol. It has the potential to serve as complementary assessment tool in cases where demanding neuromuscular tests may not be easily available, in field studies in extreme environments on Earth, and in long-term spaceflight. Sponsors | European Space Agency (ESA), DLR, Cologne, BMWI/DLR e.V., 50WB1421 to D.B.

F5.2-0007-18 INVESTIGATION OF PERIODONTAL TISSUES IN THE SIMULATION OF THE WEIGHTLESSNESS FACTOR

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"Dry" immersion reproduces changes in physiological functions in the human body, as well as weightlessness. Investigations of periodontal tissues were carried out on the 1st day (background), on the 5th day of immersion (output) and on the 7th day after the end of the immersion. All investigations were performed on an empty stomach, before brushing your teeth. Six healthy male volunteers aged 19 to 26 participated in the investigation. Sampling was conducted locally from 8 points using standard sterile tampons. The concentration of immunoglobulins (sIgA, IgA, IgM) and cytokines (IL-6, IL-8, IL-1, INF, FNO, IL-4) in the oral fluid was determined by an enzyme immunoassay using the appropriate reagent kits of ZAO Vector-Best. For statistical processing of the results of the investigations, the scientific and statistical package "Statistica v6.0" was used. There is a tendency for sIgA to grow on the 5th day of immersion, and on the 7th day after the completion of the immersion, a significant increase in 2-fold IgA ($p < 0.05$) compared with the output. It can be assumed that an increase in sIgA is associated with the appearance of parodontopathogenic microflora in the oral cavity during the experiment. Pro-inflammatory cytokines (IL-8, IL-1, INF) make the main contribution to the total pool of cytokines, that is, a pro-inflammatory cytokine shift is observed. Concentration of IL-8 at the output is increased in comparison with the input in 3 times (p

<0.05). There is a tendency to increase the concentration of INF on the 5th day of immersion, and on the 7th day after the completion of the immersion it significantly increases by 2 times ($p < 0.05$) as compared with the output. Thus, the revealed changes in local immunity indicate a decrease in the protective mechanisms of periodontal tissues and the possibility of activation of inflammatory processes.

F5.2-0008-18 "AWAKENING" OF SUPPORT RECEPTORS IN LOCOMOTOR TRAINING DURING SPACE MISSIONS AS A FACTOR OF POST-FLIGHT CHANGES IN THE NEUROMUSCULAR SYSTEM

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The development of a fundamentally new approach in constructing a countermeasure system of the human body hypogravitational disorders has begun. It is based on the concept of the trigger role of reducing the intensity of sensory inflow from the support input in the development of the neuromuscular system changes in weightlessness. To assess the intensity of support receptors stimulation (as a result of physical training on the treadmill), the values of the vertical component of the ground reaction force with a sampling frequency of 100-120 Hz were recorded using strain gauges on the treadmill that is located on the International Space Station (ISS) and equipped with a vibration isolation system. A primary processing of the values of GRF was carried out using specially developed software that integrated the curve of ground reaction force with a given step (the integration step in this study was 5 kg). We calculated the relative exposure time of the entire spectrum of GRF values per day and individual segments of this spectrum: up to 32% of the cosmonaut body weight on the Earth, from 32% to 64% of body weight, more than 64% of body weight and more than body weight. The parameter of integral stimulation of support receptors was also calculated, by which we mean the product of the time of the support impact on the magnitude of GRF, that is, the area under the graph of GRF throughout the locomotor training. Twelve cosmonauts were participated in this study (age is 47±5 years, all men, weight is 81.8 kg ± 7.9 kg, duration of space flights is 163 ± 25 days). Based on the changes after the flight of the electromyographic cost of walking along a soft surface, two groups of cosmonauts were distinguished. In group A there was a decrease or a slight increase in the maximum amplitude of the m.soleus electromyogram, in group B there was a significant increase in this parameter after the flight. The results of the study show significant differences between the groups in the total exposure time on the support receptors. In group A it was 28.0 min per day, in group B it was 23.5 min (p 0,01). Moreover, the group A was surpassed in exposure time of ground reaction force in the segments from 32% to 64% of body weight, less than 64% of body weight and less than body weight (p 0,03). Both groups were equal in exposure time on the support receptors: with the intensity less than 32% of the body weight it was 4 minutes, and with the intensity higher than body weight it was 3 minutes. We also revealed differences between the groups and the parameter integral stimulation of support receptors. In group A it was 1499 min * kg per day of the flight and in group B it was 1209.8 min * kg per day of the flight (p 0,02). Thus, for the first time, we were able to compare the changes in the motor system after a long-term effect of weightlessness in connection with "awakening" of support receptors in locomotor training during space mission. The time and intensity of the support receptors stimulation during locomotion training are connected with a post-flight change in the electromyographic cost of walking along a soft surface. In the future we are going to analyze the connection between the intensity of the sensory inflow from the support input and the post-flight changes not only of the electromyographic cost of walking, but also of the muscles' speed-strength properties and the mineral density of bone. This work was supported by Russian Foundation for Basic Research grant № 17-04-01826.

F5.2-0009-18 A NUMERICAL PHYSIOLOGICAL ELECTRICAL-LIKE MODEL FOR PREDICTING THE HUMAN CARDIOVASCULAR DECONDITIONING. RESULTS FOR DIFFERENT SPACE MISSION SCENARIOS.

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We report on the results and validation of the model NELME (Numerical Emulation of LongTerm Microgravity Effect) across a wide variety of altered gravity scenarios. Computer simulations have become increasingly available for making predictions on the outcomes of complex physiological systems in extreme environments. However, technical limitations and difficulties of finding out opportunities to produce large series of experimental data to validate the models, have made accuracy difficul for these models. In recent years, this situation has changed as computer facilities have increased their power; and more experimental data from parabolic flights and other altered gravity platforms are available to researchers as well. Details on the development of NELME model are provided, a computer electrical-like physiological model which takes into account variables such as gender, weight, height and also environmental variables like temperature or exposure to gravity. From the model, we can retrieve output results related to the cardiovascular performance under stress and/or exposure to altered gravity. These measurements lead to an assessment of the deconditioning of the cardiovascular system in different scenarios. This is of interest, for example, in cases where it is unlikely that animal models or humans can be tested, such as long-term exposure to partial microgravity.The model has been validated through parabolic flights conducted at the Barcelona-Sabadell Airport using an aerobatic aircraft CAP10B. This aircraft provides up to 8 seconds of microgravity preceded and followed by peaks of around 2 seconds of hypergravity. The model, once validated, is applied to investigate on human exposure to different altered gravity scenarios.

Results are provided about different simulations for short, medium-term and long exposures to microgravity; along with different events embedded. These simulations may include simulation of physical aerobic exercise during a mission, EVAs, thermal stress or human exposure to altered gravity scenarios (centrifuges, Martian or Lunar gravity, rocket launch, etc.). Risks for human health that may put in jeopardy a manned space mission are evaluated and discussed. Results from the simulations account for a degree of impairment of human capabilities that may be of interest for designing future long-term human missions to Mars or others. Interestingly, a long-time exposure to less than 0.35g seems to be as hazardous as a zero g for missions longer than three months, while aerobic exposure does not fully counteract the risks.

F5.2-0010-18 BIOLOGICAL CLOCK SYNCHRONIZATION AND TIME PERCEPTION IN ISOLATED FROM SUNLIGHT HABITATS

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Nearly all living organisms evolved circadian rhythms as synchronization to rotational movement of the Earth. Lunares habitat is a biological clock laboratory established in 2017 in Poland. The facility is designed to investigate optimal for physiology and health lighting conditions for future Moon and Mars human space missions. Within two-week analog simulations astronaut crews, insects, plants and algae undergo multiple experiments in fully isolated from natural sunlight and UTC time environment. A prototype of physiological lighting administrated inside the habitat activates or inhibits multiple types of photoactive proteins responsible for homeostatic regulatory pathways including nervous, endocrine, digestive and immune systems in humans as well as growth and development processes in insects and plants. During three organized analog simulations in 2017, circadian rhythms of 6 analog astronauts with independent control groups were monitored for one month starting one week before the mission, during the mission and 1 week after the mission. During stay in the habitat, analog astronauts were exposed to 4 following circadian phases: first 3 days were 24h, next 4 days 26h (8h advance shift in total), next 4 days 22h (8h delay shift in total), and finally 3 days 24h before end of the mission. Jet lag effects were analyzed including levels of stress, water consumption, urine production and motivation. 12 analog astronauts and 13 control group (without time shifts) were exposed to time illusions through three different tools used by mission control center: specially adjusted scheduling with only two reference time points for briefings and debriefings, running the whole schedule on the lunar or martian clocks and light control in the habitat. After two days of the mission, astronauts completely lost perception of time. Jet lag was detected by analog astronauts at phase III. Astronauts stress and motivation levels were decreased at the Phase III and slightly recovered at Phase IV. Interestingly, water consumption and urination was changed with changing circadian phases. The second parameter analyzed during analog simulations was subjective time perception in astronauts and control groups. Data were collected using STPA software (www.astrotech.io/subjectivetimeperception). Subjects were performing the test twice a day just after waking up and just before going to sleep. During the mission subjects were able to see their results and based on them improve their performance. Effect of training was observed in both analog astronauts groups as well as in controls.

F5.2-0011-18 CHANGE OF AEROBIC CAPACITY AFTER LONG DURATION SPACE FLIGHT

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Change of aerobic capacity after long duration space flight The research of the mechanisms of physiological adaptation of a human to weightlessness and readaptation to the gravity is one of the problems of gravitational physiology that requires extending the knowledge when it comes to preparation for interplanetary missions. At the moment it is known that the maximum oxygen uptake decreases in comparison with the pre-flight level during exercise in microgravity; but the structural changes in the cardiovascular and respiratory systems that occurs during prolonged stay in weightlessness is only fragmentary studied. All the studies described in the literature were performed when testing metabolic change during the exercise with a cycle test. However, locomotions on the treadmill require maintaining the pose and incorporating more muscle mass into the work. Knowledge of metabolic changes in the performance of a locomotor test with a stepwise increasing load can expand the views of gravitational physiology about the change in the cardiovascular and respiratory systems after long-duration space flight (SF). Abovementioned was the purpose of our investigation. The study of post-flight changes in the cardiovascular and respiratory systems was carried out on the basis of ergospirometry data and heart rate from the locomotor test with stepwise increasing load. Three cosmonauts took part in the study (age 46 ± 1 years, weight 89.6 ± 3 kg, duration of the SF 162 ± 17 days). The gas exchange parameters were recorded when performing a test on a treadmill BD-2 with stepwise increasing load (from 3 to 15 km/h with a step 1 km/h every 30 s). The test was carried out before and on the 8th day after the SF. Due to the individual characteristics only one cosmonaut reached the maximum speed running - 15 km / h, the other two cosmonauts had a maximum running speed of 13 km/h and 12 km/h. On the day 8 after the SF a maximum running speeds were 12 km/h, 12 km/h and 10 km/h respectively. The stage of running at a speed of 10 km/h, performed by all cosmonauts before and after the SF, was chosen by us as a standard load for assessing the physiological cost of this work. It was shown that after the SF on the speed 10 km/h oxygen uptake increased on average by 15.7% (85.8 ml/min), carbon dioxide production - by 6.1% (292 ml/min), ventilation - by 18.4% (10.5 l/min). The cardiovascular response, calculated at the heart rate, increased by an average of 5.9% (bpm). The research showed that the long stay in the SF conditions leads to the changes in cardiovascular and respiratory systems, as evidenced by the dynamic of the changes in the oxygen uptake carbon dioxide production, ventilation and heart rate. The results evidence that the physiological cost of the load increases in microgravity and after landing. This work was supported by Russian Foundation for Basic Research grant № 17-04-01826.

F5.2-0012-18 HUMAN PHYSIOLOGY EXPERIMENTS IN AEROBATIC AIRCRAFT PARABOLIC FLIGHTS. EDUCATIONAL AND RESEARCH ACTIVITIES.

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We report on a variety of research and educational human physiology activities related to parabolic flights conducted in Barcelona (Spain), since 2008 (1). We use a single-engine aerobatic aircraft flying out of Sabadell Airport and operating in visual flight conditions providing up to 8 seconds of hypogravity for each parabola. Aside from biomedical experiments being conducted, different student teams have flown in parabolic flight under the international contest 'Barcelona Zero-G Challenge' framework, having published their results in relevant symposiums and scientific journals.

A large aircraft provides researchers with a microgravity environment during a short period of time of about 20 seconds. Specific training of skilled licensed aerobatic pilots from BarcelonaSabadell Aeroclub led to a new opportunity for students and researchers to conduct hands-on microgravity experiments with a different gravity profile than that achieved by larger aircraft. These small aerobatic aircraft are capable of providing short periods of hypogravity of up to 8 seconds, preceded and followed by a peak of hypergravity up to 3.2g's between 3 and 5 seconds. Residual acceleration levels in the hypogravity phase are typically in the order of 0.05 to 0.1g in the Z-axis (aircraft floor to ceiling direction), while accelerations along the aircraft X-axis (aft to front) and transversal Y-axis (right to left) are typically between 0.005g and 0.05g.

These parabolic flights are an excellent opportunity for university students to conduct real hands-on experiments on space science. Examples under the 'Barcelona Zero-G Challenge' framework, are given such as Reversible Images, studying the otholit impairement, which has also flown in the ISS; a study on the influence of mental calculus on the cardiovascular system, and a distance perception estimation experiment on board. Other parabolic flight research studies include validation of NELME, a numerical electrical-like model about the effects of microgravity exposure in cardiovascular deconditioning; and an analysis of brain biosignals under altered gravity loads. In conclusion, the platform can certainly be a good testbed for a proof-of-concept before accessing other microgravity platforms, and has proved to be excellent for motivational student campaigns.

Perez-Poch, A.; González, D.V.; Lopez, D., Hypogravity research and educational parabolic flight activities conducted in Barcelona: a new hub of innovation in Europe. Microgravity science and technology. Vol. 28, num. 6, p. 603-609.

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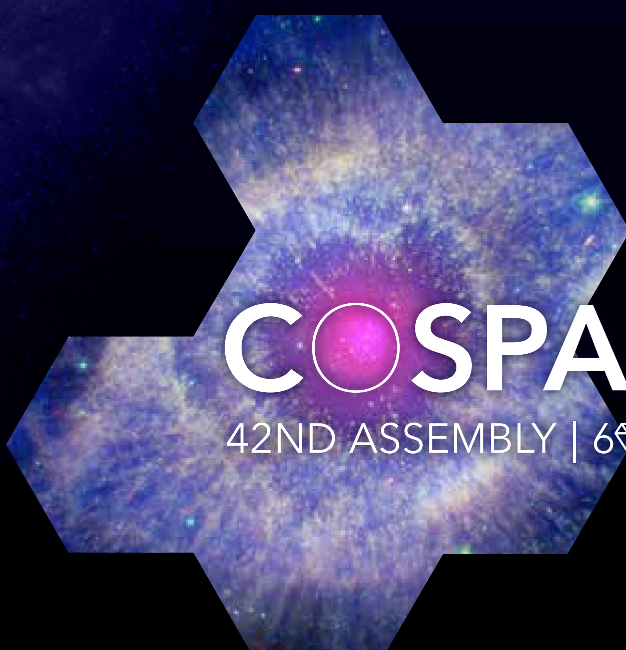

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G0.1-0001-18 REORIENTATION OF LIQUID/GAS FREE SURFACE IN A STORAGE TANK UNDER REDUCED GRAVITY

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Reorientation of liquid/gas free surface takes place when a partly filled storage tank experiences the step reduction of the gravity from the normal gravity. The reorientation behavior, such as the free surface shape, the moving of the apparent contact line, the frequency and damping of the oscillations of the free surface center point was investigated through the experiments in the Drop Tower facility at the National Microgravity Laboratory in Beijing, and corresponding numerical simulations were provided. The dependence of the reorientation behavior on the storage tank size and liquid fill ratio was discussed. This work is supported by the special project of The Chinese Academy of Sciences Strategic Guide TechnologyXDA15012700

G0.1-0002-18 EXPERIMENTAL RESEARCH ON THERMOCAPILLARY MIGRATION OF DROPS BY DIGITAL HOLOGRAPHIC INTERFEROMETRY

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The investigation of thermocapillary flow is important for basic research, as well as for material sciences, chemical engineering, and space manufacturing. When the gravity effect is greatly reduced, the interfacial phenomenon becomes important. The motion of drops driven by temperature gradients is related to the thermocapillary Marangoni convection. The Marangoni effects are caused by interface tension changes, typically interface tension becoming decreased with increasing temperatures. Under different conditions, The Marangoni effects can cause a drop to move in the opposite direction. The thermocapillary migration of drops in a temperature gradient was studied in the present experiment by utilizing digital holographic interferometry. The temperature distribution around a drop, as well as on the interface of a drop, during migration in a vertical temperature gradient were visualized and provided quantitatively for the first time. The perturbed temperature distribution and the actual temperature distribution around the drop during the thermocapillary migration were obtained, and were discussed in detail in this study. The drop was colder than the continuous phase liquid, and a thermal wake existed behind the drop. The dimensionless interface temperature difference was a monotonically decreasing function of the Marangoni number for the three different temperature gradients. When the Marangoni number was increased, the dimensionless interface temperature difference was found to decrease, which was caused by the decrease of the enhanced convective transport results in the drop's thermocapillary migration velocity. With the increasing Marangoni numbers, the length of the thermal wake region increased, and the thermal wake region was extended.

G0.1-0003-18 DYNAMIC FREE SURFACE DEFORMATION OF HIGH-PRANDTL-NUMBER LIQUID BRIDGES WITH MARANGONI CONVECTION IN MICROGRAVITY

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Temperature gradient-driven Marangoni convection is often appeared in the crystal growth process involving a liquid-gas interface (e.g., floating-zone method), and the physical understanding of this convection may lead to an improvement in crystal quality. The objective of the present study is the Marangoni convection in the liquid bridges of high-Prandtl-number (Pr) fluids. The silicone-oil liquid bridge of Pr = 67 or 112 is formed in the gap between two co-axial disks with different temperatures, and the temperature gradient along the liquid-gas interface generates the Marangoni convection because the surface tension of silicone oils depends negatively on the temperature. The convection exhibits an axisymmetric steady motion for small temperature difference between the disks, but the constancy of the flow and temperature fields are broken at the instability threshold. The characteristics of Marangoni convection depend on various factors, and the present study pays attention to the behaviors of the liquid bridge free surface. A series of microgravity experiments called "Dynamic Surf" have been carried out on the International Space Station (ISS) in order to elucidate the effects of the dynamic free surface deformation (DSD, hereafter) on the Marangoni convection. The microgravity environment on the ISS is superior in the following respects: (1) the pure Marangoni convection without buoyancy can be realized, and (2) the large-scale liquid bridges can be formed. The dynamic motions of the free surface are measured by an optical imaging technique for various experimental conditions. It is found that there are internal and external causes of the DSD in the present microgravity experiments: the former is the time-dependent flow structure inside the liquid bridge due to the Marangoni instability, and the latter is the residual acceleration of gravity called g-jitter on the ISS. The relations between the DSD and the instability of Marangoni convection as well as the resonance behavior of the liquid bridge will be discussed.

G0.1-0004-18 HEAT TRANSFER OF NUCLEATE POOL BOILING WITH LOW HEAT FLUX IN MICROGRAVITY

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A series of space flight experiments on pool boiling heat transfer in microgravity have been performed aboard the Chinese recoverable satellite SJ-10. Heat transfer performance of nucleate pool boiling with low heat flux are analyzed and compared with those obtained in normal gravity, as well as those both in normal and microgravity reported in the literature. It is observed that the boiling curves in microgravity are approximately located in the lower extensions of those at the corresponding subcooling in normal gravity. A much lower critical heat flux (CHF), however, is observed in the present study, comparing with those in the literature. Influences of other factors are also discussed. This work is supported by the CAS-NSFC joint fund under the grant U1738105.

G0.1-0005-18 STABILITY AND CONTROL OF FLUIDS IN MICROGRAVITY WITH VIBRATIONS

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Vibrations can induce a range of different interfacial phenomena in fluid systems depending on the frequency and orientation of the forcing. With gravity, (large) interfaces are approximately flat and there is a qualitative difference between vertical and horizontal forcing. Sufficient vertical forcing produces subharmonic standing (Faraday) waves that extend over the entire interface. Horizontal forcing can excite both localized and extended interfacial phenomena. In the case where the interface separates two fluids of different density in, for example, a rectangular container, the mass transfer due to vertical motion near the endwalls requires a counterflow in the interior region that can cause a Kelvin-Helmholtz type instability and a "frozen wave" pattern. In microgravity, the dominance of surface forces favors non-flat equilibrium configurations and the distinction between vertical and horizontal applied forcing can be lost. Furthermore, the vibrational field contributes a dynamic pressure term that competes with surface tension to select the (time-averaged) shape of the surface. These modified (quasi-static) surface configurations, known as vibroequilibria, can differ substantially from the hydrostatic state. In fact, there is a tendency for the interface to orient perpendicular to the main vibrational axis, which can be considered as a type of artificial gravity. In some cases, a bulge or cavity is induced that leads to splitting (fluid separation). We investigate the interaction of these prominent interfacial instabilities in the absence of gravity, concentrating on harmonically vibrated rectangular containers of fluid. We compare vibroequilibria theory with direct numerical simulations and consider the effect of surfaces waves, which can excite sloshing motion of the vibroequilibria. A saddle-node bifurcation occurs with increasing forcing on the branch of symmetric singly-connected vibroequilibria solutions for sufficiently deep containers. The interaction of vibroequilibria and frozen waves is considered. Microgravity experimental results from the "Control of Fluids in Microgravity with Vibrations" (CFVib) experiment, which flew on the 65th ESA Parabolic Flight Campaign as part of the 2016 Fly Your Thesis! programme, are described as well. This experiment had cuboidal and cylindrical containers containing water/air, silicone oil/air or silicone oil/vacuum oil mixtures. Half of the containers were subjected to vibrations using a piezoelectric bender beam assembly that generated high-frequency vibrations from 50 Hz to 12 kHz. The primary objective was to observe the behaviour of vibrated liquids in a weightless environment and to investigate the extent to which vibrations could be used to influence and control this behaviour. Surface waves and large-

scale reorientation of the interface were observed, depending on the frequency. For cuboidal containers with water, particularly good agreement was found between the experimental data and the predictions of vibroequilibria simulations.

G0.1-0006-18 THE ROLE OF FLUID DYNAMICS IN SURFACTANT MONOLAYER EXPERIMENTS

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Interfacial rheology has technological applications in the mechanical, chemical, and medical industries and is relevant in a variety of fields, such as colloid and interface science, biology, biochemistry, and biophysics. In particular, the interfacial dynamics are an important factor in understanding a variety of physical phenomena, including microfluidics, coating and drying processes, and the formation and dynamics of foams.

Interfacial rheological properties can be measured by directly changing the surfactant concentrations or by varying the interfacial area. On ground, this can be done, for example, by periodically modulating the surfactant concentration using two slightly immersed solid barriers that control the free surface area of a shallow liquid layer. Because such modulation is slow, most theoretical studies ignore fluid dynamics in the bulk. We present a long wave theory that also takes fluid dynamics coupled to the free surface. In particular we include two purely hydrodynamic effects that have been ignored and are related to each other.

The unsteady free surface deformation, whose analysis requires to also consider the fluid dynamics in the outer regions, outside the barriers. Let us anticipate that the surfactant concentration and free surface elevation at the center of the trough are in counterphase and thus reinforce each other in connection with the next item.

The dynamics of the menisci at Wilhelmy plate, which may promote several irreversible effects (including contact angle variations and contact line motion) that, in turn, could affect the surface tension measurements.

Results from this theory are discussed for various values of the parameters, which include both gravity and microgravity conditions. Specific predictions can be made for experiments, with the general conclusion that the fluid dynamics should not be ignored in the analysis of these devices.

G0.1-0007-18 SEPARATION OF WEAK MAGNETIC PARTICLES IN GENERAL THAT PROCEED BY A FIELD GRADIENT OF A PERMANENT MAGNET

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Most solid particles, categorized as diamagnetic or weak paramagnetic (i.e. weak magnetic) materials, cannot attain strong magnetization; they are commonly believed to be magnetically inert. Strong magnetic field above the level of several Tesla were applied in the past to realize significant magnetic effects in these materials. A new principle to separate ensemble of heterogeneous particles was proposed by releasing them in an area of monotonically decreasing field under microgravity condition [1]. Furthermore, it was also expected that material of an unidentified particle could be determined from susceptibility obtained from the motion of particle. The practicability of the above two functions were experimentally confirmed within a short duration below 0.2 s; here the field distribution was supplied by a pair of small NdFeB plate [2]. The principle of separation was deduced as follows. A small magnetization is generally induced in a diamagnetic particle when it is placed in an area of external field B. The magnetization is proportional to three parameters; namely B, mass of particle m and intrinsic susceptibility assigned to material. The particle translates in the direction of monotonically decreasing field by a field gradient force, because direction of the magnetization is opposite to B. Considering an energy conservation rule, variance of terminal velocity of the particle at B = 0 area is uniquely determined by intrinsic of material [2], assuming that initial particle positions are identical. Accordingly, the particle ensemble released at a single position is separated into different groups of materials as the translation proceeds[1]. Using the above method, material abundance of a heterogeneous particle ensemble is determined in a simple manner without consuming sample. Such a pre-treatment is important in efficiently performing refined analysis on solid mixtures. In this sense, the significance of the proposed method may be comparable to the "chromatography" technique, which is a conventional method in separating and identifying mixture of organic molecules. Resource exploration of rare materials will become possible using the simple circuit from both natural and urban resources. That is, the explored particle can be simply collected by the apparatus after a "physical" crashing without any chemical treatment that may cause various hazard problems. In the present report, the validity of the proposed principle of separation is examined based on the numerical data obtained in the extending experiments, where the field gradient is considerably enhanced. In order to put the system to a practical use, the separation should be realized in two different materials that have small variance of values. [1] Hisayoshi, Uyeda Terada (2016) Sci Reps, 6, 38431. [2] Uyeda,

Hisayoshi, Kanou, (2010) J. Phys. Soc. Jpn. 79, 064709,

G0.1-0008-18 THE EXPERIMENTAL FURNACE FOR MATERIAL PROCESSING IN CHINESE SJ-10 RECOVERABLE SATELLITE

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The experimental facility named "multifunctional materials processing furnace" has been developed for material experiments in space microgravity. It was designed for materials processing by Bridgman method. It's made up of four units: vacuum chamber unit, heating furnace unit, sample management unit, and drive control unit. The total weight of the facility is less than 19kg and the maximum power input is less than 140W. The double-zone heating structure is one of its main features. Based on this feature, the temperature field distribution can be adjusted to adapt the materials processing demands. This facility can be heated to 950C under vacuum level of less than 1×10-1Pa. The maximum axial temperature gradient is 75C/cm. There are 6 sample cartridges of 16mm×231mm in this furnace, and they can be exchanged automatically and accurately by the sample management mechanism. The maximum sample processing length is 80mm, and the moving speed range is from 0.5 to 120mm/hr. This facility served successfully in Chinese SJ-10 recoverable satellite in April 2016.

G0.1-0009-18 THERMOPHYSICAL PROPERTY MEASUREMENTS OF MOLTEN OXIDES BY THE ELECTROSTATIC LEVITATION FURNACE ONBOARD THE INTERNATIONAL SPACE STATION

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The electrostatic levitation method is a containerless technique that levitates a charged sample by Coulomb force between the sample and the surrounding electrodes. Since the technique doesn't utilize container, high temperature liquids can be handled without contamination under wide temperature range including undercooling range. Therefore, the technique has been utilized for precise measurements of thermophysical properties as a function of temperature, which are necessary for improvement of materials processing and investigation of liquid structure. Originally the technique was developed by Rhim et al. 1 at the Jet Propulsion Laboratory (JPL). On the basis of their knowledge, the Japan Aerospace Exploration Agency (JAXA) has been developing the technique for more than 20 years2. As a result, JAXA succeeded in measuring thermophysical properties of molten metals with high melting temperature such as W, Re and Ta on the ground. However, the measurements of molten oxides were scarcely performed on the ground, because oxides are difficult to charge and then do not levitate. In order to resolve this problem and measure physical properties of oxides, JAXA designed and fabricated the Electrostatic Levitation Furnace onboard the International Space Station (ISS-ELF) 3which enables to levitate oxides with small charge due to an effect of microgravity. First, to measure molten density, one of the fundamental thermophysical properties, the capabilities of levitation and heating were checked by using alumina (Al_2O_3). As a result, each sample was succeeded in levitating and melting fully in dry air by four semiconductor lasers. When the sample was fully molten, all lasers were powered off to cool it. During cooling, the temperature was measured by a pyrometer. The sample images were recorded by using CCD camera and UV-light. From the image and weight after the measurement, the density was calculated. The density as a function of temperature shows good agreement with that obtained by Langstaff et al. (2013)4 using aerodynamic levitator. It also shows about 2 % lower than our earlier results obtained by using electrostatic levitator on the ground in high vacuum condition (Paradis et al. 2004)5. This result proves the validity of the density measurement with the ISS-ELF. The functional check for the surface tension and viscosity measurement is being currently conducted, and detailed results will be reported later.

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G0.1-0010-18 A TWO-ZONE HEATER FOR MATERIAL EXPERIMENTS IN MICROGRAVITY

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Heating furnace is one important material processing facility in microgravity, since most kinds of materials, such metal alloys, semiconductors, oxide crystals, ceramics, are fabricated generally under high temperature. Here we introduce one kind of two-zone heater for materials experiments in microgravity. The core of this heater is two individual resistance coils which are enwound spirally into one tube. This tube is composed by several circular alumina pans whose symmetrical axis are in the same line. The inner diameter of the tube is 18mm and its length is 82mm. Two S-type of thermocouples are designed for temperature control. The electrical current of the two resistance coils can be controlled separately to achieve various temperature profiles along the axes in accordance with each special experimental requirement. The resistance coils as well as the tube are enclosed by some ceramic felt and five columnar radiation shields, which have the ability to severely decrease the heat transfer. The maximum of the axial temperature can get up to 950 centigrade. This kind of heaters were used to perform high temperature material experiments in Chinese Tiangong 2 space laboratory and Chinese SJ-10 recoverable satellite in 2016. Up to now, totally more than 20 experiments have been carried out in microgravity in such heaters.

G0.1-0011-18 PHOTOELECTROCATALYSIS: SOLAR-ASSISTED HYDROGEN PRODUCTION IN MICROGRAVITY ENVIRONMENTS

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California Institute of Technology, Pasadena, California, United States Photoelectrocatalysis

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Artificial photosynthesis systems, which follow the concept of the Z-scheme of natural photosynthesis, are presently being realized as catalyst-functionalized photovoltaic tandem devices for the photoelectrochemical oxidation of water and the simultaneous generation of hydrogen as a so-called “solar fuel”. The successful implementation of an efficient photoelectrochemical (PEC) water splitting cell is not only a highly desirable approach to solving the energy challenge on earth: an effective air revitalization system generating a constant flux of O2 while simultaneously recycling CO2 and providing a sustainable fuel supply is also essential for the International Space Station and long-term space missions, where a regular resupply from earth is not possible. Here, we present the photoelectrochemical production of hydrogen in microgravity environments on p-type indium phosphide electrodes with deposited rhodium electrocatalysts. Our findings indicate that microgravity has a significant impact on the gas bubble evolution behaviour and the mass transfer rate of the evolved hydrogen gas on the electrode surface. Furthermore, microgravity influences the current-voltage characteristics and the overall solar-to-hydrogen efficiency of the catalyst functionalized semiconductor-based half-cell. Further experiments with nanostructured rhodium catalysts fabricated by shadow nanosphere lithography on the InP surface suggest that the structure of the electrode surface plays a significant role for the gas bubble evolution behaviour and for the further the development of efficient prototypes for solar-assisted water splitting and hydrogen production that operate in microand hypergravity environments.

G0.1-0012-18 STUDY OF ELECTROSTATIC LEVITATION FURNACE BASED ON DUAL HIGH SPEED CAMERA DETECTORS

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The containerless electrostatic levitation technology is an important research direction in the development of space materials science. The materials can obtain a large degree of supercooling, thus forming new materials or research on solidification. Electrostatic levitation technology does not generate additional interference factors in the process of material solidification. And it is easy to combine with other non-contact measuring equipment to realize the thermal measurement of materials, which is more suitable for the scientific experiment of space materials. The optical path and other factors in the electrostatic levitation furnace, cause unpredicted error interference for the position detection of Position Sensitive detector. At the same time, during the processing of the material, the high temperature and brightness of the laser heating samples have a great influence on the Position Sensitive detector. Therefore, two high-speed cameras are used to detect the three-dimensional position of the sample. The electric field analysis of high voltage electrode in electrostatic levitation position control system is carried out. And the model of the control system is theorized. The position information of the sample is obtained by the image and optical acquisition system, which helps to control the potential of the high voltage electrode. By adjusting the position of the sample using the closed-loop feedback algorithm, the stable suspension of the charged samples is realized, which lays a foundation for further space free processing experiments in the future.

G0.1-0013-18 BASIC FLOWS AND HYDROTHERMAL WAVE INSTABILITY IN THERMOCAPILLARY DRIVEN FLOW IN A THIN LIQUID FILM WITH LONG SPANWISE LENGTH

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We target the thermocapillary-driven flow in a free liquid film which has two gas-liquid interfaces. We performed a series of experiments employing silicone oil of 6 cSt (Pr = 83.5) as the test fluid in rectangular geometry. We also use gold-coated acrylic particles of 15 µm in diameter as the tracers of flow in the film. By exposing the film to designated temperature difference between the end walls, two types of basic flows occur in the film; 'single-layered flow' and 'double-layered flow.' In the 'single-layered flow,' the cellular flow is realized over free surfaces. Increasing the span-wise length of the film, the number of the cells increases. We evaluate the cell number against the horizontal aspect ratio; the horizontal aspect ratio is defined as the ratio of the span-wise length per the length in the temperature gradient direction. In the 'double-layered flow,' one-directional flow emerges over the free surface, and then return in the inner region of the film toward the hot-end wall. Increasing the temperature difference, the two-dimensional basic flow exhibits the transition to the three-dimensional oscillatory flow. Increasing the temperature difference, thermal waves over free surfaces induced by hydrothermal wave (HTW) instability are observed by the infrared (IR) camera, and those waves steadily propagate from the cold-end wall to the hot-end wall. It is indicated that there are two types of propagation forms of thermal waves induced by HTW instability in the free liquid film; 'planar waves' and 'radial waves,' as indicated in the case of the liquid layer with a single free surface. Especially, in the film with long span-wise length, thermal waves change their propagation form near the side walls. Moreover, increasing the temperature difference, uneven distribution of tracer particles is exhibited in the film. We investigate the correlation between the surface temperature variation and the flow field observed in the top and cross-sectional views of the film with long span-wise length.

G0.1-0014-18 EFFECT OF AMBIENT-GAS FORCED FLOW ON OSCILLATORY THERMOCAPILLARY CONVECTIONS IN A HALF-ZONE LIQUID BRIDGE OF HIGH ASPECT RATIO

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A series of fluid physics microgravity experiments were performed in the Japanese Experiment Module, "KIBO." aboard the International Space Station. Among the experiments, it was examined that the transition to chaos of the thermocapillary convection in a half-zone liquid bridge of silicone oil with a Prandtl number of 112. It was detected by the infrared (IR) camera that 'X' shaped cold temperature regions composed with a pair of thin cold temperature 'band'- like structure emerged over the free surface of the liquid bridge. In other words, a pair of cold lines propagated in the opposite direction with the same velocity over the free surface. This flow was realized in pulsating-wave oscillation. From numerical analysis, the effect of heat transfer between the ambient gas and the liquid bridge on realizing such flows was indicated as one of causes. We focus on such effect in the terrestrial experiment on the thermocapillary convection in the half-zone liquid bridge of high Prandtl number fluid and high aspect ratio ($\Gamma = 2.0$, where Γ is defined as the ratio of the height to the radius of the bridge). The working fluid is 2-cSt ($Pr = 28$) silicone oil for the liquid bridge, and the air for the ambient gas. The liquid bridge is suspended in a gap between the upper heating rod and the lower cooling rod. Whole of the liquid bridge is settled in a coaxial cylindrical external shield in which upward forced flow of the ambient gas is added. Heat transfer between the liquid bridge and the ambient gas through the free surface is evaluated using the Biot number by measuring the temperature distribution in the ambient region. Reynolds number of forced flow is defined as Reamb. We investigate the thermal-convection field as functions of the Marangoni number (Ma) and Reamb as the parameters. We visualize the flow field by suspending tiny particles as the tracers. We indicate the surface-temperature variations over the free surface and their Fourier spectrum to make comparisons with the results of the space experiments.

G0.1-0015-18 THE FUNDAMENTAL CALCULUS AND TEMPERATURE DRIFT PROBLEM OF THE ELECTROMAGNETIC INDUCTIVE PRESSURE SENSOR

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The pressure sensor is an object that transfers the pressure signals to electrical information, and it is widely used in the industry and national defense area. Especially, the electromagnetic inductive pressure sensor, which shows high reliability and high environmental adaptability, is employed in the aircraft and aerospace area. This paper describes the mechanical principle and circuit principle of the inductive pressure sensor, and provides the mathematical model with the main influence parameters. Similarly, the signal of pressure sensor in the zero state is calculated, and the precautions of the designing are provided. Meanwhile, the temperature drifts performance and failure modes of the pressure sensors are discussed and analyzed, the structural asymmetry or magnetic materials defects can both lead to the failure, thus the improving methods for solving the temperature drift problem are also proposed. Besides, the electromagnetic inductive pressure sensor samples are designed and fabricated, the performance of the products have been verified by the tests, the results of which are close to the expectations. This research offers guidance and reference for electromagnetic inductive pressure sensors designing and manufacturing in future.

G0.2-0001-18 DESIGN AND EVALUATION OF AN AIRBAG DECELERATION SYSTEM FOR A DROP TOWER FACILITY

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The design of a proper deceleration system is one of the major challenges in the development of a drop tower facility. One of the major systems that are used for decelerating drop capsules is the airbag. An airbag offers a controlled deceleration for a wide range of masses impacting at different velocities by having a controlled air venting arrangement. In the drop tower facility at Indian Institute of Technology Madras, a deflatable airbag system is used as the deceleration mechanism. The paper here describes the design of the airbag system and the method to predict the systemic variations of the airbag and the outlet control valves using the equations that govern their motion. The different control parameters viz. inflation pressure, the initial opening area and the delay time for valve closing for the airbag system are varied to obtain the desired deceleration levels. The required variation of the vent area during the deceleration process is achieved using a combination of spring valves, gate valves and electromagnet controlled openings.

G0.2-0002-18 THE GRAVITOWER BREMEN - PROTOTYPE: A NOVEL ACTIVELY DRIVEN DROP TOWER SYSTEM

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The Center of Applied Space Technology and Microgravity (ZARM) founded in 1985 is part of the Department of Production Engineering at the University of Bremen, Germany. ZARM is mainly concentrated on fundamental investigations of gravitational and space-related phenomena under conditions of weightlessness as well as questions and developments related to technologies for space and their applications on Earth. At ZARM about 100 scientists, engineers, and administrative staff as well as many students from different disciplines are employed. Today, ZARM is one of the largest and most important research center for space sciences and technologies in Europe.

With a height of 146 m the Bremen Drop Tower is the predominant facility of ZARM and also the only drop tower of its kind in Europe. ZARM's ground-based laboratory offers the opportunity for daily short-term experiments under conditions of high-quality weightlessness at a level of 10(-6) g - microgravity. Scientists may choose up to three times a day between a drop experiment with 4.74 s or an experiment in ZARM's worldwide unique catapult system with 9.3 s in free fall. Since the start of operation of the drop tower facility in 1990, over 8000 drops or catapult launches of more than 200 different experiment types from various scientific fields like fundamental physics, combustion, fluid dynamics, planetary formation / astrophysics, biology and material sciences have been accomplished so far. In addition, more and more technology tests have been conducted under microgravity conditions at the Bremen Drop Tower in order to prepare appropriate space missions in advance.

Beside an introduction about ZARM and its various activities like ZARM's contributions to interesting programs/opportunities for Bachelor, Master and/or PhD students - (i) Drop Your Thesis!" by the European Space Agency (ESA), (ii) DropTES" (Drop Tower Experiment Series) by the United Nations Office for Outer Space Affairs (UNOOSA) and the German Aerospace Center (DLR), and (iii) the GermanSwedish Student Program REXUS / BEXUS" (Rocket / Balloon Experiments for University Students) by DLR and the Swedish National Space Board (SNSB) - a comprehensive insight into the technology and the development of the GraviTower Bremen - Prototype (GTB-Pro) will be presented. The GTB-Pro represents a novel class of drop tower system, which is actively driven being capable to perform over 100 microgravity experiments per day.

G0.2-0003-18 ALONG THE G-CONTINUUM: SUBORBITAL FLIGHTS ON BLUE ORIGIN'S NEW SHEPARD VEHICLE

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With the emergence of a vibrant commercial space industry, researchers now have more options than ever for conducting research along the continuum of microgravity exposure. Blue Origin's New Shepard reusable spacecraft offers a large-format crew capsule, capable of carrying a wide range of payloads above the Karman Line (100 km), where they can experience approximately three minutes in a high-quality microgravity environment before returning for a soft landing. In collaboration with drop tower facilities worldwide, investigators can advance their science, technology, and education payloads stepwise towards longer exposure times and higher Technology Readiness Levels. This talk will introduce the standard interfaces, environments, and operations for payloads within the New Shepard capsule, which began payload flights in 2016. We will discuss specific microgravity use cases already being demonstrated on the platform, including fluid physics, particle interactions, materials science, acute biological responses, and technology demonstrations. And we will highlight collaborations with the ZARM Drop Tower in advancing such payloads from concept to flight.

G0.2-0004-18 STUDY ON FLUID TRANSPORTATION AND INTERFACE BEHAVIOR IN PLATE SURFACE TENSION TANK

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Surface tension tank which is applied on fluid transportation and gas-liquid separation by surface tension and provides the engine or propeller with non-gas pure propellant is the most widely used satellite propellant tank in the world. The plate surface tension tank has the advantages of simple structure, easy processing and high reliability. In this paper, experiment and numerical calculation for fluid transportation and interface behavior of plate tank are conducted. Based on the national microgravity drop tower, the experiments of a plate low temperature tank with different acceleration vector and different liquid filling are conducted independently. In all cases, except for 5% and 20% filling in reverse acceleration, the fluid outlet of tank can be covered by liquid. And the suggestion that baffles must be installed in inner ring is put forward to meet the satisfaction. The capillary climbcaused by the surface tension generated by the eccentric of inner ring is greater than that caused by inertia force in the internal sphere. And the velocity of the climb increases as the gap of inner ring reduces. In the same acceleration vector, the relocation time of tank will decrease along with the decrease of liquid filling. The VOF method and the global hexahedral structured grid are used to simulate the static balance of the 20L-plate tank. The surface tension of the 20L tank is larger in the corner formed by baffle and the wall and the velocity of the liquid climbing is faster along the baffle, which proves that the baffle has good transportation. The liquid sloshing amplitude of liquid, the impact force and impact torque loading on the tank drop significantly with the application of anti-sloshing vane under harmonic excitation. During acceleration period, PMD can effectively reduce the shaking effect. After acceleration, PMD can succeedin collecting the liquid covering the fluid outlet in the tankto ensure the next supplement.

KEY WORDS: plate surface tension tank, microgravity drop tower, VOF, interface behavior, fluid transportation

G0.2-0005-18 CAPILLARY FLUIDICS: DISCOVERY VIA DROP TOWER

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The Dryden Drop Tower is a safe, low-cost, high-rate drop tower located in the atrium of the engineering building at Portland State University. The unique combination of these features serves to lessen the burdens of scientific discovery, creating a low-g access point for commercial entities as well as students of all levels. In this presentation we share drop tower experiment test footage for a variety of large length scale capillary fluidic phenomena. The first drop test investigating a specific phenomena is often preformed on a whim, as will be apparent from the select video clips we present, where unearthly phenomena of 'giant' liquid volumes interacting with non-wetting surfaces are as enjoyable as they are good applied science. We discuss in detail a subset of such phenomena that warranted further investigation including large jet rebounds, spontaneous particle ejections, and spontaneous ejection of non-oscillatory droplets from super-hydrophobic wedges.

G0.2-0006-18 FERROFLUID DYNAMICS IN MICROGRAVITY CONDITIONS

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Ferrofluids are colloidal suspensions of magnetic nanoparticles in a carrier liquid. It is beneficial, for both fundamental research and future applications of ferrofluids in space, to obtain reliable measurements of the dynamics of ferrofluids in microgravity. This field remains unexplored since experiments in microgravity are expensive and the access to associated facilities is limited. In this work, the free surface displacement of a ferrofluid solution is measured in microgravity conditions in the ZARM Drop Tower in Bremen as part of the Drop Your Thesis! 2017 educational programme run by ESA Education. The ferromagnetic solution is subjected to a controlled magnetic field while an initial percussion is imposed.

The ferrofluid solution was produced with a commercial water-based ferrofluid. The solution filled two Plexiglas containers up to a quarter of their height. A copper coil was placed around each container and imposed a constant magnetic field on the ferrofluid solution. A monoscopic fringe reflectometry detection system and a complementary lateral visualization were employed to measure the position of the free ferrofluid surface. The complete set-up was given an initial percussion which produced a vertical acceleration profile. This experiment was launched five times in the ZARM Drop Tower in Bremen with different magnetic field intensities.

From the video data, a 3D representation of the free surface of the ferrofluid and relevant dynamical parameters are extracted. Simultaneous acceleration, temperature and current intensity measurements are employed to generate a CFD simulation, which is compared with the measurements of the real free surface. The validated CFD model leads to more reliable simulations of the dynamics of ferrofluids in microgravity, with multiple applications in fields like ferrofluid sloshing control or magnetothermal convection in Space.

G0.2-0007-18 EXPERIMENTAL EVALUATION OF LIQUID SLOSHING OSCILLATION IN A SPHERICAL TANK UNDER LOW GRAVITY

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The science missions around low gravity planet will be more valuable if a planetary lander can stay and observe on the planetary surface. In order to cruise between planets, the planetary lander has to carry a large amount of propellant which can be heavier than the dry mass of the probe. The acceleration to the tank when the lander touches down on the surface under the low gravity can evolve the sloshing of the liquid in the tank and might cause to fail the landing. In addition, the residual shaking of sloshing in the low gravity environment has a long period in the bare tank without the damping device and it is difficult to damp the fluctuation. Accordingly, it can affect the probe dynamics even though the probe successfully lands on the surface under the micro-gravitational celestial body. Therefore, basic investigation to identify the influence of sloshing is important for a spacecraft landing and staying the environment. However, it is difficult to continuously find analytical solutions since the most of propellant tanks used for satellites and probes are spherical. Furthermore, the surface tension of the liquid cannot be ignored compared to the low gravity. Thus, to evaluate the period on the ground is difficult. In this study, liquid behavior under 1/200 gravity environment is observed using parabolic flight by aircraft. The behavior of colored water which is filled with 75% or 45% in a transparent container simulating a spherical tank of the probe was visualized. The period of the primary sloshing observed in the container filled with water at 75% was roughly consistent with the assumption of a mechanical model to evaluate its eigenfrequency. However, liquid behaviors that surface tension is not negligible based on the observation even if the number of bonds in this container were greater than 1.

G0.2-0008-18 ADVANCEMENTS IN THE QUANTIFICATION OF THE CRYSTAL STRUCTURE OF ZNS MATERIAL PRODUCED IN VARIABLE GRAVITY

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Screens and displays consume tremendous amounts of power. Global trends to significantly consume less power and increase battery life have led to the reinvestigation of electroluminescent materials. The state of the art in ZnS materials has not been furthered in the past 30 years and there is much potential in improving electroluminescent properties of these materials with advanced processing techniques. Self-propagating high temperature synthesis (SHS) utilizes a rapid exothermic process involving high energy and nonlinearity coupled with a high cooling rate to produce materials formed outside of normal equilibrium boundaries thus possessing unique properties. The elimination of gravity during this process allows capillary forces to dominate mixing of the reactants which results in a superior and enhanced homogeneity in the product materials. ZnS type materials have been previously conducted in reduced gravity and normal gravity. It has been claimed in literature that a near perfect phases of ZnS wurtzite was produced. Although, the SHS of this material is possible at high pressures, there has been no quantitative information on the actual crystal structures and lattice parameters that were produced in this work. Utilizing this process with ZnS doped with Cu, Mn, or rare earth metals such as Eu and Pr leads to electroluminescence properties, thus making this an attractive electroluminescent material. The work described here will revisit the synthesis of ZnS via high pressure SHS and will re-examine the work performed in both normal gravity and in reduced gravity within the ZARM drop tower facility. Quantifications in the lattice parameters, crystal structures, and phases produced will be presented to further explore the unique structure-property performance relationships produced from the SHS of ZnS materials.

G0.2-0009-18 COOLING OF GRANULAR GASES

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Granular gases represent one of the simplest systems for investigations of non-equilibrium statistical physics. They are dilute ensembles of macroscopic grains, which move erratically and interact through inelastic collisions. This statistical system is easy to picture, but still insufficiently understood. There are various theoretical treatments on this system, especially for spherical particles under periodic boundary conditions, including numerical simulations and analytical predictions. Experiments on such systems have been performed mainly in two dimensional (2D) systems. An experimental realization of a 3D granular gas requires strong external forces or microgravity. Potential microgravity platforms for such experiments are sounding rockets, drop towers or satellites. Often experiments are dominated by wall particle interactions. Recently we determined translational and rotational velocity distributions under permanent excitation in a stationary state, during a sounding rocket ight. The use of elongated grains allows the realization of a 3D granular gas beyond the Knudsen regime. Here, we provide novel results on granular cooling (energy dissipation after stopped excitation) in a 3D granular gas. We focus on the evolution of kinetic and rotational energy during cooling in drop tower experiments and compare our results to Haff's law and recent numerical studies.

G0.2-0010-18 FLUFFING AND RISING OF GRANULAR MEDIA IN TRANSITION TO LOW GRAVITY ENVIRONMENT

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In Japan, we are planning landing exploration missions such as OMOTENASHI, SLIM, Martian Moons Exploration (MMX) and Solar Sail within the next 10 years. In these missions, asteroids, Earth moon and Mars moon are target objects, and in order to safely landing on them, it is necessary to design a landing gear on the basis of the mechanical characteristics of the planetary surface. For verification of the design, interaction between the gear and the surface is generally confirmed by using a drop tower or an aircraft under a low gravity environment. In the low gravity environmental test using simulated regolith covering the planetary surface, it is essential to properly arrange regolith's initial conditions, but there are various issues. One of the issues is a phenomenon in which the gas trapped in the regolith is blown up in a vacuum environment. It is a supposed solution to leave the regolith for a long time while stirring it in a vacuum environment in advance. Next, the surface of the regolith fluffs or rises up when transitioning from the Earth's gravity or the high gravity environment to the low gravity environment. Regarding the latter, similar behaviour of the regolith is observed not only by the experiment using the drop tower and the aircraft, but also by numerical calculation using a DEM software. As a tendency of the experiment and simulation results, it has been confirmed that more amount of particles flight as the size of the particles increases, and particles that fly at higher speed appeared as particles become smaller. In ground tests, it is difficult to leave regolith in a low gravity environment for a sufficient time; hence, in order to prevent the regolith particles fluff and rise up, it is a solution to utilize fine natural sands or install a device to put a covered sheet on the sand and open it just before the test.

G0.2-0011-18 MECHANICAL FEATURES ANALYSIS OF THE NITINOL ALLOY UNDER MICROGRAVITY CONDITIONS

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Mechanical qualities of the alloy known as Nitinol(Nickel and Titanium) were analized to determine their changes by means of two experiments executed under microgravity conditions (10-6g) compared to those of Earth gravity. The first experiment is to analize the angular velocity throughout the reconfiguration process of the material. Additionally, a second experiment was carried out to analyze the elasticity coefficient and rupture force capacity of the same material. The experiments outcomes were gathered at the ZARM institute in the Drop Tower facility.

G0.2-0012-18 SEPARATION AND IDENTIFICATION OF VOLATILE DIAMAGNETIC PARTICLES REALIZED BY A FIELD GRADIENT OF A NIOBIUM MAGNET

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Many of the solid materials that exist in nature (including outer space) are composed of diamagnetic volatile materials which do not exhibit saturated magnetization; these materials are generally believed to be magnetically inert. An apparatus to separate various volatile and refractory particles, using a monotonically decreasing field, was newly designed and experimentally examined; the setup was based on an apparatus that was recently operated in a micro-gravity condition [1]. Using the new system, magnetic separation was realized for the first time on an ensemble of heterogeneous particles that included solid H2O and CO2; the former setup could conduct the experiment only at room temperature. Furthermore, the material of an unidentified particle can be estimated from the value of magnetic susceptibility that is obtained from the velocity of the translating particle. It is expected from the above results that the material abundances of heterogeneous solid particles that exist in the low temperature regions in the outer solar system are speedily determined without consuming sample, as it is necessary to survey the material distribution of volatile particles over a wide region. The mechanism of the separation is explained as follows.When an external field B is applied on a diamagnetic particle, a small magnetization (i.e. diamagnetic magnetization) is generally induced in a direction opposite to the field; this magnetization is proportional to B, mass of particle m and an intrinsic magnetic susceptibility (per unit mass) assigned to a material. Accordingly, terminal velocity of the translating particle outside the field does not depend on m; it is uniquely determined by the intrinsic susceptibility of the material.It is expected from the above properties that an ensemble of heterogeneous diamagnetic particles can be separated into different groups of materials as translation proceeds [1]. In the experiment, the NdFeB plates were fixed in an insulating container together with the homogeneous particles. Then the container was filled with dry ice blocks to maintain temperature at T=198 K, and was installed inside a compact drop box. A hi-vision camera was set to observe the translation, and susceptibility is calculated by obtained terminal velocity [1]. Micro-gravity condition is produced inside the drop box as it dropped through a short shaft Based on the numerical data obtained in the experiment, the validity of the separation principle is examined, and the possibility of applying the system in a remote sensing mission is discussed. The prototype machine developed in the present study has a rigid and compact structure, and is operated by a simple principle that is easy to examined; its power consumption is small, and finally, analysis is completed without consuming sample.

So far, the spec of the apparatus is suitable for a remote a sensing mission. [1] Hisayoshi, Uyeda Terada (2016) Sci Reps 6 38431.

G0.2-0013-18 READINESS OF SURFACE EXPLORATION ROVER MINERVA-II IN HAYABUSA2 ASTEROID MISSION THROUGH POST-LAUNCH VERIFICATION EXPERIMENTS USING A DROP TOWER

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Introduction

Hayabusa2 spacecraft launched in 2014 makes a round-trip travel to one of the small solar system bodies named "Ryugu." It will arrive at the target this year and make a proximity stay around the asteroid for one and a half years in order to make scientific remote observations as well as to land onto the surface for sample acquisition. The obtained samples are brought back to the Earth in 2020.

The authors developed a tiny rover package for Hayabusa2 mission. The package consists of two rover containers, a relay module and an antenna to communicate with the rovers. Three rovers are included in the two containers. Two of them installed together in one container are the responsibilities of the authors. Another one in the secondary container came from domestic university members. All the rovers were developed without the official budget from the mission to seek for technology-driven challenges on the surface of the target asteroid.

This paper addresses the results of the microgravity experiments of the rovers. The microgravity experiments included the deployment mechanism of the rovers as well as the hopping mobile system of the rover. The results of the experiments are reflected in the deployment operation scheduled to make in 2018 – 2019 when the spacecraft stays in the vicinity of the asteroid.

Post-launch verification using a drop tower

After the launch of the spacecraft, we made two ground-based microgravity experiments needed for the proximity operation. The experiments were made at the drop tower at ZARM, Bremen, Germany, in which 4.7 seconds of microgravity was provided inside the capsule falling for more than 100 meters from the top of the tower.

The rovers are pushed by the springs to be ejected outside from the container when the wire to tightly hold the rover is cut. The microgravity experiments of the deployment mechanism were made for evaluating the deployment direction and speed of the rovers accommodated together in one container.

The deployment speed of the rover from the container highly affects the altitude from the asteroid surface when the rovers are ejected. Deployment from high altitude will accelerate the rover during the fall onto the asteroid and the rover speed might exceed over the escape velocity from the surface.

We used the backup model of the rover container and two aluminum rigid masses whose weights are identical to the ones of the flight models of two rovers.

The evaluation of the hoppping mobile system of the rovers were also accomodated together in a long capsule to conduct two experiments simultaneously in one drop. The speed and direction of the rovers during the fall were measured by the image processing.

We will adjust the torquer acceleration in the autonomous navigation software used on the asteroid surface because the maximum hopping speed of the rover must not be larger than the escape velocity from the surface.

Rover operation

The spacecraft makes remote sensing observation from the distance of 20 kilometers for a couple of month after the arrival. The observation results are used to make a three-dimensinal shape model of the asteroid, and to derive the physical parameters of the asteroid such as gravity, rotational period, and so on.

After the characterization of the asteroid is finished, the spacecraft makes some descent operations including rover deployments and sample acquisitions. Rover deployment may be done around September – October 2018 when the spacecraft descends to the altitude of 50 meters.

After arriving at the asteroid, the rovers move autonomously over the microgravity environment of the surface by hopping with use of a torquer installed inside the body. The rovers are powered by the solar cells, activating the onboard computer and the communication module. The extra power is charged into the capacitors, which assist additional power demand such as hopping by the torquer or image shooting by cameras. The obtained data by the rovers are transmitted to the relay component of the mother spacecraft by radio. The rover operation continues as long as the radio link from the rovers retains.

Acknowledgement

The opportunities of the microgravity experiments at ZARM were granted by the agreement between DLR and JAXA about Hayabusa2 project. The authors are deeply grateful for the technical and operational supports from ZARM.

G0.2-0014-18 PARABOLIC FLIGHT EXPERIMENT FOR MEASURING LANDING IMPACT ON SMALL GRAVITY ENVIRONMENT AND APPLICATION TO LANDER DYNAMIC SIMULATOR

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For the small body landing exploration, it becomes important to know the feature of the contact dynamics between the landing gear of the spacecraft and the celestial soil. It is difficult to know the feature of the celestial soil under the small gravity environment on Earth. We conducted a parabolic flight experiment with a vacuum chamber and a Martian regolith simulant. The projectile was shot into the Martian regolith simulant by a compressed spring. The contact acceleration and sinkage were measured on board. Based on this result, the difference of the force and sinkage under the Earth gravity and small gravity were discussed. Then, the result was applied to the dynamical landing simulator. The landing on the Martian Moon Phobos which is assumed for Martian Moons Exploration (MMX) mission in Japan is verified by the result of the experiment and this simulator.

G0.2-0015-18 DEPLOYMENT TESTS OF PW-SAT2 DEORBIT SAIL IN MICROGRAVITY CONDITIONS DURING FREE-FALL AT DROP TOWER IN BREMEN

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Testing space technology devices, especially deployable ones, is always the most time-consuming and complex activity during the space-related projects. This was experienced by young engineers from Warsaw University of Technology in Poland working on the PW-Sat2 CubeSat. The satellite is going to be launched by SpaceX Company in the third quarter of 2018. The primary objective of PW-Sat2 is to test the deorbit sail system as well to verify its effectiveness.

Deorbit system designed by PW-Sat2 team takes the form of a square sail (2 m side) stretched across four flat springs, coiled around a specially shaped center core. Sail deployment system requires low power for a very short period of time i.e. less than 2 W of power for less than 1 minute. The deployment of the sail is driven completely by the energy stored in folded flat C-shaped springs, that release and unfold the structure of the sail. Therefore, the deployment process is very dynamic, lasts less than 0.7 s and strongly varies depending on environmental factors like gravity, the friction of surfaces or moment of inertia of the mechanism. Due to the sail dimensions, the gravity influence on the sail deployment is significant while testing on the ground. Gravitational forces acting on all parts of the sail cause drag between the ground and the sail material when testing in two dimensions. This does not allow to observe the effects of the sail deployment that may occur in weightlessness conditions. About 25 exact sail models have been built for testing purpose on the ground, but none of these tests provided a sufficient microgravity imitation. Hence, the team was looking for an opportunity to fully simulate sail deployment in a 3D environment without constraints.

The PW-Sat2 team finally has been qualified to DropTES Program organized by ZARM in collaboration with UNOOSA and DLR. Students had a chance to perform 4 sail deployment tests in the high-quality microgravity conditions under low pressure during the free-fall in Drop Tower in Bremen, Germany. In order to get reliable results, a real size dummy mass model of the satellite was prepared, that contained the sail deployment system in the final configuration. Due to the large size of the sail, the experiment had to be dropped from the height of 8 meters in the Drop Tower deceleration chamber. This resulted in about 1.2 s of free-fall. It was enough to observe 4 full deployments of the deorbit sail and to record the process using high-speed cameras. The experiment successfully conducted at Drop Tower in November 2017 proved the reliability of the PW-Sat2 sail's deployment system. Moreover, the readouts of accelerators mounted on satellite's model and footage gathered during the experiment series allowed to fully understand the influence of the sail deployment process on the satellite. The team is going to build a reliable and correct model of sail deployment, which is going to be used to investigate the PW-Sat2 sail scalability and the possibility to be used on larger satellites.

As PW-Sat2 deorbit sail system passed deployment test in microgravity conditions, the effectiveness of the deorbit sail will be verified on the orbit. These tests will make the sail viable to be used onboard other satellite missions and could help prevent the Earth's orbit from space debris in the future.

G0.2-0016-18 QUANTUS-2 - A MOBILE HIGH-FLUX BEC SOURCE IN MICROGRAVITY

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Matter-wave interferometry allows to realize highly sensitive quantum sensors for applications in inertial sensing as well as for tests of fundamental physics. The sensitivity of such measurements thereby greatly benefits from extended free fall times on the order of several seconds. Thus, the operating of matter-wave interferometers in microgravity, ideally in space is currently pursued by research groups worldwide.

To implement such complex experiments on a space-based platform, a validation of the stringent requirements concerning compactness and robustness is needed. Thus, the mobile high-flux BEC source QUANTUS-2 [1] was developed as a pathfinder experiment to perform measurements in microgravity at the ZARM drop tower in Bremen, Germany. The payload is integrated into a catapult capsule and can be launched in a parabolic flight inside a 110m high vacuum tube, providing 9.3s microgravity time.

Here we report on the preparation of a Rubidium-87 BEC to provide an ideal input source for a matter-wave interferometer, where ultra-low residual expansion rates are crucial to reach long interferometer times. We use magnetic lensing (delta-kick collimation) to narrow the momentum distribution of the atomic ensemble and demonstrate expansion rates of 100µm/s, which corresponds to a three-dimensional effective temperature below 100pK. This enables the observation of the ensemble after 2s of free evolution time with a high signal to noise ratio. With this results we are able to provide an ideal input state for a highly sensitive matter-wave interferometer and verify the technical readiness for future space missions.

Acknowledgements:

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G0.2-0017-18 PRIMUS - AN OPTICAL DIPOLE TRAP FOR COLD ATOM EXPERIMENTS IN MICROGRAVITY

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PRIMUS is a drop tower experiment set up to explore the potential of matterwave interferometry in microgravity to realize quantum sensors with increased sensitivity and to enable future space-based fundamental physics tests in particular. To exploit the benefit of extend free fall times in such interferometers, the atoms need to be cooled to the low nK regime, possibly to quantum degeneracy by evaporative cooling. While most cold atom experiments in microgravity rely on magnetic trapping with atom chips for subsequent evaporative cooling, we employ an optical dipole trap instead. This offers several advantages such as improved harmonicity, trapping of all magnetic substates and the possibility to apply Feshbach resonances to control atomic interactions. However, while dipole traps are well established in ground based experiments, their application in a microgravity environment is significantly more demanding.

In this talk, we will present our drop capsule setup and show first results of trapping and cooling atoms in an optical trap in the drop tower. To our knowledge this is the first time an optical dipole trap has been operated in a microgravity environment. We will also outline the next steps to cool the atoms further to ultra-cold temperatures e.g. by applying spatial modulation of the trapping beam to decouple the trapping volume from trapping frequency thus significantly accelerating the evaporative cooling process.

G0.2-0018-18 WHAT IS SO SPECIAL ABOUT QUANTUM TECHNOLOGIES?

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Quantum technologies are becoming more and more important. There is, for example, a European Research flagship on Quantum Technologies, one is building quantum computers for solving real problems for the first time in the near future, one plans to use quantum cryptography having the advantage that it cannot be decoded, there was a Chinese mission which realized the entanglement of quantum states on a satellite with states on the Earth, one is building quantum sensors for geodesy, positioning, and navigation, and one now will base the international system of physical units, the SI system, on quantum realizations replacing analogue units like the Paris kilogram prototype which still is in use today. Why there are so many activities in the direction of quantum technology?

The speciality of quantum systems lies in the fact that they are unique in the sense that they can be uniquely characterized by a finite number of rational numbers. As a consequence, by giving some rational numbers, everybody in the universe can single out a particular type of atoms and extract a particular frequency which then may serve as universal time standard. And from that, e.g. by defining natural constants like the velocity of light and the Planck, Avogadro, and Helmholtz constants, one can define the units of metre, kilogram, mol, and temperature. For that additional quantum effects like the Josephson effect or the quantum Hall effect are needed. Furthermore, quantum systems are given by nature. They cannot and need not to be machined. They are are same everywhere, they are uniquely and unchangeably given. The "only" work left for physicists is to read out the characteristic frequencies or other unique effects or properties of the given quantum systems.

This uniqueness, complemented by the special features of the measurement process and the linear evolution of the quantum systems, then makes such systems perfect for all the purposes described above. In this talk we will describe these unique features, their fundamental consquences, as well as their practical applications. We also will mention the role of fundamental physical symmetries in this context, that is, in which sense the use of quantum technologies depends on the validity of Special and General Relativity.

G0.3-0001-18 ANALYSIS OF DATA FROM ATOMIC OXYGEN MONITOR SYSTEM ONBOARD TSUBAME/SLATS SATELLITE

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JAXA has proposed a brand-new concept for satellites in Low Earth Orbit (LEO). The Super Low Altitude Test Satellite (SLATS) also known as Tsubame is the first Earth observation satellite to adopt a "super low orbit" at an altitude lower than 300 km. Higher resolution optical observation and the reduced emission power of such active sensors as radar are expected in Earth observations from super low altitude orbits in the future. Launched on December 23, 2017 from the Tanegashima Space Center, Tsubame (SLATS) successfully completed its critical operation phase. The Atomic oxygen MOnitor (AMO) is one of the mission sensors of Tsubame. The AMO consists of two mission sensors-the Atomic Oxygen Fluence Sensor (AOFS) and the Materials Degradation Monitor (MDM). The AOFS will obtain AO environment data in Tsubame's orbit. It consists of eight sensor heads (AOFS-Hs) and one readout electronics. For AO measurement, six Thermoelectric Quartz Crystal Microbalances (TQCMs) with polyimide sensors (AOFS-Hs) were mounted at several positions of the satellite. Two non-coated TQCM sensors were also mounted next to the AO sensors for measuring contamination background. Two AOFS-Hs have shutter mechanisms that control incident AO fluence on the front of the AOFS-Hs. The MDM will observe the degradation of candidate materials selected for future use in super low altitude satellites. It consists of a sample control unit (MDM-S) and a CCD camera unit (MDM-C). Thirteen temperature-controlled samples were fixed at MDM-S. The samples are thermal control films, power cables, and an AO monitor material. MDM-C will take an image once a week with LED lights that illuminate from the front and back of the material surface. Such AMO data will be used for a design standard and material usage guidance on future super low altitude orbit satellites. The initial verification of AOFS and MDM functions began on January 4, 2018. The status and functions of both sensors pose no problem. This final paper presents the initial observation data from both the AOFS and MDM.

G0.3-0002-18 SPACECRAFT CHARGING MATERIAL DATABASE (SCMD) IN THE FREE SPACE ENVIRONMENT

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Materials exposed to the free space environment will charge to a net potential due to differential collection of ion and electron currents from the space radiation and plasma environment. The magnitude of the electric fields generated by an excess charge density on (or in) a material is an important consideration for space system design and operations. Accumulation of significant charge can lead to electric fields which exceed the electrostatic breakdown strengths of materials, resulting in electrostatic discharges which are responsible for a number of detrimental effects including material degradation, electromagnetic interference, and even catastrophic failure of electronic components in extreme cases.

We will first provide an introduction to the physics of surface and internal charging processes and identify the relevant material properties required to model charging in each case. We then will describe the Spacecraft Charging Materials Database (SMDC) under development by NASA. This new database of material properties will collect information on the material properties required for conducting charging analyses. Examples of relevant material parameters are volume and surface conductivity, dielectric constant, secondary electron and backscatter yields, photoelectric current density, and material density. We intend for the database to be open to the international community. The goal is to provide a resource for the exchange of information on electrical properties of materials available to both contributors providing fundamental measurements of electrical properties of materials and the analysis community conducting quantitative modelling studies of spacecraft charging. The Spacecraft Charging Material Database will be an archive for ground based testing to support the community's understanding of materials in the free environment.

G0.3-0003-18 HAS THE PLASMA ENVIRONMENT INFLUENCE ON SPACECRAFT INSTRUMENTS?

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Electromagnetic waves in a plasma have a unique propagation behavior as the free electrons and ions react on the electric field of the wave. In the dispersion relation distinct resonances and cut-off frequencies occur depending on the magnetic field strength and plasma density. We focus in our discussion on very low frequencies below 10 kHz which propagate in the so called whistler mode. These frequencies can excite coherent phonons which transport the electric field through the metal. We compare this hypotheses with already performed experiments and the literature of coherent phonons. We will discuss why these frequencies cannot be shielded by metals and how this can affect space instruments. We found this disturbances on accelerometers flying in the ionosphere. We review the disturbances which can be seen on the GRACE and GOCE gravity field missions, like impulsive disturbances due to different switching processes and twangs and continuous disturbances detected on the gravity gradients of the GOCE mission. The relation to very low frequencies excitations in a plasma is given, as well as an explanation why accelerometers are extremely sensitive to these disturbances. The accelerometers suffers from the electromagnetic incompatibility but other instruments may be more disturbed by mechanical interactions. As an outlook we show observations on the Swarm accelerometers where a coupling of mechanical and electrical influences occur.

G0.3-0004-18 CHARACTERISTICS OF THE FREE SPACE ENVIRONMENT AND MATERIAL PROPERTIES CONTROLLING THE DEVELOPMENT OF AURORAL CHARGING

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Spacecraft materials charge to significant negative potentials relative to the ambient space environment when an incoming electron current to a surface exceeds the incoming ion and outgoing secondary electron and photoemission currents. Materials on spacecraft surfaces may charge to potentials of a few hundred volts to a few thousand volts in low Earth orbit when exposed to the electron currents responsible for producing discrete auroral features at high latitudes. These large negative potentials are a concern to spacecraft designers and operators since they can result in electrostatic discharges that damage materials or spacecraft components. While discrete aurora generated by both inverted-V and Alfenic type electron spectra can exhibit strong electron currents, charging to large negative potentials only occurs when spacecraft pass through the inverted-V type electron environments. This paper will summarize the characteristics of the electrons and ions in the free space environment and electrical properties of materials including the secondary electron yield and photoemission yields of importance in controlling the charging process. We will first provide a background on the physics of surface charging. Next, we will describe the characteristics of the secondary electron yield and photoemission yield properties of materials that are important to the charging process. Finally, we will provide examples of charging due to both inverted-V and Alfenic type electron spectra using records from the space environment sensors on the Defense Meteorological Satellite Program spacecraft.

G0.3-0005-18 ADDITIVE LAYER MANUFACTURING FOR CUBESAT MISSION TO STUDY THE BEHAVIOR AND PERFORMANCE ON STRUCTURAL MATERIAL IN THE SPACE ENVIRONMENT

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CubeSats are a class of nano-satellites that use a standard size and form factor. The standard CubeSat size uses a “one unit” or “1U” measuring 10x10x10 cms and is extendable to larger sizes; 1.5, 2, 3, 6, and even 12U. The concept was originally developed in 1999 by California Polytechnic State University at San Luis Obispo (Cal Poly) and Stanford University to provide a platform for education and space exploration. CubeSat has a several systems and subsystems, among one of them is the primary mechanical structure which supports all the subsystems including the Solar Panel and Antenna. The prospective to develop and launch a 1-Unit CubeSat “AlbiSat” for Institut Clement Ader, Albi proposes the concept of utilization of Additive Layer Manufacturing (ALM) process to develop the primary Mechanical structure. Traditionally the mechanical structure in present time for the CubeSat is built using machining and other manufacturing processes. The application of Additive Layer Manufacturing to design and manufacture the primary mechanical structure for the CubeSat as a novel mission concept to study the behavior and performance of the structural material in space conditions as a prospective preparation towards understanding the effects of the space environment on the material performance and structural health can help us in utilizing the Additive Layer Manufacturing Process for future applications in space exploration. Aluminum 7075 and 6061, alloys which are the only two materials permitted by the CubeSat specifications so only these two materials can be used to prepare the powder to use in the ALM process. By utilizing the ALM process to manufacture the mechanical structure which has several advantages over conventional manufacturing process like moving parts such as hinges which support the solar panel deployment can be printed in metal directly into the product, which can significantly reduce the part numbers as well as several other advantages like whatever we design in the CAD software we can create easily and only the material that is needed is used, there is very little (if any) material wasted. Considering our future perspective of space exploration,future spacecrafts and objective to build base camps on Moon and Mars, ALM process to design and manufacture them can reduce the manufacturing costs. It costs less to print a complex part instead of a simple cube of the same size. The more complex (or, the less solid the object is), the faster and cheaper it can be made through additive manufacturing. In this regard the development of the Mechanical structure for the AlbiSat CubeSat project utilizing the ALM process can help us to better understand the behavior and performance of the material and the overall mechanical structure in the condition in Low Earth Orbit at a low cost to simulate and analyse both Mechanical and Thermal behaviour, to find out the feasibility of utilising ALM process in space environment which can help us to do further research and utilize the concept of ALM in minimizing the manufacturing cost and time in building future spacecrafts.

G0.3-0006-18 QUANTIFICATION OF NIOBIUM ALLOY C-103 SUBLIMATION IN EXTREME SPACE ENVIRONMENTS

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Late in the Parker Solar Probe (PSP) development, high temperature emissivity testing uncovered a possible risk related to sublimation of niobium alloy C-103. Although the experiment inadvertently demonstrated that sublimation of the alloying elements of C-103 could occur at high temperatures and vacuum conditions, determining the risk to the spacecraft and its components required an estimate of the amount of material that would sublimate over the mission lifetime. In order to quantify this, the rate limiting mechanisms of sublimation need to been well understood for the C-103 alloy. From there one can construct a mathematical model for the behavior of the material and predict what species will sublimate, when the sublimation will occur, and how much material is sublimated. The major hurdle in the approach lies with the very limited information available for C-103 in this environment, and for the major alloying component hafnium in particular. Since time for defining the risk to PSP was limited, an engineering approach was devised to acquire estimates for the missing information, mainly diffusion rates and sublimation rates at the surface of the C-103 alloy.

Through the use of high temperature vacuum ovens at Oak Ridge National Laboratory, JHUAPL, and NASA Glenn Research Center (including vacuum thermogravimetric analysis), C-103

coupons were exposed to temperatures up to 1800 °C at pressures as low as 10−5 Torr. From the mass losses observed and concentration gradients of hafnium and titanium across the thickness of the coupon, improved transport properties have been obtained.

Within two months of discovering that there was a fundamental physics problem with the potential to affect everything on the spacecraft, the scope of the problem was narrowed down to two instruments based on the predicted sublimation rates and ray tracing analysis.

G0.3-0007-18 MODELING THE INFLUENCES OF ELECTROSTATIC DISCHARGE IN MATERIALS ON A FAILURES OF ONBOARD ELECTRONIC EQUIPMENT IN UNDER MICROGRAVITY

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It is known, that during SV exploitation failures of automated systems happens as the result of complex influence of Space leading to SV's shorter life span, sometimes to their lose. All of the SV, functioning in the near-Earth Space (NES), subjected to influence of different Space factors. Causes and character of failure onboard equipment are different. Many researchers think that failures of onboard electronics connected to changing solar activity level. However, by the numerous onboard experiments established that even in the absence of solar burst in magnetostatic days there are registered failures of onboard electronics. In this paper discussed the results of modeling the impact of electrostatic discharge (ESD), occurring in the materials, on a failures of electronic onboard equipment in microgravity. The paper discusses the conditions of formation and influence of electrostatic discharge in microgravity on the elements of the onboard electronics in Space. Developed technique using circuit simulation in ISIS Proteus environment is discussed. Developed the recommendations for noise immunity of on-board equipment from ESD in Space. The results are used to predict the failure rate on-board electronics with the long term of space mission.

G0.3-0008-18 INFLUENCE OF SPACE FACTORS ON PHYSICAL PROCESSES, TAKING PLACE IN MATERIALS AND ON-BOARD ELECTRONICS IN SPACE

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It is known that during flights of manned and unmanned spacecraft failures of on-board electronic equipment occur which are related to physical processes in functional materials. It is accepted that these failures are caused by charged high-energy particles that are of solar and galactic cosmic rays (SCR, GCR). In real conditions, there are other factors SF, which must be taken into account in the design and planning of missions of various spacecraft. Therefore, it is very important to study the complex influence of space factors (KP) on the degradation of materials and on-board electronic equipment in the space. In this paper we analyze the results of ground modeling studies and space experiments to study the physical properties of materials exposed in the space. Criteria of reliability of on-board electronic equipment and material degradation are developed and discussed. Criteria include the factors of space, including: radiation exposure, thermal shock, microgravity, electrostatic discharge, vacuum; factors of technological and functional purpose. The mechanism of material degradation in conditions in the space and microgravity is discussed. Practical recommendations are discussed to increase the reliability of functional materials, as well as on-board electronic equipment.

G0.3-0009-18 STUDY ON THE THERMAL-MECHANICS COUPLING CHARACTERISTICS OF COMPOSITE ENVELOPE STRUCTURE OF HIGH ALTITUDE STRATOSPHERIC AIRSHIP

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A thermodynamic coupling model of the high latitude stratospheric airship envelope structure is established in this study based on the damage theory of laminated composite. Based on the flight test data, the mechanics response of composite envelope is revealed under different flight altitudes, different pressure difference conditions and different temperature conditions. The mechanical characteristics of the different structural parts of the airship under the same temperature and pressure difference are discussed in depth. The results show that the thermal stress of the composite envelope is small under low temperature and low pressure, and the influence on the envelope material damage is almost negligible. The in-plane shear thermal stress (S12) distribution along the longitudinal axis direction (from head to tail) of the airship gradually increases when the temperature is lower and the pressure difference is smaller, but the thermal stress (S12) along the circumferential central axis direction of the airship almost no change; The in-plane thermal stress (S11) between the two ends of is larger along the longitudinal axis direction of the airship, while the thermal stress (S11) along the circumferential central axis direction of the airship is smaller in the middle. The difference is that the circumferential thermal stress is greater overall than the axial thermal stress. Through the analysis also found that the mechanical properties of composite envelope structure are stable, and almost no damage is observed under low temperature and low pressure thermal-mechanics coupling conditions. Keywords: Thermal-mechanics coupling, Stratospheric airship, Composite envelope, Thermal stress, Damage theory

G0.3-0010-18 PARTICLE RADIATION EFFECTS REPRESENTING GCR AND SPE SPACE RADIATION ON SPACECRAFT AND SPACESUIT MATERIALS-OF-CONSTRUCTION

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The effect of particle radiation on materials-of-construction used in inflatable habitat, composite habitat, and space suits was investigated. The materials irradiated are lightweight candidates having a variety of applications such as permeation barriers, micrometeoroid and orbital debris (MMOD) protective layers, and restraint layers. The types of particle radiation used were chosen to be representative of the species and energies present in galactic cosmic ray (GCR) and solar particle event (SPE) space radiation. For example, low-Z (proton) and high-Z (iron) 1- GeV particle beams were used to bracket GCR ionization and displacement effects. Intermediate energy (ca. 20 to 40-MeV) protons were used to simulate ionization effects due to exposure to SPE radiation. The amount of damage caused by either form of radiation was quantified by determining changes in relevant mechanical and physical properties. Although lower and higher dose effects were ascertained in the study, materials were generally irradiated to doses representing up to a 50-hear exposure to deep space radiation (approximately 700 and 10,000 cGy for GCR and SPE dosese, respectively). The test logic was, therefore, to qualify materials out to 50-years, rather than to determine terminal doses leading to catastrophic property loss.

In most cases, little or no significant property change was observed after exposing materials to particle radiation representing a 50-year GCR or SPE dose. However, in certain cases, moderate property changes were observed. For example, a 325-denier Spectra® space suit restraint layer exhibited a 20.6 percent drop in the initial puncture extension after receiving a 10,300-cGy proton dose simulating a worst case 50-year exposure to SPE radiation. Similarly, significant drops in the initial puncture extension were also noted for 325-denier Spectra® after receiving a 400 to 709 cGy

1-GeV 26Fe dose emulating an exposure to high-Z GCR radiation. The largest mechanical property changes noted in this study were 133 to 205 percent increases in the room temperature ultimate tensile strength (UTS) for a bladder materials reinforced with 210-denier Spectra® receiving 709 and 10,300 cGy doses emulating 50 year GCR and SPE exposures, respectively. Other commercially available bladder materials (Cadpak® HD200 and Armorflex® ST10) exhibited small but reproducible increases in the UTS, consistent with predominant cross-linking. Thermogravimetric analysis (TGA) of selected bladder materials suggested the occurrence of some cross-linking of high molecular weight polymeric species, with some increase in liberation of low molecular weight (non-polymeric) species; however, the changes noted were small. Permeation results for an Armorflex® ST10 bladder material revealed an initial drop in the permeation resistance after irradiation, which recovered to acceptable levels after repeated pressure cycling. Deterioration in ballistic performance was noted after exposure of inflatable habitat MMOD protective layers receiving doses equivalent to a 50- year high-Z GCR exposure. Results on filled and unfilled sandwich core constructions showed that panels with filled honeycomb core are significantly strengthened after iron proton 1-GeV particle exposures. Last, the combined effects of radiation exposure and thermal aging on high density polyethylene (HDPE, similar make-up to Spectra®) were demonstrated, suggesting that physical aging may exacerbate radiation degradation processes occurring in spacecraft and space suit materials used in long term applications in space radiation environments.

While catastrophic end-of-life material failure indicative of a terminal dose was not observed for any material investigated, the potentially antagonistic (accelerative) degradation by simultaneous radiation exposure and physical aging was. The relevance of the current findings to NASA's missions is discussed and recommendations for future testing are made. Corroboration of current data with available scientific literature is also discussed.

G0.3-0011-18 MATERIALS INTERNATIONAL SPACE STATION EXPERIMENT-9 (MISSE9) POLYMERS AND COMPOSITES EXPERIMENT

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Spacecraft in low Earth orbit (LEO) are subjected to harsh environmental conditions, including radiation (cosmic rays, ultraviolet, x-ray, and charged particle radiation), micrometeoroids and orbital debris, temperature extremes, thermal cycling, and atomic oxygen (AO). These environmental exposures can result in erosion, embrittlement and optical property degradation, threatening spacecraft performance and durability. To increase our understanding of effects such as AO erosion and radiation induced embrittlement of spacecraft materials, NASA Glenn has developed a series of experiments flown as part of the Materials International Space Station Experiment (MISSE) missions on the exterior of the International Space Station (ISS). These experiments have provided critical LEO space environment durability data such as AO erosion data for many materials and mechanical properties changes after long term space exposure. In continuing these studies, a new experiment called the Polymers and Composites Experiment has been selected for flight on the MISSE-Flight Facility (MISSE-FF). The Polymers and Composites Experiment will be flown as part of the MISSE-9 mission, the inaugural mission of MISSE-FF manifested on SpaceX-14. This experiment includes 138 samples being flown in ram, wake or zenith orientations for space environmental durability assessment. The primary objective is to determine the LEO AO erosion yield, Ey (the volume loss per incident oxygen atom (cm3/atom)), of polymers, composites, and coated samples, as a function of solar irradiation and AO fluence. In addition, epoxy samples with varying levels of ZnO powder are included to study the effect of filler quantity on AO erosion. An AO Scattering Chamber is included to help improve the understanding of AO scattering mechanisms for improved AO undercutting modeling. Indium tin oxide (ITO) coated samples are included to validate the durability of ITO conductive coatings in LEO. Tensile samples of Teflon fluorinated ethylene propylene (FEP) of varying thicknesses and back-surface coatings will be flown in wake and zenith orientations to study radiation embrittlement versus thickness, and the effect of heating on FEP embrittlement. Finally, shape memory composite and cosmic ray shielding samples will be flown for LEO durability assessment. This paper presents an overview of the MISSE-9

Polymers and Composites Experiment.

G0.3-0012-18 LARGE CONSTRUCTIONS FOR FUTURE SPACE EXPLOITATION

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Future space exploitation requires large space structures. A sufficient large volume of pressurized modules for crew, passengers, space processing equipment, etc are required. However the size and mass of modern space ship and stations is limited by possibilities of a launch vehicle. It limits our future in exploitation of space by human crew and makes space industry projects non-profitable. Large-size space construction can be made with using of the curing technology of the fibers-filled composites and a reactionable matrix applied directly in free space. For curing the fabric impregnated with a liquid matrix (prepreg) is prepared in terrestrial conditions and shipped in a container to an orbit. In due time the prepreg is unfolded by inflating. After curing reaction, the durable construction can be fitted out with air, apparatus and life support systems. Our experiments of the curing processes directly in the free space environment showed that the curing of composite in orbit is possible. The large-size space construction can be created in Earth orbit. Large size space station, Moon base, Mars base, mining station, interplanet space ship, telecommunication station, space observatory, space factory, antenna dish, radiation shield, solar sail are proposed. The study was supported by Humboldt Foundation, ESA (contract 17083/03/NL/SFe), NASA program of the stratospheric balloons and RFBR grants (05-08-18277, 12-08-00970 and 14-08-96011).

G0.3-0013-18 STUDY OF MASS LOSS OF POLYMERIC COMPOSITES IN VACUUM UNDER SPACE RADIATIONS

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Polymeric materials find ever-widening application in space technique. This is tied with the simplicity of producing the polymeric-based composites with the predetermined set of properties. However, these materials in space become the sources of volatile products that increase density of spacecraft outer atmosphere that undermines on serviceability of the on-board equipment. Therefore, study of mass loss of spacecraft materials in service conditions is a vital task. Polymeric composites are often used as thermal control coatings (TCC), which are subjected to maximum radiation exposure in service. It is known that irradiation of a PC is accompanied by intense gas formation but evolution of volatile products (VP) through the material-vacuum surface is limited by diffusion. Well-developed surface together with little thickness of a TCC film facilitate migration of radiolysis products to free coating surface. In this case outgassing and destruction of material augment permeability of the film, accelerate migration processes and make them easier. This work is devoted to studying action of separate (electron, proton, and electromagnetic), paired, and the whole set of radiations on mass loss of a pattern material in vacuum. The primary focus was on studying and interpretation of synergistic effects appearing in the course of mass loss of the pattern materials EKOM-1 and EKOM-2 polymeric composites, the widely used spacecraft TCC. Irradiation was made by 20-40-keV electrons and protons and electromagnetic radiation in vacuum chamber of the UV-1/2 test facility. It was found that parameters characterizing the synergistic effects of mass loss of the material for fixed conditions of electron-proton and combined radiations are the functions of irradiation time. To interpret the experimental data, a physical-mathematical model of mass loss of polymeric materials in vacuum was proposed. The obtained data can be explained by diffusion fluxes associated with the gradient of concentration of radiolysis products and increase of gas permeability of a material under radiation.

G0.3-0014-18 ELECTROSTATIC DISCHARGES UNDER SEPARATE AND COMBINED RADIATION OF SPACECRAFT SOLAR ARRAY PROTECTIVE GLASSES BY ELECTRONS AND PROTONS

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It is known that irradiation of low-conductive dielectric by charged particles which track lengths do not excess the sample dimensions results in formation of areas with high density charge. The field induced by the accumulated charge can initiate the electrostatic discharge between the charge location area and surface of the dielectric. The study of electrostatic discharges in low conductive dielectrics under radiation is essential both from a scientific point of view and for the solution of applied problems. In particular, interaction of a spacecraft with ambient plasma causes accumulation of electric charges on its surface producing, as a consequence, electric potential between the spacecraft surface and the plasma. Initiation conditions and features of evolution of electrostatic discharges on surface of K-208 and CMG glass used as the protective covering of spacecraft solar arrays, under combined irradiation by electrons and protons in vacuum were studied in this work. Energies of electrons and protons were 20- 40 keV and 20 keV respectively. The particles beam current was varied within 1.5 -200 nA. Surfaces of irradiated samples were studied by AFM methods. It was shown that changes of sample morphology due to radiation are determined by radiation annealing of defects in the near-surface layer of the glass, mass transfer processes accompanying by forming various structures on its surface and electrostatic discharges, surface modification having depended on radiation type and intensity. It was ascertained that microprotrusions either presenting on glass surface due to the process of its fabrication or appeared at the early stage of irradiation promotes discharge development. Changes of glass surface morphology due to radiation, as was shown, are stipulated both radiation annealing and electrostatic discharges, surface modification having depended on radiation type and intensity. The observed differences in the development of discharges in the K-208 and CMG glass are attributed to the fact that the latter has a magnesium fluoride coating and exhibits a higher conductivity and a lower concentration of defects and dislocations that the former.

G0.3-0015-18 SIMULATION OF COSMIC RADIATION DOSE OF A SOLAR CELL AND A LI-ION BATTERY FOR A LOW EARTH ORBIT (LEO) SATELLITE WITH GEANT4 AND COMPARISON FOR TWO DIFFERENT ORBITS

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Space radiation environment consists of high energy particles, mostly electrons and protons and devices that operate in space are exposed to these cosmic rays during their operation. This radiation may cause damage to the solid structure of devices and result in operational failure. Therefore the amount of absorbed radiation for each component should be calculated carefully before the production and qualification. Components can be sensitive to the total ionizing dose as well as the single event effects and displacement damage. Solar panels which provide power are one of the most vital parts of a satellite and consist of solar cells which are semiconductor devices and are very sensitive to radiation. Even a short term power cut may result in a total failure of the satellite. Similarly, Li-Ion batteries have a vital importance for satellites because of the energy storage requirements. Radiation can cause a Li-Ion battery to lose storage capacity dramatically. As a result, the operational lifetime or performance of a satellite can be reduced.

In this study, the trapped proton and electrons fluxes and some solar ions fluences from the Space Environment Information System (SPENVIS) program for Sun-synchronous LEO orbits with two different altitudes have been compared. The solar cell and the Li-Ion battery of a specific LEO satellite were analyzed layer by layer for these two different altitudes. The data output from SPENVIS is used as input to a GEANT4 simulation which calculates the energy deposition in the layers of the solar cell and the Li-Ion battery. The results obtained from this simulation are considered in determining the amount of radiation hardness needed for the cells and the batteries and to improve their designs after future testing.

G0.3-0016-18 PACKING AND DEPLOYMENT OF LARGE-SIZE SHELL CONSTRUCTIONS FOR USE IN SPACE ORBIT

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The raising in Earth orbits of large-size working modules may be used for biological, technological, logistic and other purposes is driven by the exploitation of near-Earth space [1-3]. In the report a possibility of using modules such as large-sized shell structures is considered. It is assumed that the shell is delivered into orbit in the folded state in the spaceship container. Packaging of large-sized compound shell structures (corrugated, cylinder and truncated cone) and their deployment by internal pressure loading are considered. It is believed that the middle surfaces of the composite elements of the shells have a sweep, with which these surfaces coincide in a packed state. The constituent elements of the corrugation are rings, and the cylinder and cone have trapezoidal plates. The considered structural elements, in contrast to pneumatic products made from soft materials (fabric, film), take bending loads. When the structure is deploying (bringing into working shape by internal pressure), resistance to stretching strain and also bending strain, is taken into account. The composite elements are made of carbon fiber with orthotropic or transversely isotropic elastic properties and are stitched together by seams that do not perceive resistance to rotation around the tangent to the seam line. The minimum internal pressure required to deploy a large-size shell structure is determined. Geometrically nonlinear problems of the deformable solid mechanics are solved using the ANSYS engineering software. The dependence of the pressures unfolding the shell to the working shape, on the shell thickness, and the constituent elements number is considered. It is shown that the deployment pressure of large-sized casings is commensurate with the excess pressures of pneumatic structures made of soft materials. It is revealed that the stresses in the shells unfolding into the corrugation can reach critical values, while the stresses in cylinder and the truncated cone are insignificant. The formulation and solution of the problem of the thermodynamic state of the injected gas is given for quasi static shell loading by internal pressure. It is established that at the beginning of the deployment the gas is cooled depending on the composition at 50-80

° C, subsequently its temperature grows to the injection temperature. The results show the possibility of manufacturing large-size pneumatic structures for space exploitation. The study is supported by the grants RFFI 16-48-590844, 17-41-590649, and subsidy (grant) of Perm Krai (Agreement C-26/793 of December 21, 2017).

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G0.3-0017-18 INVESTIGATION OF SPACECRAFT CHARGING IN NEAR-EARTH ORBITS

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The spacecraft charging is an important factor which gives rise to anomalies in the operation of on-board electronic equipment and damages spacecraft dielectric materials. Two types of spacecraft charging can be considered separately: surface charging, which is caused by hot magnetosphere plasma with electron and proton energy of E 0.1-50 keV, and internal charging of dielectrics due to the influence of electrons of the Earth's radiation belts with energy of E 1- 10 MeV. In general, the main consequence of spacecraft charging are electrostatic discharges that create electromagnetic noise leading to malfunction of on-board electronics and damage spacecraft materials. To study processes of spacecraft charging, computer modeling as well as ground-based and in-flight experiments are carried out.

This paper discusses methods of mathematical modeling of spacecraft charging and laboratory experiments to study surface and internal charging, including investigations of electrostatic discharges, and presents the information related to in-flight observations of charging effects on Russian spacecraft in the low-Earth orbits (LEO) and the geostationary orbit (GEO). The Russian spacecraft charging model, COULOMB 2, which was developed in SINP MSU to study surface charging in LEO and GEO, is described, and some calculated electric potential distributions over spacecraft surfaces of GEO and LEO spacecraft under different space conditions are given. The main directions of further research in this field are outlined.

G0.3-0018-18 EFFECTS OF COMBINED IRRADIATION OF 500 KEV PROTONS AND ATOMIC OXYGEN ON POLYIMIDE FILMS

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Polyimide films are widely used on the external surface of spacecraft. The space ionizing radiation can alter the mechanical, optical and electrical properties of polyimide. For example, it is well known that 20-100 keV proton irradiation causes breaking of chemical bonds and destruction of the surface layer in polyimide, deterioration of its optical properties, etc. In lowEarth orbits serious danger for polymeric materials is atomic oxygen of the upper atmosphere of the Earth, which is the main component in the range of heights of 200-800 km. Due to the orbital spacecraft velocity, the collision energy of oxygen atoms with the surface (5 eV) enhances their reactivity and opens additional pathways of their reaction with near-surface layers of materials. Hyperthermal O atom flow causes erosion of the polyimide surface by breaking chemical bonds and forming of volatiles products (primarily, CO and CO2), which leads to mass losses and degradation of material properties.

Combined effect of protons and oxygen plasma is expected to enhance the destruction of polyimide surface layers. This paper describes experimental investigation of polyimide films sequential irradiation by protons and atomic oxygen. The samples were irradiated by 500 keV protons at fluences of 1014-1016 cm−2 produced with SINP cascade generator KG-500 and 5-20

eV neutral oxygen atoms at fluence of 1020 cm-2 generated by SINP magnetoplasmodynamics accelerator. The comparative analysis of polyimide optical transmission spectra, Raman and XPS spectra obtained at different stages of the sample irradiation, data on mass loss due to polyimide erosion by atomic oxygen are given. The report also presents the results of computer simulation of protons and oxygen atoms interaction with polyimide, and a comparison of the experimental and calculated data.

G0.3-0019-18 COMPUTER SIMULATION OF REACTIONS OF HYPERTHERMAL O ATOMS WITH POLYIMIDE

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Atomic oxygen (AO) of the upper Earth's atmosphere is one of the most important space factors that can cause degradation of materials on the external surface spacecraft in the low-Earth orbits. AO impact leading to erosion and mass losses of materials is well studied experimentally for most spacecraft materials, however, elementary physical and chemical processes occurring in polymers under AO attack are not completely understood. This paper presents some results of computer simulation of chemical reactions between hyperthermal O atoms and polyimide chains, carried out with ab initio density functional theory (DFT) and semi-empirical density functional based tight-binding (DFTB) methods on Lomonosov supercomputer of MSU. The study focuses on reactions with formation of volatile products like 2, ,. The computer simulation demonstrated that the probability of volatile species elimination depends on sites of O atom attacks. For reactions with CO2 and CO formation that give the main contribution to mass losses of polymers the highest probability is obtained for the cases when an incident O atom trajectory goes in the vicinity of an imide group. The characteristic time of direct reactions of hyperthermal O atoms with polyimide is 20-500 fs. The results of the mathematical simulation are in good agreement with the available experimental data and can be used to evaluate the polyimide durability to atomic oxygen effects of in near-Earth space.

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Fundamental Physics in Space (H)

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FUNDAMENTAL PHYSICS IN SPACE (H)

COMMISSION H HIGHLIGHT TALKS (H0.1)

H0.1-0001-18 TESTING THE EQUIVALENCE PRINCIPLE IN SPACE: THE MICROSCOPE MISSION

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The MICROSCOPE space mission tests the Weak Equivalence Principle (WEP), which states that the acceleration of a test object falling in an external gravitational field is independent of its mass and internal composition. The Equivalence Principle is at the basis of General Relativity, which has passed all experimental tests, including on-ground WEP tests whose record accuracy, reached in 2012 with torsion-balance experiments, is a few 10^{-13}. However, General Relativity does not allow the unification of the gravitation with the three other fundamental interactions.

Most alternative theories for the unification predict an apparent violation of the WEP. The accuracy of the on-ground tests of the WEP is limited by the numerous perturbations in the terrestrial environment. Being performed in space, the MICROSCOPE experiment overcomes these limitations and aims to test the WEP with an accuracy of 10^{-15} never reached before.

The MICROSCOPE drag-free microsatellite, developed by CNES, was launched in April 2016 and is currently quasi-circularly orbiting the Earth at a mean altitude of 710 km. It embarks a differential electrostatic accelerometer developed by ONERA and composed of two cylindrical test masses in electrostatic levitation made of different materials. Control loops with electrostatic actuation keep the two masses concentric, so that they both are submitted to the same gravitational field. The drag-free system compensates for external non-gravitational perturbations, thus allowing the satellite to follow the free-fall motion of the masses.

The electrostatic acceleration applied to the masses to maintain them relatively motionless are measured and will demonstrate a violation of the WEP if found unequal.

MICROSCOPE first results, based on only 1/15th of the scientific data collected during the mission, have already improved by one order of magnitude the accuracy of the previous test of the WEP. They are being completed and analyzed.

After a brief presentation of the MICROSCOPE mission and its payload, the presentation will focus on the data analysis method leading to this result as well as the determination of the systematic and stochastic error. The measurement is indeed impacted by systematic environmental and instrumental errors, which are calibrated in-orbit during dedicated sessions. Other perturbations must be considered during the data analysis: in the case of missing data, spectral leakage effects increase the noise of the measurement. Specific methods have thus been adapted and developed in order to extract the Equivalence Principle violation parameter with minimal numerical perturbations. The on-going process to further improve the accuracy and tend toward the mission objective will be presented: the systematic error should be reduced by a better knowledge of the instrument in order to correct the systematics, while the random error can be reduced by cumulating data.

H0.1-0002-18 DISCUSSION

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Discussion

H0.1-0003-18 LISA AND ITS PATHFINDER

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The LISA Pathfinder mission has demonstrated spurious acceleration performance over the complete measurement band more than a factor of two better than required for LISA, demonstrating that a low-frequency gravitational wave observatory in space is possible. ESA has selected LISA in June of 2017 as the L3 mission in its future science program. LISA is now entering Phase-A in preparation for a 2034 launch.

H0.1-0004-18 DISCUSSION

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Discussion

H0.1-0005-18 SPACE BORNE BOSE-EINSTEIN CONDENSATION FOR PRECISION INTERFEROMETRY

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QUANTUS-MAIUS Team

On January 23rd 2017 the first Bose-Einstein Condensate (BEC) in Space has been created onboard the sounding rocket mission MAIUS-1. The successful operation of the atom-chip based BEC source marks a major advancement in the effort of performing matter wave interferometry in weightless in space vehicles. Thanks to the high-flux source, experiments could be performed during the microgravity phase of the flight, which lasted six minutes. The experiments served to characterize the creation and features of the space BECs: the transition between a thermal ensemble and a BEC, the free evolution of BECs, their coherence and state preparation. In addition the creation of cold atomic clouds in highly dynamic environments was observed during the launch and ascend of the rocket. There will be two follow-up missions planned which will include dual-species atom interferometry using Rubidium-87 and Potassium-41. Thus, MAIUS-1 opens a new path towards space born inertial sensing employing atom interferometers with high accuracy and unprecedented sensitivity. In the recent past several missions have been proposed ranging from a test of the universality of free fall using a dual-species atom interferometer for earth observation. Due to their small initial size and low expansion rates BECs are the ideal source for such an interferometric measurement in space. This research has been funded by the German Space Agency DLR under grant number DLR 50WP1435.

H0.1-0006-18 DISCUSSION

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Discussion

H0.1-0007-18 ON THE INTERFACE OF QUANTUM AND GRAVITY

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Quantum mechanics and general relativity constitute two major pillars of modern physics. Although their predictions have been tested in numerous experiments we still have not been able to completely crasp their consequences nor put to use their subtleties to the fullest extent. Indeed, even today the measurement problem, the application of entanglement to technology and the unification of the two theories illustrate in a striking way this fact by representing active fields of research.

In the present lecture we focus on the last issue and discuss three questions located on the interface between quantum and gravity: (i) inertial and gravitational mass in quantum mechanics, (ii) proper time in atom interferometry, and (iii) quantum clocks. We argue that the answers to these questions will shine some light on why general relativity and quantum mechanics still resist their unification. Moreover, the recent experiments with cold atoms in space in the framework of the MAIUS-rocket mission provide an excellent testing ground for these ideas.

H0.1-0008-18 DISCUSSION

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Discussion

H0.1-0009-18 EARTH OBSERVATION BASED ON QUANTUM OPTICS AND RELATIVITY

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Novel developments in quantum physics can excellently be used for geodetic applications, where new technologies and concepts lead to enhanced capabilities for satellite geodesy and terrestrial gravity sensing. We will focus on two new concepts: one applies atom interferometry for (satellite) gravimetry, the other uses clock networks for determining potential differences at the Earth surface. In the first case, gravity anomalies are obtained by observing free-falling atoms (quantum gravimetry), such technique can also be applied for future gradiometric measurements in space. In the second case according to Einstein's theory of general relativity, frequency comparisons of highly precise optical clocks connected by fibres give access to differences of the gravity potential (relativistic geodesy). In addition, laser interferometry between test masses in space with nanometer accuracy belongs to these novel concepts. For the latter, technology developed for gravitational wave detection and successfully tested in the LISA/pathfinder mission is being prepared for geodetic measurements. Those concepts are recently elaborated in close cooperation between physicists and geodesists at the University of Hannover under the umbrella of the Collaborative Research Center SFB 1128 "Relativistic geodesy and gravimetry with quantum sensors (geo-Q)". We will illustrate where geodesy will potentially benefit from these novel developments and show future perspectives. Examples are the direct determination of physical height differences over large distances and the unification of height systems. We will also underline the strengths of the new methods for Earth observation, where local and global mass variations can be observed with unforeseen accuracy and resolution, for a multitude of geoscience applications.

H0.1-0010-18 ESA'S STUDIES OF NEXT GENERATION GRAVITY MISSION CONCEPTS

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The presentation addresses the preparatory studies of future ESA mission concepts devoted to improve our understanding of the Earth's mass transport phenomena causing temporal variations in the gravity field, at different temporal and spatial scales, due to ice mass changes of ice sheets and glaciers, continental water cycles, ocean masses dynamics and solid-earth deformations.

The ESA initiatives started in 2003 with a study on observation techniques for solid Earth missions and continued through several studies focussing on the satellite system, technology development for propulsion and distance metrology, preferred mission concepts, the attitude and orbit control system, as well as the optimization of the satellite constellation. These activities received precious inputs from the GOCE, GRACE and GRACE-FO missions.

The latest results concerning the preferred satellite architectures and constellations, payload design and estimated science performance will be presented as well as remaining open issues for future concepts.

H0.1-0011-18 THE GERMAN MICROGRAVITY PROGRAM IN PHYSICAL SCIENCES

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As German Space Agency, the DLR Space Administration manages the German Space Program. This program integrates the German participation in the ESA programs, the activities in the National Program as well as the RD activities of the DLR research institutes. One core element of the German space activities is called Research under Space Conditions. This program covers life and physical sciences experiments utilizing space conditions such as weightlessness and space radiation and is based on the provision of microgravity platforms, the development of flight hardware, and the preparation, execution, and analysis of experiments in microgravity.

The German Physical Sciences Program deals with gravity-dependent effects on physical and chemical processes and covers the research disciplines material sciences, fundamental physics, soft matter, and the physics of fluids and combustion processes. The main program goal is to gain scientific knowledge by addressing fundamental questions in physics, to foster new technological developments and to reveal new application potentials by both fundamental as well as application-oriented research.

In this talk, major German research topics and on-going facility developments for the ISS and other microgravity platforms such as sounding rockets, parabolic flights and the Bremen drop tower will be presented, and the important role of international co-operations will be outlined. Results of some microgravity experiments and the status of the program implementation will be discussed.

H0.1-0012-18 SHADOW SIZES AROUND BLACK HOLES AS POSSIBLE SIGNATURES OF HORNDESKI GRAVITY

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The classical general relativity (GR) is remarkably confirmed in different astronomical tests. Recently, gravitational waves have been detected from binary black holes and binary neutron star systems. Moreover, constraints on alternative theories of gravity have been obtained, so that graviton mass bounds have been found such as mg < 7.7 $10^{-}2^{3}$ eV. It means that theories of massive gravity, if they are realized in nature, have to be very close to GR. In spite of a great progress of GR now there exist a number of alternative theories of gravity, such as f (R) theories, theories of massive gravity, scalar-tensor theories etc. Scalar-tensor theories proposed by Hordeski are among popular alternatives for classical general relativity (GR). There are no-hair theorems in such a theory, however, there exist hairy black hole solutions under some assumptions. for instantce, Babichev et al. (2017) constructed a set of hairy static black hole solutions (for quartic Hordeski Lagrangian of scalar-tensor theory of gravity). We show that analytical expressions for shadow size obtained for Reissner – Nordström metric (with electric and tidal charges) may be used to compare theoretical predictions and observations for asymptotically flat black holes with a scalar hair which mimics an electric charge. We present analytical expressions for shadow size for static black hole solutions with de-Sitter and antide-Sitter asymptotics. The relations could be used for comparison of the theoretical models with observational data obtained with the Event Horizon Telescope for the black hole at the Galactic Center or in galaxy M87.

H0.1-0013-18 AN OVERVIEW OF THE COLD ATOM LAB MISSION

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Microgravity offers a wealth of advantages for studies of ultra-cold atomic gases and their applications. These include the ability to achieve exceptionally low temperatures via expansion into very weak traps, which don't need to be supported against gravity and the ability to achieve very long interaction times with samples that have been released from traps. The Cold Atom Laboratory (CAL) will be a flexible, multi-user ultra-cold atom facility that will enable the precise study of quantum gases at effective temperatures well below the coldest achievable on Earth. CAL will launch to the International Space Station in May 2018, giving scientists a unique window into the quantum world.

CAL is supported by SLPS and ISS-PO. Jet Propulsion Laboratory, California Institute of Technology

H0.1-0014-18 TOWARDS SPACE-BASED TESTS OF MACROSCOPIC QUANTUM PHYSICS

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We will present recent developments in the context of the mission proposal MAQRO and a potential future space platform for testing quantum physics with massive objects. In 2017, the European Space Agency (ESA) selected tests of the quantum to classical transition and quantum decoherence as a topic of interest in the context of its call for New Science Ideas. During the first half of 2018, ESA will perform a study of this topic at its Concurrent Design Facility (CDF). In this presentation, we will present the results from this CDF study and provide an overview of on-going and future efforts towards realizing MAQRO or similar missions for tests of macrosopic quantum physics in space, to develop enabling technology, and to perform proof-of-principle experiments towards that goal.

H0.1-0015-18 NANOHERTZ-FREQUENCY GRAVITATIONAL WAVE ASTROPHYSICS WITH PULSAR TIMING ARRAYS

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The gravitational wave (GW) landscape is expansive and ripe for discovery, offering unparalleled insights into a plethora of astrophysical systems. While the present and future successes of LIGO-Virgo and LISA rely on precision control of mechanical systems, Pulsar Timing Arrays (PTAs) are GW detectors that are themselves forged out of extreme astrophysical objects. PTAs exploit the exquisite rotational stability of millisecond pulsars to establish a Galactic network of clocks, capable of registering the correlated influence of passing extragalactic GWs. At nanohertz frequencies (where PTAs are sensitive) the most promising target is the ensemble signal of many inspiraling supermassive black-hole (SMBH) binary systems throughout the Universe. A detection of this signal (or even a stringent constraint) can teach us much about the merger history of massive galaxies, the dynamical environments of galactic cores, and the scaling relationships between massive black holes and their host galaxies. I will review the latest methodological and technological advances toward GW detection in the nanohertz band, whose rogues gallery of signals includes stochastic backgrounds of astrophysical (and potentially cosmological) origin, bright resolvable SMBH binaries, and memory bursts. I will also discuss the unique science accessible to PTAs beyond GWs, including new insights into Solar System dynamics as a by-product of PTA searches, and detailed characterization of the ionized interstellar medium.

H0.1-0016-18 GROUND-BASED GRAVITATIONAL WAVE DETECTORS AND THE SYNERGY WITH LISA

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Ground-based gravitational-wave observatories have just recently succeeded in detecting gravitationalwave sources from astrophysical events. In particular, the realization of multi-messenger astronomy including gravitational waves via the GW170817 neutron-star merger, observed with many electromagnetic observatories, has demonstrated the potential for this field. Groundbased instruments will be evolving in the coming years, and the instruments operating simultaneously with LISA will have capabilities to see further, and with higher signal-to-noise, many gravitational-wave sources. The is the high likelihood of multi-band detections - binaries seen first in LISA and then years later in ground-based detectors and EM observatories allowing unprecedented detailed characterization of these systems. A brief introduction to present instruments and results, followed by our roadmap for the future of the ground-based gravitational-wave observatories, will be given.

H0.2-0002-18 DETECTION OF CHAMELEON DARK ENERGY IN SPACE

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Dark energy constitutes 70% of the universe, which explains the observed accelerated expansion of the universe. While little is known about the nature of dark energy, it is conjectured that it is a new scalar field that interacts normal matter at the cosmological scale. Due to the lack of any evidence of a violation from general relativity in the solar system so far, screening mechanisms are implemented in all dark energy scalar field models. Possible scalar fields are described in the forms of chameleon, symmetron, and galileon models. Recently, cold atom experiments in laboratory have contributed significantly on the constraints of chameleon and symmetron parameters. These experiments are currently limited by the knowledge of the Newtonian gravity of the test masses, and eventually by the uncertainty of the gravitational constant G.

In this talk, we will describe an experimental concept of using atom interferometry in microgravity to improve the sensitivity to chameleon and symmetron by orders of magnitude than the state-of-the-art, without relying on future precision measurements of G. In this scheme, spatially modulated chameleon forces will be induced at a specific frequency with a periodic geometry of the local mass distribution. Gravitational forces of the mass structure will be minimized at the spatial frequency using trim masses. Multiloop atom interferometers will measure the periodic acceleration while largely reject forces at other spatial frequencies. We will present the dark energy force calculation and design analysis, and will show that regions of interest of the chameleon parameters will be tested at high confidence levels, and all systematics will be below the anticipated signal size.

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

H0.2-0003-18 ELECTROMAGNETIC CASCADE MASQUERADE: ASTROPHYSICAL BACKGROUNDS FOR GAMMA-ALP OSCILLATION SEARCHES USING EXTREME TEV BLAZAR SPECTRA

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Extreme TeV blazars are active galactic nuclei with spectral energy distribution peaked at an energy of 1 TeV or above. These sources, while still rare in currently available surveys of space and ground-based gamma-ray telescopes, nevertheless play an extraordinary important role in extragalactic gamma-ray propagation studies. Some works report the existence of the "pair-production anomaly", an apparent excess of observed gamma-rays in the highest energy bins, where the optical depth of the γγ pair production process exceeds unity. This anomaly is frequently interpreted as an evidence for gamma-axion-like particle (ALP) oscillations. We inquire whether such an anomaly may be explained by any conventional astrophysical process. We show that the development of electromagnetic (EM) cascades in the intergalactic volume may potentially provide a strong source of background for gamma-ALP searches in extreme TeV blazar spectra. We provide detailed fits for a number of extreme TeV blazar spectra that were measured by atmospheric Cherenkov telescopes in the past, and make detailed predictions that will allow to verify/falsify the proposed model (see Sect. 4 of [AA, 603, A59 (2017)] for more details).

H0.2-0004-18 EXCAVATING BLACK HOLE CONTINUUM SPECTRUM: POSSIBLE SIGNATURES OF SCALAR HAIRS AND OF HIGHER DIMENSIONS

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Continuum spectrum from black hole accretion disc holds enormous information regarding the strong gravity regime around the black hole and hence about the nature of gravitational interaction in extreme situations. Since in such strong gravity regime the dynamics of gravity should be modified from the Einstein-Hilbert one, its effect should be imprinted on the continuum spectrum originating from the black hole accretion. To explore the effects of these alternative theories on the black hole continuum spectrum in an explicit manner, we have discussed three alternative gravitational models having their origin in three distinct paradigms-(a) higher dimensions, (b) higher curvature gravity, and (c) generalized Horndeski theories. All of them can have signatures sculptured on the black hole continuum spectrum, distinct from the standard general relativistic scenario. Interestingly all these models exhibit black hole solutions with tidal charge parameter which in these alternative gravity scenarios can become negative, in sharp contrast with the Reissner-Nordström black hole. Using the observational data of optical luminosity for eighty Palomar Green quasars we have illustrated that the difference between the theoretical estimates and the observational results gets minimized for negative values of the tidal charge parameter. As a quantitative estimate of this result we concentrate on several error estimators, including reduced $\chi2$, Nash-Sutcliffe efficiency, index of agreement etc. Remarkably, all of them indicates a negative value of the tidal charge parameter, signaling the possibility of higher dimensions as well as scalar charge at play in those high gravity regimes.

H0.2-0005-18 DETECTING THE ANGULAR MOMENTUM OF THE GALACTIC DARK HALO

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It is well known that general relativity predicts the presence of a gravito-magnetic component of the gravitational interaction induced by a rotating mass. Such contribution has been verified for the angular momentum of the earth. Here we present a proposal to measure the gravitomagnetism of the sun and possibly of the dark galactic halo currently assumed to incorporate our galaxy (as well as the others). The experimental approach is based on the fully relativistic version of the Sagnac effect. When an electromagnetic signal is led to travel along a spacely closed path and the material device with which the beam interacts rotates with respect to the "fixed stars", the time of flight for a complete turn depends on the direction of rotation. The same happens when the loop is immersed in a gravito-magnetic field, even if it is not rotating: this is the typical Lense-Thirring drag. In this case the asymmetry in the time of flight is proportional to the projection of the angular momentum of the main body onto an axis perpendicular to the plane of the loop. This behavior is the basis of measurements using ringlasers. Going to space and having the sun and its angular momentum as a target, the implementation of a "Sagnac" approach is still possible but the size of the closed circuit must be at the scale of the orbit of the earth. Furthermore the geometry of the loop needs be reasonably stable. The solution we propose is to exploit the Lagrange points of the sun-earth system. The configuration of the Lagrange points is indeed stable (if not strictly rigid) and moves around together with the earth. Considering as an example the triangle L2-L_4-L_5 (according to the standard enumeration of the points) the expected time of flight asymmetry due to the angular momentum of the sun is approximately 4x10−13 s. Other combinations of the L-points are of course possible, but the order of magnitude of the effect is more or less the same. In this case the technique cannot be the same as for ringlasers, rather a local measurement of the proper time interval between the arrivals of "right" and "left" signals is required. The same approach lends also an interesting opportunity to verify the presence or absence of an effect originating from the dark halo of our galaxy. In fact if the halo is there and it interacts gravitationally with the visible matter of the Milky Way, it has also to rotate with the same peripheral speed as the stars. If, then, the halo is much more massive than the baryonic matter its angular momentum too has to be large and, if general relativity is true, it must produce a gravito-magnetic field. To work out numbers requires the knowledge or reasonable guesses about the mass distribution of the dark matter, but the very nature of that matter is unimportant and the scale of the halo and its total mass tell us that the effect could be non-negligible. An advantage of the Sagnac-like approach, worth mentioning, is that it neutralizes the dominant effect of the gravito-electric component of the field, since the latter has no chiral symmetry.

H0.2-0006-18 DARK MATTER SEARCHES WITH HAWC

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The High Altitude Water Cherenkov (HAWC) Observatory is an extensive air shower array sensitive to gamma rays between 500 GeV - 100 TeV. TeV photons provide unique tests of fundamental physics phenomena, such as dark matter annihilation and decay. HAWC is capable of performing indirect dark matter searches in a mass range that is inaccessible to most other experiments. For such searches, one promising class of objects are dwarf spheroidal galaxies, which are expected to have few astrophysical gamma rays but large dark matter content. In addition, we consider the Milky Way halo, the M31 galaxy and the Virgo Cluster, because of the expected flux boost due to the substructure of the main dark matter halo. We present limits on the dark matter annihilation cross-section and decay lifetime from 15 dwarf spheroidal galaxies within the HAWC field of view, the Milky Way halo, the M31 galaxy and the Virgo Cluster.

H0.2-0008-18 SECOND-ORDER COSMOLOGICAL PERTURBATIONS ENGENDERED BY POINT-LIKE MASSES

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In the ΛCDM framework, presenting nonrelativistic matter inhomogeneities as discrete massive particles, we develop the second-order cosmological perturbation theory. Our approach relies on the weak gravitational field limit. The derived equations for the second-order scalar, vector and tensor metric corrections are suitable at arbitrary distances including regions with nonlinear contrasts of the matter density. We thoroughly verify fulfilment of all Einstein equations as well as self-consistency of order assignments. In addition, we achieve logical positive results in the Minkowski background limit. Feasible investigations of the cosmological backreaction manifestations by means of relativistic simulations are also outlined.

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H0.2-0010-18 DARK MATTER PRODUCTION MECHANISMS AND THE DARK COUPLING

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Understanding the nature of Dark Matter (DM) and Dark Energy (DE) are the most important problems in modern cosmology, with profound implications for astronomy, high-energy physics and general relativity, that demands ambitious programs at both theoretical and observational level. In particular, the Euclid mission, an ESA scientific mission selected to be launched at the end of 2020, is conceived to probe the physical origin of the DE and DM by using two independent probes, the redshift clustering and the weak lensing tomography of about a billion of galaxies. In this paper we investigate the possibility of the DE coupling with different matter components introducing a new force, the fifth force, mediated by the DE.

We consider the possibility that DE can interact with a fraction of DM particles in the form of sterile neutrinos produced by two complementary mechanisms: neutrino oscillations in a leptonasymmetric Universe and scalar decays interacting with Standard Model particles. The presence of the fifth force changes the stress-energy tensor for all components in the expanding Universe (general covariance requires that the sum of stress-energy tensor components is conserved) modifying the background and perturbations evolution. We will evolve the perturbed Einstein's equations in the expanding Universe and compute the matter and radiation power spectra. Then we will employ a Monte Carlo technique to place constraints on DM particle masses and couplings, the DE properties and the main cosmological parameters, by using the mock Euclid datasets for both spectroscopic and weak lensing surveys, complemented with Planck and other existing cosmological astrophysical observations.

H0.2-0011-18 COSMOLOGICAL CONSTANT CONSTRAINTS FROM OBSERVATION-DERIVED ENERGY CONDITION BOUNDS AND THEIR APPLICATION TO BIMETRIC MASSIVE GRAVITY

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Among the various possibilities to probe the theory behind the recent accelerated expansion of the universe, the energy conditions (ECs) are of particular interest, since it is possible to confront and constrain the many models, including different theories of gravity, with observational data. In this context, we use the ECs to probe any alternative theory whose extra term acts as a cosmological constant. For this purpose, we apply a model-independent approach to reconstruct the recent expansion of the universe. Using Type Ia supernova, baryon acoustic oscillations and cosmic-chronometer data, we perform a Markov Chain Monte Carlo analysis to put constraints on the effective cosmological constant Ω^0. By imposing that the cosmological constant is the only component that possibly violates the ECs, we derive lower and upper bounds for its value. For instance, we obtain that 0.59 $< \Omega^0$

< 0.91 and $0.40 < \Omega^0$

< 0.93

within, respectively, 1σ and 3σ confidence levels. In addition, about 30% of the posterior distribution is incompatible with a cosmological constant, showing that this method can potentially rule it out as a mechanism for the accelerated expansion. We also study the consequence of these constraints for two particular formulations of the bimetric massive gravity. Namely, we consider the Visser's theory and the Hassan and Roses's massive gravity by choosing a background metric such that both theories mimic General Relativity with a cosmological constant.

Using the Ω^0 observational bounds along with the upper bounds on the graviton mass we obtain constraints on the parameter spaces of both theories.

H0.2-0012-18 CONSTRAINING A COSMOLOGICAL CONSTANT-TYPE PARAMETER WITH PULSAR TIMING IN THE GALACTIC CENTER: PERSPECTIVES

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Independent tests aiming to constrain the value of the cosmological constant Λ are usually difficult because of its extreme smallness (Λ 1 10^{-5}2 m−2). Bounds on it from Solar System orbital motions determined with spacecraft tracking are currently at the 10^{-43} 10^{-44} m−2

level, but they may turn out to be somewhat optimistic since Λ has not yet been explicitly modeled in the planetary data reductions. Accurate $\sigma\tau p$ 1 10 s timing of expected pulsars orbiting the Black Hole at the Galactic Center, preferably along highly eccentric and wide orbits, might, at least in principle, improve the planetary constraints by several orders of magnitude. By assuming for such a hypothetical pulsar the orbit of, say, the very far star S85, characterized by an eccentricity as large as e = 0.78 and an orbital period as long as Pb = 3580 2550 yr, the cosmological constant would induce an instantaneous timing orbital shift $\Delta\delta\tau\ {}^{\Lambda}E$ as large as just ~ 1 − 10 s for some given values of its eccentric anomaly *E* at different epochs. By looking at the average time shift per orbit $\Delta\delta\tau$ of closer pulsars, a S2-like orbital configuration with e = 0.8839, = 16 yr would allow to obtain an upper bound as little as $|\Lambda|$ 9 × 10^{-47} m−2. Our results can be easily extended to modified models of gravity using Λ−type parameters.

H0.2-0013-18 DARK ENERGY BEYOND Z GREATER THAN 1 WITH SUPERNOVAE

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We will review the status of dark energy determinationa at z > 1 with the ongoing very high redshift supernova projects. We will present results obtained and the prospects of using new methods involving supernovae to track the behavior of dark energy at z 20. The role of the new generation of telescopes and new methods will be outlined. We will discuss *Lambda* versus modified gravity as dark energy in view of the evidence so far available.

H0.2-0014-18 EXPECTATIONS FOR GRAVITON MASS CONSTRAINT IMPROVEMENTS WITH FUTURE OBSERVATIONS OF APOCENTER SHIFTS FOR BRIGHT STARS AT THE GALACTIC CENTER

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We analyze a potential to reduce upper bounds for graviton mass with future observational data on trajectories of bright stars near the Galactic Center. Since gravitational potentials are different for these Yukawa gravity and GR, expressions for relativistic advance for these theories potential are different functions on eccentricity and semimajor axis, it gives an opportunity to improve current estimates of graviton mass with future observational facilities. In our considerations of an improvement potential for a graviton mass estimate we adopt a conservative strategy and assume trajectories of bright stars and their apocenter advance will be described with general relativity expressions and it gives opportunities to improve graviton mass constraints. We express expectations to improve current constraints for graviton mass, assuming the GR predictions about apocenter shifts will be confirmed with future observations. We concluded that if future observations of bright star orbits during around fifty years will confirm GR predictions about apocenter shifts of bright star orbits it give an opportunity to constrain a graviton mass at a level around 5 10^{-2^3} eV or slightly better than current estimates obtained with LIGO observations.

H0.2-0015-18 PACZY'NSKI-WITTA POTENTIAL FORM OF SCALARIZED NEUTRON STAR

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We present a detailed study of the circular geodesic motion of neutral test particles on the equatorial plane of a spherically symmetric scalarized neutron star (NS). We also examined the stability criteria for massive and massless particles for the said NS by computing the effective potential. We compute the radii of innermost stable circular orbit (ISCO), marginally bound circular orbit (MBCO) and circular photon orbit (CPO). We also derive the Paczyński-Witta potential which is so called the pseudo-Newtonian potential which is very crucial to analyze the accretion disk properties. By analyzing the null circular geodesics we compute the Lyapunov exponent for the scalarized NS. Moreover, we show that in the eikonal limit, the real and imaginary parts of the quasi normal modes (QNM) of the scalarized NS could be determined in terms of the frequency of the NS and instability time scale of the unstable circular photon geodesics.

H0.2-0016-18 THE HIGH RELIABLE CONTROL LOGIC FOR PLASTIC SCINTILLATOR ARRAY DETECTOR OF DARK MATTER PARTICLE EXPLORER

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As one of the payloads of the Dark Matter Particle Explorer (DAMPE) satellite, the new type of plastic scintillator array detector developed by Institute of Modern Physics, Chinese Academy of Sciences (CAS) has two main tasks: first one is to distinguish high energy photons and electrons in near-earth space, second one is to measures the charge of high energy particles with the charge number of 1 26. All these functions are implemented by four front end readout circuit boards, each board contains one FPGA which is configured a set of high reliable control logic developed by us. The control logic is not only used to control multiple ASIC, ADC, DAC chips on front end readout circuit boards to achieve the operations of signal sampling, processing, data caching, and data transmission with upper payload manager which is inspired by valid triggers from trigger generator system, but also to configure, self-calibrate and monitor the whole detector system when received commands from earth. In order to acquire mass reliable particle information with detector in complex electromagnetic radiation environment for a long time, many effective error checking and correcting methods such as odd parity check, accumulate check, CRC check, double backup for the key modules are applied in the control logic. Especially, we design a new TMR error correct solution for RAM to recover some error key parameters from single event upset. When reading key parameters from three backed up RAMs to every raw data processing, the control logic compares three same address bytes at the same time, if it checks out that the value in one byte is different from other two bytes, control logic will update the byte with other two byte's value and then rewrite them to three RAMs using the same address. The satellite was launched at the end of 2015, it has been discriminated over 2.8 billion high-energy particles and completed the energy spectrum of particles with the atomic number of 1 26 in space up to now. It still works well.

H0.2-0017-18 PHENOMENA OF TRANSFER AND THEIR ROLE IN THE UNIVERSE

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Dark matter-IZMIRAN

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Neutrinos are postulated as particles of space, whereas quarks are postulated as particles of action. The mechanism of transfer of isospin vectors and time in quark-neutrino interactions is obtained. Overcoming of the separating barrier at the expense of combined symmetry leads to the occurrence of linear spaces and masses of particles, volume and its surface. The role of surface consists in the synchronization of quark-neutrino processes and energy release in the volume, which leads to the Big bang. The channel in which the intermediate complex Zw is dark matter, is proposed for the synthesis of hydrogen. The intrinsic chaos in the complex, responsible for its undetectability, is caused by the absence of the Coulomb field. The mechanisms of origination of the gravitational and Coulomb fields are presented. The asymmetry of matter and antimatter in the universe, as well as its extension, is explained by different directivities of the vectors of isospin and time in matter and antimatter.

H0.2-0020-18 DARK MATTER AND DARK ENERGY AS REMNANTS OF FORMATION OF LARGE SCALE-STRUCTURE IN COSMOLOGICAL MODELS

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The accelerated expansion of our universe needs consistent theoretical models to explain the origin of this acceleration. The cosmological equations describing the formation of large scale structures in a homogeneous and isotropic universe are systems of ordinary differential equations. The formations of large scale structures depend of the cosmological model and the frame work of the theory in which the model has been formed. It is assumed, in this work, that the remnants after the formation of large scale structures (visible universe) represent the dark matter and dark energy. Different cosmological models have been used as Saez and de Juan model, The self-consistent model and the standard model. It is found that the description of dark matter and dark energies as remnants of visible matter depends on a parameter which depends on the model itself.

H0.2-0021-18 TIMELIKE GEODESICS AND THEIR FLOWS AROUND A CHARGED BLACK HOLE SURROUNDED BY QUINTESSENCE

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Quintessence is one among the several candidates to represent the presence of mysterious dark energy in our universe. It would therefore be quite interesting to study the geodesics and their deformations/flows in the background of a Black Hole spacetime surrounded by quintessence to see the effect of dark energy, if any, on the universe locally. We investigate the motion of timelike geodesics in the spacetime of a charged Black Hole surrounded by quintessence. The nature of effective potential along with the structure of the possible orbits for test particles in view of the different values of equation of state parameter for quintessence is discussed. The evolution of timelike geodesic congruences in the background of such black hole spacetime is investigated by solving the Raychaudhuri equations numerically for three kinematical quantities namely the expansion scalar, shear and rotation (or ESR variables) along the geodesic flows. Both the weak and the strong energy conditions for the focusing of timelike geodesic congruences are also analysed. The effect of all the concerned parameters on the evolution of the expansion scalar of geodesic congruences is discussed in the presence and absence of an initial shear and rotation. In general, it is observed that there always exists a critical value of the initial expansion below which we have focusing with smaller values of the normalisation constant and equation of state parameter.

H0.2-0022-18 DARK ENERGY'S ROLE IN GRAVITY

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Gravity had been expressed mathematically by Newton and subsequently modified by Einstein where Newton's Equation represents a special case within General Relativity. So far General Relativity has successfully withstood every experimental test to date but yet this theory of gravity cannot be reconciled with the other known forces of nature.

When Newton first tackled gravity, he left us to solve the question of how two objects seemingly separated by nothing can develop forces on each other. While Einstein answered this question by showing us that objects exist in spacetime, in doing so he left us with two even more puzzling questions:

1) What is the mechanism by which mass bends spacetime? 2) If spacetime has the property of bending, then what is spacetime composed of such that it can bend?

This presentation proposes a solution to these questions by revealing the role dark energy plays in gravity and spacetime.

H0.2-0023-18 ABOUT STABLE, PLAIN, NON-COMPACT MATTER STRUCTURES IN SPACE, AND POSSIBLE REMNANTS IN GALAXIES

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A solution of tenuous matter and magnetic field with its gravitational and magnetic stresses in equilibrium for a simple fully toroidal solution is discussed. (A specific constitutive nature of a steady state of magneto - matter is assumed 1).) This solution, if correct, would contain the fundamentals of nebula structures commonly observed to undergo negligible change in time. See the local molecular cloud currently explored in-situ by VOYAGER 1 with an extension of several kilo-parsecs. This nebula is the first one explored in-situ. From current observations2), it appears to possess the strong presence of an ordered magnetic field, with a mean value <|B|>

= 0.42 nT and a matter density of about 1 - 2 neutrals per cm3 as well as solely one tenth of that in its ionized state. We point out that it is most likely that this state of matter and magnetic field, if located further away, could hide from our observational capabilities, thereby constituting a non-negligible amount of matter and field literally too dark for our abilities to record, i.e. an amount of mass common in nature but dark to our observational skills. 1) Berdichevsky, D., B., On fields and mass constraints for the uniform propagation of magnetic-flux-ropes undergoing isotropic expansion, Solar Phys., 284, 245-259, DOI; 10.1007/s11207-012-0176-5, 2013; Berdichevsky, D., B., and K. Schefers, On the thermodynamics and other constitutive properties of a class of strongly magnetized matter observed in astrophysics, Astrophysical J., 805, 70, 2015. 2)Private communication, Professor D. Gurnnett, (a mean value at the Sun orbit (R 8.5 kpc, and at that orbit for a width of 1 kpc) the presence of 0.98 hadrons per cm3, of which about 80

H0.2-0024-18 UNIFIED COSMOLOGICAL EVOLUTION: WILL THE UNIVERSE DECELERATE IN FUTURE?

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We propose a new scalar factor for the description of unified cosmological evolution (early inflation, deceleration and present acceleration) for a spatially flat homogeneous and isotropic model in Einstein general relativity. The scale factor leads to the variable equation of state of effective matter that serves all matter (quintessence, relativistic and non-relativistic baryonic matter, stiff matter and cosmological constant) exactly in same manner as it is required for governing the whole cosmological evolution. We depict the statefinder parameters to know the geometrical behaviour of the model. The proposed scalar factor predicts a decelerated epoch of the universe in near future.

H0.3-0001-18 A TEST OF THE RELATIVISTIC GRAVITATIONAL REDHSHIFT WITH GALILEO SATELLITES IN ECCENTRIC ORBITS

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The European GNSS satellites Galileo 5 and 6 launched in August 2014 have not reached their targeted circular orbit. Instead they have been accidentally injected into an eccentric orbit, due to a failure of the Fregat upper stage. After a series of correction maneuvers their orbits now possess an eccentricity of 0.16 corresponding to a periodic variation of altitude of about 8000 km. While this is of some disadvantage for navigation purposes it offers a unique possibility to perform a precise test of the gravitational redshift as predicted by Einstein's theory of General Relativity.

Thus, with support from the European and German space agencies ESA and DLR we have conducted an analysis of the clock and orbit data from these two satellites. Both satellites are equipped with passive hydrogen maser clocks and Rubidium atomic frequency standards. The modulation that these clocks' frequencies undergo due to the gravitational redshift is approximately $\Delta\nu = 5 \times 10^{-11}$. Here we show that with the clocks onboard of these satellites a test of this general relativistic effect competitive to the most accurate such test, as obtained by the Gravity Probe A (GPA) experiment in 1976, can be achieved. We present an analysis of the available data so far covering approximately 3 years and discuss the main systematic effects we have identified. We finally give a combined statistical and systematic uncertainty and compare our result to that of GPA.

H0.3-0002-18 BOOST: A TEST OF SPECIAL RELATIVITY

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BOOST is a mission that aims at testing the foundations of Special Relativity. The centre piece of BOOST are two frequency references mounted on a satellite. It is dedicated to test the validity of Lorentz invariance by comparing a length reference (i.e. a highly stable optical resonator) with a molecular frequency reference. Similar experiments have been performed on Earth. The current best Earth-bound test has been performed by Tobar et al. [1] in 2010, being able to determine the Kennedy-Thorndike coefficient with an accuracy of 4 10^{-8}. By operating a state-of-the-art Res experimental setup in space for aduration of two years that accuracy could theoretically be improved to 1 10^{-10}. With the restrictions induced by the choice of orbit and the achievable stability of the in-build clocks an improvement of the accuracy in the order of two orders of magnitude is targeted. In addition, BOOST could be employed to observe Lorentz violations These violations are described by the standard model extension (SME) by introducing new terms to the according Lagrangians [2]. The accuracy of some of the associated standard model extension coefficients could be improved by a two orders of magnitude in the fermion sector by executing BOOST.

In addition to the expected scientific outcome, BOOST offers substantial technological progress with impact on other space-based missions, such as LISA, NGGM, STE-QUEST, and future GNSS namely:

Operating optical clocks with unprecedented frequency stability in orbit

High performance thermal stabilization of the optical resonator

Space-qualification for state of the art diode laser technologies

Efficient, space qualified electronics

BOOST is a phase 0 study funded by DLR that is planned to be constructed in a combined effort by participants from the University of Bremen, DLR, the University of Hannover, the Humboldt University Berlin, and Airbus Defence and Space.

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H0.3-0003-18 PROBING THE GRAVITATIONAL REDSHIFT WITH RADIOASTRON

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A unique test of a cornerstone of general relativity, the gravitational redshift effect, was conducted with the space radio telescope RadioAstron, which has been in a highly eccentric orbit around the Earth since 2011. We probed the flow of time on board, which varies while RadioAstron passes through the varying gravitational potential of the Earth, by recording the spacecraft's downlink signal, which is synchronized to its ultra-stable on-board H-maser, at the ground radio telescopes. The experiment requires us to extract the tiny gravitational redshift signal from the mixture of a number of much larger effects, including those of the nonrelativistic Doppler frequency shift, signal propagation through the Earth's troposphere and ionosphere, higher-order kinematic effects of special relativity, Earth tides, and various instrumental effects. A total of 17 successful experiments were performed while the on-board H-maser was operational. Preliminary data analysis of the data from two experiments gives us a fractional accuracy of the gravitational redshift test of at least 2 10^{-4}, which is comparable to that obtained by Gravity Probe A. We present arguments in favour of the experiment uncertainty currently being dominated by that of the ionospheric frequency shift and discuss prospects for improving the achieved accuracy further.

H0.3-0004-18 TEST MASS CHARGE CONTROL FOR FUNDAMENTAL PHYSICS MISSIONS: PAST, PRESENT AND FUTURE

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Fundamental physics experiments in space often rely on free falling test masses as the reference for gravitational measurements. Electrostatic charge control is a crucial factor in maximizing the sensitivity of these experiments. At the University of Florida we are developing a testmass charge control system as part of a NASA contribution to the LISA gravitational wave observatory. We present the lessons learned from the successful LISA Pathfinder technology demonstration mission, the developments that will improve the robustness of the system for LISA taking advantage of new, semiconductor UV LED light sources and the torsion pendulum facility that provides a ground-based test-bed for new gravitational reference sensor technology and discharging methods.

H0.3-0005-18 SATELLITE-BASED FREE SPACE QUANTUM COMMUNICATION

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Quantum information science and technology are emerging and fascinating technologies formed by combining coherent manipulating of individual quantum systems and information technology, which enables secure quantum cryptography (quantum communication), super-fast quantum computing, revealing laws of complex physical systems (quantum simulation), and improving measurement precision (quantum metrology) etc., to beat classical limits. This presentation will highlight a few of our progress along quantum communication, quantum computing, quantum simulation and quantum metrology, based on photons and atoms. For fundamental aspect, one is led to the conception of quantum entanglement when apply quantum superposition principle to multi-party system. The appeared 'spooky action at a distance' phenomena referred by Einstein, is often explained by seemingly reasonable assumptions of "local realism". The inequalities proposed by John Bell and others provide immediate tests for correctness of quantum mechanics. Many efforts are addressing loophole-free tests of Bell inequalities, which tries to close various loopholes, in which some of loopholes are still needed to be addressed including freedom of choice loophole, the collapse locality loophole. Well, the final test is ongoing, many developed ground-breaking technologies for coherent manipulation of quantum systems offers elegant and feasible solutions for satisfying increasing needs of computational power and information security. Based on state-of-the-art fiber technology and rich fiber resources, we have managed to achieve prevailing quantum communication with realistic devices in real-life situation. This constitutes demonstrations by developing decoy state scheme over 100km firerextending its employment in the metropolitan area network, as well as maintaining Measurement Device Independent QKD (MDI-QKD) over 400km. At the meantime, we are also developing practically useful quantum repeaters that combine entanglement swapping, entanglement purification, efficient and long-lived quantum memory for the ultra-long distance quantum communication. Another complementing route is to attain global quantum communication based on satellite. We have spent the past decade in performing systematic ground tests for satellite-based quantum communications. Our efforts finally ensure a successful launch of the Micius satellite. Three major scientific missions have been finished, which includes achieving QKD between satellite and ground station at thousand kilometer scale, achieving satellite-based entanglement distribution between two ground stations separated by a distance of 1200 km, achieving quantum teleportation from ground to satellite over 1400 km. Very recently, using Micius satellite as a trustful relay, the intercontinental QKD between Beijing and Vienna over a distance of 7600 km has also been realized. Future Prospects include building a global quantum communication infrastructure with satellite and fiber networks, quantum computing by employing manipulating coherently more

than 50 qubits to exceed the simulating power of the current best supercomputers and reaching "quantum supremacy", Bell-test experiment with human-observer at a distance on the order of one light-second.

H0.3-0006-18 ISLAND: THE INVERSE SQUARE LAW AND NEWTONIAN DYNAMICS SPACE EXPLORER

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The Inverse Square Law And Newtonian Dynamics Space Explorer (ISLAND) is a new science concept developed by ONERA and collaborators to test the gravitation inverse square law at small scales and at the largest scales reachable in the Solar System. Its instruments are based on the same (tested and proven) technology as that of missions like LISA Pathfinder and MICROSCOPE.

The small scale experiment will rely on measuring the torque exerted by a massive plate onto an electrostatic pendulum put at the center of gravity of the spacecraft. A gradiometer surrounding it will allow us to finely measure and correct for any gravity gradient in the pendulum's environment; moreover, a drag-free system will ensure that the experiment is done in an optimal gravitational environment.

The large scale experiment will rely on the accurate and precise measurement of the orbit of the spacecraft on its outbound cruise in the Solar System, to the giant planets and beyond, together with the model-independent measurement of non-gravitational accelerations with onboard accelerometers. This will allow us to make sure that we consider only purely gravitational effects when constraining the parameters of modified gravity theories.

Using a Yukawa parameterization to quantify deviations from the Inverse Square Law, we expect ISLAND to improve the current constraints by two orders of magnitude at scales smaller than 100 microns and at scales larger than 6 AU (beyond Jupiter's orbit).

In this talk, I will present and motivate the science case for ISLAND, and show how we can meet the aforementioned improvement of constraints on Yukawa-type deviations from Newton's gravity. The first goal can be reached by using existing concepts of torsion pendulums, that must nevertheless be adapted for the micro-gravity environment. This adaptation can be readily done with, for example, ONERA's experience in ultrasensitive electrostatic accelerometry. The second goal can be reached by using accurate absolute accelerometers, which are able to measure absolute accelerations of 1 pm/s2. Such accelerometers are developed at ONERA: they add a bias rejection system to the more common accelerometers that have flown in GOCE and LISA Pathfinder.

H0.3-0007-18 THE SYSTEM OF TRIGGERS FORMATION OF GAMMA-TELESCOPE GAMMA400 AND TIMING PROPERTIES OF ITS PROTOTYPE FROM A BEAM TEST

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Scientific project GAMMA-400 (Gamma-Astronomy Multifunction Modules Apparatus) relates to the new generation of space observatories intended to perform a search for signatures of dark matter in the cosmic gamma-emission, measurements of characteristics of diffuse gamma-ray emission and gamma-rays from the Sun during periods of solar activity, gamma-ray bursts, extended and point gamma-ray sources, electron/positron and cosmic-ray nuclei fluxes up to TeV energy region by means of GAMMA-400 gamma-telescope represents the core of the scientific complex. For gamma-rays with energy >100 GeV expected energy and angular resolution are 1% and 0.01° respectively and electron/protons rejection factor is 5 10^5. The GAMMA-400 space observatory will be launched at the middle of the next decade on the Navigator service platform designed by Lavochkin Association on the elliptical orbit with following initial parameters: an apogee 300000, a perigee 500 km, a rotation period 7 days and inclination of 51.4°. The GAMMA-400 observatory is expected to operate more than 5 years, reaching an unprecedented sensitivity in the indirect search of dark matter signatures and in the study of the unresolved and unidentified gamma-ray sources.

We present the structure, logic of operation and distinctive features of the system of triggers formation of GAMMA-400 gamma-telescope in the main aperture constitutes the processor system which collects data from the gamma-telescope subsystems and produces summary information used in forming the trigger decision for each event. The system's design is based on the use of state-of-the-art recongurable logic devices and fast data links.

The properties of a prototype of time-of-ight detector of gamma-telescope constitutes of BC-408 scintillator bars of 128 cm long with a cross-section of 10x1 cm^2, viewed from opposite ends by matrixes of silicon photomultipliers SensL MicroFC-60035-SMT were studied using 100- 300 MeV/c positron beam at the test beam of synchrotron "PAKHRA" of Lebedev Physical Institute (Russia). The test results in different configurations show that the time resolution better than 500 ps was reached.

H0.3-0008-18 HIGH PRECISION MODELLING WITH APPLICATION TO THE MICROSCOPE MISSION: NON-GRAVITATIONAL FORCES AND AERONOMY

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After more than 15 years of planning, developing, building, and testing, the french MICROSCOPE satellite was finally launched on 25th of April 2016. It is the first satellite in a low Earth orbit using a drag-free attitude control system. The payload comprises two differential accelerometers, each containing two test masses. Due to the drag-free system non-gravitational disturbances are canceled thus allowing the test masses to follow a pure gravitational orbit. The goal of the mission is the test of the validity of the weak equivalence principle to an accuracy of 10−15. An initial evaluation of the first science data has already led to an improvement of the Eötvös parameter characterizing the relative difference in test mass free-fall acceleration by one order of magnitude compared to the best values achieved by torsion balance experiments.

However, for calibration purposes and as a means to identify residual couplings between test mass motion and external perturbations simulations of the satellite system and the mission are necessary. We present our approach for a high precision analysis of the non-gravitational perturbations acting on MICROSCOPE by means of the High Performance Satellite Dynamics Simulator (HPS), which is being developed by the Center of Applied Space Technology and Microgravity (ZARM), at the university of Bremen, Germany in cooperation with the Institute of space systems (DLR-IRS) of the German Aerospace Center. Here the calculation of the non-gravitational effects include the specifics of spacecraft geometry and illumination condition thus allowing for highest modeling accuracy.

Furthermore we introduce an application for MICROSCOPE which can be used for any spacecraft employing high performance accelerometers to conduct aeronomy experiments. By accurately modeling all non-gravitational effects we achieve subsequent estimates of all accelerations acting on the craft. When the satellite is operated in non-drag free mode and other dynamical effects derived from the rotational behavior are known, we can subtract these estimated values from the accelerometer signal. By means of a fit of the atmospheric density parameter in the drag model with respect to the residual acceleration we can get an improved estimate on the thermospheric density. We show details of the procedure as well as an application for the MICROSCOPE satellite after its primary science phase.

H0.3-0009-18 THE SOFT MATTER DYNAMICS EXPERIMENT FOR THE ISS

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Soft Matter Dynamics is an experiment platform developped under ESA contract to enable a variety of soft matter experiments with extended micro gravity time from August 2018.

Soft matter are materials that are "supramolecular, exhibit macroscopic softness, have metastable states and a sensitivity of their equilibrium to external conditions" [de Gennes], for example colloidal suspensions, emulsions, foams and granular media. On the one hand these materials are used in many industrial processes, are well understood empirically and have interesting future potential, for instance as design materials. On the other hand Soft Matters are primary research candidates for investigations on non-equilibrium thermodynamics, phenomena at the critical point or rheology, like jamming and glass transitions. Fundamental research under gravity conditions is generally limited by the macroscopic softness of these materials, i.e., most of the internal processes are completely hidden by gravity induced dynamics and stresses.

The Soft Matter Dynamics experiment platform provides optical microscope, single and multi specke diffusing wave spectroscopy, supporting also time resolved correlations, to investigate primarily dynamics on the surface of and inside opaque but translucent materials. The experiment platform can be extended with on-orbit replaceable science cartridges. These so called sample cell units not only allow the extension of the mission by adding additional material samples. These are smart inserts that can include their own custom agitation mechanisms, sensorics, thermalization and thereby expand the science goals of the mission. The initial research are non-equilibrium dynamics in dense granular media and coarsening of wet foams. Potential future experiments include for instance coarsening of emulsions and rheology of foams.

The experiment will be launched with Space-X 15 and is scheduled for commisioning in August 2018. The mission, instrument, its mayor design elements, performance and limits will be presented.

H0.3-0010-18 HYDRODYNAMICS OF DROPLET LATTICES IN QUASI-2D FREE-STANDING LIQUID FILMS

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The layered molecular structure in smectic A and smectic C phases allows the preparation of stable thin and homogeneous films with huge aspect ratios, quasi as two-dimensional fluids. One can prepare them even in spherical geometry, as macroscopic bubbles. In an experiment on the ISS, we created such bubbles with centimeter-size radii to study the hydrodynamics of inclusions in these quasi 2D systems [1]. Here, we present the study of nearly regular triangular lattices of micron-sized inclusions in the free-standing films, to investigate inclusion mobilities and interactions in such lattices. We record the trajectories and derive their diffusion characteristics. The experiments are compared to numerical simulations of inclusion arrangements, assuming specific repulsive interaction potentials. The temporal evolution of the mean-square displacement of the inclusions reveals mobilities within the lattice and the strength of the repulsive interaction potential.

The study was supported by NASA, DFG and DLR and a fellowship of Sachsen-Anhalt.

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H0.3-0011-18 METRIC: A DEDICATED EARTH-ORBITING SPACECRAFT FOR FUNDAMENTAL PHYSICS TESTS AND GEOPHYSICS

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A dedicated mission in low Earth orbit — called METRIC — is proposed to test selected predictions of theories for the gravitational interaction and to directly measure the atmospheric density in the covered altitude range, at the same time providing a metrological platform able to perform a tie between different space geodesy techniques. The core of the mission would be a rather simple spacecraft placed in a highly eccentric orbit between 450 and 1200 km; it should be tracked from ground with high precision, and an on-board accelerometer would measure the non-gravitational accelerations acting on it. A precise orbit determination is expected to provide estimates of fundamental physics and geophysical parameters, while the accelerometer data are fundamental in constraining the atmospheric density along the orbit. Together with the mission scientific objectives, a possible baseline for spacecraft configuration, including a typical payload complement, and for data analysis is described and discussed.

H0.3-0012-18 TESTING GRAVITATION IN THE SOLAR SYSTEM: A BRIEF REVIEW

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In this talk our current knowledge of the gravitational interaction is discussed in the context of the Solar System dynamics. Thus far, general relativity theory appears to be the best description of this interaction. The most important predictions of the theory are briefly discussed in the post-Newtonian approximation, which provides a way of describing also an important set of alternative theories, the so-called metric ones. The Solar System indeed remains a privileged arena for performing precise tests of gravitation, and these tests are often strictly related to the exploration of Solar System itself. A selection of past, ongoing and future tests of the theory and its foundations is presented, giving emphasis on main results and technological requirements, and with an outlook to the near future.

H0.3-0013-18 QUANTUM KEY DISTRIBUTION WITH A 3U CUBESAT

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Cryptography via Quantum Key Distribution (QKD) is one of the most promising applications of quantum optics. Unlike current classical cryptography methods such as RSA, quantum cryptography does not rely on the assumption that a mathematical function is too hard for an adversary to invert. The fundamental laws of quantum physics therefore allow for unconditionally secure communication schemes.

Generating a secure key via QKD is most conveniently achieved by exploiting the quantum properties of single photons. However, unavoidable losses restrict glass fiber based QKD to

<400 km. The most efficient alternative is to establish quantum optical free-space links to satellites. In this talk we will demonstrate the feasibility of a QKD scheme that can be carried out with a 3U CubeSat of only 4 kg, using commercial off-the-shelf components. So far, QKD in space has only been shown by a much larger 600 kg satellite mission. Our approach is to establish an uplink to the satellite rather than a downlink. This allows for the more complex sending apparatus to stay on ground, therefore relaxing the requirements for the CubeSat. A comprehensive link budget was generated to calculate the key rates and tolerable losses in detail. The study includes considerations about orbit and ground station choice, pointing, tracking, the CubeSat's field of view, varying weather conditions and the implementation of different protocols as well as a size, weight and power analysis. We discuss design choices and trade-offs to maximize the key rate while minimizing the cost and development needed. Thus, show that up to 13 Mbit of secure key per year could be acquired with the low-cost satellite of our design.

H0.3-0014-18 DETERMINING THE SPIN AXIS ORIENTATION OF THE ECHOSTAR-2 INACTIVE GEOSYNCHRONOUS SATELLITE

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For the first time, the spin axis orientation of an inactive geosynchronous satellite has been determined using ground-based optical photometric observations. The light curves that resulted from high-frequency Echostar-2 observations conducted in 2012 contained very bright specular sunlight reflections having a period of one half the satellite's inferred spin period. These regularly observed reflections suggested two highly reflective surfaces with surface normals separated by approximately 180 degrees on the satellite body. A geometrical method, based on these observed reflections, was used to determine the late-2012 spin axis orientation coordinates of the Echostar-2 satellite.

H0.3-0015-18 CONSTRAINING EXTENDED GRAVITY BY SOLAR SYSTEM EXPERIMENTS

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We consider Extended Theories of Gravity and in particular, models containing scalar-tensor and higher-order curvature terms, as well as models derived from some fundamental theories. In the weak-field approximation, we take into account the geodesic and Lense-Thirring processions, deriving constraints on the free parameters by the experimental data of Gravity Probe B (GPB) and Laser Relativity Satellite (LARES). The main result of this research is that constraints on fundamental theories of gravity can be achieved at Solar System level.

H0.3-0016-18 AN ASSESSMENT OF LISA PATHFINDER MISSION EXTENSION TO THE SUN-EARTH SADDLE POINT. A MISSED OPPORTUNITY?

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Methodologies for the design, navigation, and guidance of potential transfer trajectories to the Sun-Earth gravitational Saddle Point are presented. In particular, this work investigates the feasibility of transferring LISA Pathfinder from its Sun–Earth L_1 Lissajous orbit to the Saddle Point. Unlike the Lagrange points where the gravitational potential has to cancel out the centrifugal acceleration, the Saddle Points are regions of arbitrarily small gravitational force residing in a finite domain. They are, therefore, ideal locations for undertaking tests of the ultra-weak gravitational force and where possible deviations from General Relativity can be tested. Hitting the Saddle Point with precision presents a major orbital mechanics and flight dynamics challenge.

Many optimal trajectories that fly through the Sun–Earth gravitational Saddle Point are found with a series of impulsive maneuvers imparted to LISA Pathfinder, assumed to have thrust-tomass ratio of 0.2-2 µN/kg and Δv levels of 1-2 m/s. An efficient algorithm is then demonstrated that converts each impulsive maneuver into a finite thrust arc by solving a pseudo-rendezvous problem. The impulsive-to-finite burn conversion shows versatility and robustness when applied to a wide variety of transfers. Orbit determination and navigation analysis are simulated by modeling both the space and ground segments. The capability to navigate platforms with ultra-limited control authority is strongly limited by the frequency of ground station passes, the accuracy of the radiometric data from ground stations, the accuracy of the orbit determination and propagation, the frequency of the orbit determination and orbit correction cycle, and the accuracy of the Δv correction. Evidence is here provided on the feasibility to accurately navigate LISA Pathfinder by the Sun–Earth Saddle Point.

H0.3-0017-18 BACKGROUND FRACTAL DIMENSION OF EVENT TEMPORAL PROFILES IN ADDITIONAL APERTURE OF GAMMA-TELESCOPE GAMMA-400 BY RESULTS OF CALIBRATIONS ON SYNCHROTRON "PAKHRA".

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Gamma-telescope GAMMA-400 (Gamma Astronomical Multifunctional Modular Apparatus) consists of the converter-tracker (C), time-of-flight system TOF (2 sections S1 and S2), top (ACtop) and lateral (AClat) sections of anticoincidence system, position-sensitive calorimeter CC1 makes of 2 strips layers and 2 layers of CsI(Tl) detectors, electromagnetic calorimeter CC2 composed of CsI(Tl) crystals, scintillation detectors of the calorimeter (S3 and S4). Installation of lateral detectors of the calorimeter (LD) required for particles registration from lateral directions. All detector systems ACtop, AClat, S1-S4, LD consist of two BC-408 based sensitive layers of 1 cm thickness each. The thickness of CC1 and CC2 is ~ $2X_0$ (~ $0.1\Lambda_0$) and

~ $20X_0$ (~ $0.9\Lambda_0$) respectively (where Λ_0 is nuclear interaction length). The total calorimeter thickness is $22X_0$ ($1.0\Lambda_0$) for vertical incident particles registration and $56X_0$ ($2.5\Lambda_0$) for laterally incident ones.

Three apertures provide events registration both from upper and lateral directions. Gammatelescope GAMMA-400 is optimized for the γ-quanta and charged particles with energy 100 GeV detection with the best parameters in the main aperture. Other apertures used for studying of transient events do not require best angular resolution as solar flares and gamma-ray bursts. The main aperture created firstly due to converter-tracker (C): gammas converted in tungsten conversion foils are registered. Triggers in the main aperture will be formed using information about particle direction provided by TOF system and about presence of charged particle or backsplash obtained from ACtop and AClat anticoincidence detectors in energy band 20 MeV

1.0 TeV for gammas and E > 100 MeV for electrons. Additional aperture allows to registered particles from upper directions which don't interact with converter-tracker and don't formed TOF signal. Particles detection in additional aperture starts with signal of CC1 fast discriminators in anticoincidence with TOF. Energy band for gammas registration in this aperture is similar to the main one. In the lateral aperture low energy (0.2 - 100 MeV) photons classified by using simple anticoincidence signals from the individual detectors of LD and CC2. Higher energies γ-quanta (E > 100 MeV) recognized using energy deposition analysis in the individual detectors of S3, S4, LD and CC2.

High-energy γ-quanta registered in scintillator mostly after formation of electron-positron pairs. Thus electron and positron beams also used to gamma-detectors calibration. The positron beam with energies 100-300 MeV was used for calibrations of prototypes of GAMMA-400 detectors on synchrotron "PAKHRA". GAMMA-400 prototype of additional aperture functioning consist of two detectors. One of them is BC-408 based with dimensions of 128 10 1 cm3 (AC/LD prototype) and other composed of CsI(Tl) crystal with dimensions of 33 5 2 cm3 (CC1 prototype).

A fractal analysis often used for investigation of time series corresponding to transitive events (solar flares, gamma-ray bursts and so on). The fractal dimensions must be different for the temporal profiles of events caused by different physical processes. It has some features that allow it to be used to study sets with characteristics varying over a wide range: scaling (two events with similar temporal profiles but with different durations have a similar fractal dimension) and the possibility to process simultaneously the fractal dimension distributions obtained by using data from different detectors if the background fractal dimensions for these detectors are the same. Thus background fractal dimension is useful characteristic of detector. We calculate fractal dimension of AC/LD and CC1 prototypes temporal profiles measured during calibrations and obtain preliminary results of 1.50 0.05 and 1.48 0.08 correspondingly. This is similar to Poisson statistics with coefficient of error in counting up to 10. Analogous results were previously obtained for other detectors used for GRBs registration such as BATSE/CGRO and Swift/BAT.

H0.3-0018-18 SUN GRAVITATIONAL LENS MISSION TO 550 AU

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It is well-known that the Sun Gravitational Lens (SGL) would provide magnified radio pictures of whatever lies on the other side of the Sun with respect to the probe position, if the probe can get to 550 AU and beyond.

See, for instance, the popular video https://www.youtube.com/watch?v=Hjaj-Ig9jBs This space mission could be used for two different goals:

Imaging exoplanets possibly hosting Life (Astrobiology) or even Alien Civilizations (SETI).

Enabling radio communications across interstellar distances by virtue of relay probes sent to 550 AU and beyond.

In his book "Deep Space Flight ad Telecommunications" (2009) this author studied extensively the above goal 2), while, in recent years, a NASA Team based at both JPL and Marshall Space Flight Center studied extensively the above goal 1).

In this presentation we give the state-of-the-art of this space mission to 550 AU and beyond. We will point out that this innovative space mission would open up unprecedented prospects for the exploration of space beyond the Solar System. For instance, traveling to the nearest stars (Breakthrough StarShot) and getting in touch with Alien Civilizations (Breakthrough Listen SETI).

H0.3-0019-18 RIEMMANN PENDULUM (AND OSCILLATOR) IN FREE FALL SYSTEM

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The possible detection in space and in different free fall systems of the tidal effects, via metric deviations, occurring in Riemann oscillators or in pendulum systems in orbit space, is considered in detail. The possibility to perform such an experiment for educational purpouse and General Relativity test, by a Moire' or Holographic double exposure detection, is described. The International Space Station may obtain high quality test for complex 3D anisotropic Riemann pendulum patterns in a simple set up.

H0.3-0020-18 INTEGRATION AND TESTING ACTIVITIES DEDICATED TO LISA SPACE INSTRUMENT

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LISA is an ESA project dedicated to space gravitational waves observation in the very low frequency range from 10−1 to 10−4 Hz, opening a window on massive black hole binaries which are not observable from ground based interferometers. The LISA space observatory consists of three satellites planned to be launched in 2034 by Ariane 6.4 launcher. The three satellites will be positioned on their final orbits in a triangular shape constellation with an arm of 2.5 million of km, orbiting around the Sun at 1 AU and following the Earth at a distance of 50 to 65 million of km. The gravitational waves detection is based on laser interferometric measurement of very tiny distance variations (i.e. several tens of picometers) between pairs of free falling test masses (TM), core elements of the two instrument terminal units mounted in each satellite at the end of each triangle arm. One instrument terminal unit consists of a telescope, an optical bench, a gravitational reference sensor (including free falling TM) and a support structure, this entity being called MOSA (Movable Optical Sub-Assembly). An assembly of two MOSA's together with various electronics sub-systems (e.g. Phasemeter, Laser, Payload Commanding and Processing) forms the instrumental payload or the LISA Core Assembly (LCA) of every LISA satellite. Each MOSA emits a laser beam towards its associated MOSA receiver based on the opposite satellite and, reciprocally, it receives the beam emitted by the distant MOSA. These dual links form one of the three interferometric arms of the triangular LISA satellites constellation. The interferometric measurement accuracy, expressed in optical path length has to present a single pathlength stability of 10 pm/*sqrtHz* above 3 mHz, also implying a beam pointing stability of 10 nanoradians/*sqrtHz* in the same frequency range. These performances have to be verified (by measurements or modeling) at MOSA level and therefore require a very sophisticated testing and verification process. France will contribute to this project with the development of the data processing center and the achievement of integration and testing (AIV/T activities) for the six MOSA flight models. The presentation describes the integration and testing steps, the verification tests principle with associated specifications, and the ground support equipment's that are required for the MOSA AIV/T activities. The MOSA assembly activities will be performed in a clean controlled environment and they will consist of µm precision alignment of the telescope relatively to the optical bench by mechanical adjustments on the MOSA support ring structure, followed by the assembly of the gravitational sensor (GRS). At the end of the assembly process, the size of a MOSA will be of 1 meter length and

0.6 meter diameter, with a mass of 75 Kg. Once the assembly of various sub-assemblies and their mechanical alignment step was achieved, the MOSA optical testing will be carried out inside a vacuum chamber, in order to comply with high precision requirement for optical path length (OPL) measurement. A vacuum pressure below 10-5 mb is required to provide a very stable and homogeneous thermal environment and consequently a limited thermal expansion. Moreover, stable low pressure below 10-5 mb avoids also refraction disturbances on the laser beam path. A pressure of 10-5 mb induces an optical path elongation of several picometers. The aimed accuracy is about 1 picometer stability over 30 seconds' time span in order to verify the intrinsic optical length path stability inside MOSA. Slow and slight thermal drifts will be performed to quantify the thermal effects affecting optical path length and wavefront quality for each MOSA. A major test equipment, called far-field optical simulator, is required to simulate the distant satellite laser beam. Its mechanical stability must comply with OPL accuracy requirement and the wave front of the emitted beam has to verify a flatness of Lambda/30. The simulator must also respect pointing stability and strict polarization requirements. The verification of the beam pointing angle requires a measurement stability of one nano-rad over a 30 seconds time span. This far field simulator is fixed on a cradle also bearing the MOSA during testing under vacuum. The material of the cradle must have a very low coefficient of thermal expansion (CTE) and it can be the same material as the telescope one (e.g. Zerodur ceramics). Moreover, three interferometers will measure the relative far-field simulator displacements in order to compensate them for the OPL measurement intrinsic to MOSA. The full MOSA performance verification is based on interferometric measurement involving the main MOSA elements, but also two additional major LISA sub-systems: the Phasemeter and the Laser source. Moreover, the full test of gravitational reference sensor (GRS), of which principle is based on a free falling test mass, cannot be implemented on ground, under gravity. Therefore, an optical sensor simulating the flight movements of the TM inside of its enclosure will be used as GRS substitute. Cleanliness is of paramount importance since a single 10 µm size dust is able to generate interference pattern by scattering laser light that could impair the detection sensitivity or jam gravitational events detection. Drastic precautionary measures will be defined and taken to avoid particle contamination during assembly and testing.

H0.3-0021-18 IN QUEST OF AXIONIC HAIRS IN QUASARS

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The presence of axionic field can provide plausible resolutions to several long standing problems like dark matter, dark energy etc. The pseudo-scalar axion whose derivative corresponds to the Hodge dual of the Kalb-Ramond field strength in four dimensions plays crucial roles in explaining several astrophysical and cosmological observations. Therefore, the detection of axionic hairs/Kalb-Ramond field which appears as closed string excitations in the heterotic string spectrum may provide a profound insight to our understanding of the current universe. The current level of precision achieved in solar-system based tests employed to test general relativity, is not sufficient to detect the presence of axion. However, the near horizon regime of quasars where the curvature effects are maximum seems to be a natural laboratory to probe such additions to the matter sector. The continuum spectrum emitted from the accretion disk around quasars encapsulates the imprints of the background spacetime and hence acts as a storehouse of information regarding the nature of gravitational interaction in extreme situations. The surfeit of data available in the electromagnetic domain provides a further motivation to explore such systems. Using the optical data for eighty Palomar Green quasars we demonstrate that the theoretical estimates of optical luminosity explain the observations best when the axionic field is assumed to be absent. However, axion which violates the energy condition seems to be favored by observations which has several interesting consequences. Error estimators, including reduced $\chi 2$, Nash-Sutcliffe efficiency, index of agreement etc. are used to solidify our conclusion and the implications of our result are discussed.

H0.3-0022-18 ASSESSMENT OF DEDICATED MISSIONS TO SUN-EARTH SADDLE POINT

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Saddle points are peculiar regions of space where the net gravitational acceleration is null. The interest in exploring those locations is increasing in the scientific community. Close-tozero background acceleration environments allow to perform experiments in order to quantify possible deviations from General Relativity and test alternative theories of gravitation in a very weak field region. Multiple passages through the saddle point are needed to collect relevant data. Highly non-linear orbits can be exploited in order to accomplish this aim.

In this paper, periodic orbits through the Sun–Earth Saddle Point are sought. A systematic approach is designed, exploiting the hierarchical structure of astrodynamical models. The periodic orbits survey is firstly addressed in the circular restricted three-body problem with the Sun and the Earth as main bodies: first attempt trajectories are sought through a grid search and then refined using a simple shooting, differential correction scheme. Stability is evaluated and a classification is made. Restricted four body problem adding the Moon is used as middle complexity model in order to find quasi-periodic orbits. These are refined in a full ephemeris high-fidelity n-body model.

Preliminary results show different possible solutions with diverse characteristics and properties.

H0.3-0023-18 TRAJECTORY ANOMALIES IN INTERPLANETARY SPACECRAFT

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For almost two decades after its detection, the Pioneer Anomaly stood as a possible breach in the experimental record of General Relativity (GR), allowing for the formulation of a number of alternative theories. This trajectory anomaly was ultimately found to be caused by the radiative heat dissipation from the spacecraft itself. A similar phenomenon was observed during a specific experiment designed to test GR on the Cassini mission. The non-gravitational acceleration was accounted for using a method that employs techniques originally developed for computer graphics and video games. One examines the surprising role that a shading algorithm from the !970's played in solving these riddles. The prediction made for a similar effect on the New Horizons probe is also presented, as well as the overarching implications for the study of gravity in the solar system.

H0.4-0001-18 MEASURING FEMTO-G ACCELERATION NOISE DOWN TO 20 MUHZ: LISA PATHFINDER RESULTS

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The LISA Pathfinder ESA probe mission has measured the residual acceleration between two free falling reference test masses orbiting in the same apparatus at femto-m/s2Hz^1/2 level and performed sub 100f m/Hz^1/2 interfero metric measurements of their relative distance, during its one year and half lifetime frequency science potential of the next–coming LISA mission for gravitational waves observation in space.

H0.4-0002-18 SUCCESSFUL INTERMITTENT CONTROL CONFIRMS THE LISA PATHFINDER PERFORMANCE: THE FREE-FALL EXPERIMENT RESULTS

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The continuous compensation of the gravitational imbalance between the two free-falling test masses (TMs) that has been achieved in flight by LISA Pathfinder ESA probe mission in standard operations control loop, can be also performed with intermittent control, by forcing electrostatically one of them with brief periodic impulses, with TMs free to move in between two “kicks”. The actuation-free motion is then analysed for the remaining sources of acceleration noise below the repetition frequency of the experiment (3 mHz). This alternative control method allows to test a LISA-like actuation configuration, free from the actuator noise and its calibration and obtains a measurement of the residual acceleration at subfemto-m s–2 Hz–1/2

level in the frequencies below 1 mHz, in agreement with that achieved with continuous control.

H0.4-0003-18 THE GRACE FOLLOW-ON LASER RANGING INTERFEROMETER: MAKING HERITAGE FOR LISA

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By measuring the distance between two satellites orbiting the earth with microwaves, the Gravity Recovery and Climate Experiment (GRACE) mission has successfully monitored the gravity profile of the Earth for over a decade. GRACE observed the Earth’s environment due to shifting water masses, giving insight into global climate change over long time scales. GRACE has now reached the end of its lifetime. Its replacement, GRACE Follow-On (GFO) will launch in the spring of 2018. The GRACE Follow-On microwave instrument is a build-to-blueprint replacement of GRACE. In addition, a nanometer-precision laser interferometer demonstration instrument has been incorporated to demonstrate a much finer precision measurement.

A partnership between NASA and Germany, the Laser Ranging Interferometer (LRI) on GRACE Follow-On is based on technology originally developed for gravitational wave detection for the Laser Interferometer Space Antenna (LISA). The LRI implements one arm of the three-arm LISA observatory at a distance of hundreds of kilometers. Between the ESA LISA Pathfinder mission and the GFO LRI, many of the elements of a picometer-sensitivity space-based gravitational wave detector will be demonstrated in space.

H0.4-0004-18 LISA SCIENCE BEFORE LISA: DETECTION OF ULTRA-COMPACT BINARIES WITH THE ZWICKY TRANSIENT FACILITY

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Ultra-compact galactic white dwarf binaries will be the most numerous astrophysical sources detectable by LISA. These binary systems are the result of evolutionary pathways that involve a rich collection of astrophysical phenomena including episodes of common envelope evolution, gravitational wave emission, tidal interaction and mass transfer. Several LISA-detectable binaries are already known through optical observations. These are ultra-compact white dwarf binaries with orbital periods, masses, and distances such that they should be detected by LISA.

The Zwicky Transient Facility (ZTF) is a new ground-based large-area optical survey instrument that saw first light in October 2017 and is now performing science surveys. ZTF has a 47 square degree field of view and acquires an image every 45 seconds with a median limiting magnitude of R=20.3. ZTF will be carrying out variability surveys of the Galactic Plane at both moderate and high cadence. We expect that ZTF will more than double or triple the number of known LISA-detectable sources, as well as identify numerous other ultra-compact binaries that will provide better understanding of the many potential evolutionary pathways for the binaries that LISA will detect.

We will describe ZTF and discuss preliminary results from some of its observations. We will also discuss recent results from the Palomar Transient Factory (PTF), a smaller prototype survey to ZTF. These include detection of AM CVn systems, compact He star systems, and one new LISA-detectable “verification binary”.

H0.4-0005-18 SUPERMASSIVE BLACK HOLE BINARIES AND LOW-FREQUENCY GRAVITATIONAL WAVES

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Compact Supermassive Black Hole Binaries (SMBHBs) are the most promising sources of lowfrequency gravitational waves, and are expected to be detected in the near-future by Pulsar Timing Arrays, such as the North American Nanohertz Observatory for Gravitational Waves. Such systems should form frequently in galactic nuclei as a result of galaxy mergers. Despite their expected ubiquity, the observational evidence for systems at small (sub-parsec separations) remains elusive. I will summarize ongoing multi-wavelength efforts to identify sub-parsec SMBHBs from their electromagnetic signatures (e.g., quasars with periodic variability, Doppler shifted spectra, etc.). I will also discuss the astrophysical implications of the detection of the gravitational wave background from a population of merging SMBHBs and the prospects of multi-messenger astronomy in the low-frequency part of the gravitational wave spectrum.

H0.4-0006-18 RUNAWAYS: RECOILING BLACK HOLES AND THEIR GRAVITATIONALWAVE SIGNATURES

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Binary black holes radiate linear momentum in gravitational waves as they merge. Recoils imparted to the black-hole remnant can reach thousands of km/s, thus ejecting black holes from their astrophysical hosts with deep consequences for both spaceand ground-based gravitationalwave observatories. In this talk, we present some advances in modeling recoiling black holes. In particular, (i) we show how waveform approximants able to model higher harmonics provide an innovative way to estimate black-hole recoils without relying on fitting formulae, and (ii) we exploit the Doppler shift induced by the recoil on the emitted signal to show how future detectors have the potential directly detect these "runaways".

H0.4-0007-18 SCOPING OUT THE LISA CATALOG

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A conventional astronomical catalog contains a list of detected sources, along with their best-fit parameters and (ideally) the error bars for those parameters. There are several reasons why this structure would be far from optimal for LISA: different sources may often have strongly correlated errors; fits with different numbers of sources will have comparable posterior probability; and even for many individual sources, the posterior probability distributions of source parameters may often have many local maxima of comparable probability. Furthermore, the great majority of sources will be very long-lived, with most detectable signals emerging gradually out of the noise, so the catalog will need to be updated very frequently throughout the mission. In this talk, we explain these and related problems that arise as we plan for the creation and dissemination of useful LISA data products. We will describe what we understand already, but this talk will contain more questions than answers.

H0.4-0008-18 STRUCTURED DOCTORAL PROGRAMMES FOR THE NEXT GENERATION OF GRAVITATIONAL SCIENTISTS IN HANNOVER

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Uni Hannover/AEI Hannover, Hannover, Germany the IMPRS on Gravitational Wave Astronomy has become major resource for education in the field of gravitational wave physics. We have also set up a new programme called the the geo-Q Research Training Group. It aims to study relativistic geodesy and gravimetry with quantum sensors. The two programme started to provide substantial synergy to members of both programmes by our strong cross disciplinary approach. Our effort to create a joint programme has received excellent feedback from our scientists and various external committee members. Building on this successful establishment of a joint programme, we aim to expand globally, and to create a joint programme among international institutions. This will help to further foster collaborations among researchers all over the world in the field of gravitational wave physics and astronomy.

H0.4-0009-18 CAN ACCRETION DISKS AROUND BLACK HOLES AFFECT THE GRAVITATION WAVE SIGNALS?

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Recent observations of LIGO has opened up a new window to the Universe, a window which is likely to be very very noisy, because every celestial body emits this wave. Simplest templates which are created using two point like objects are wishful thinking and enforcing data to fit such templates could give rise to wrong parameter extraction. There is one good candidate to cause significant perturbation of the signal and it is the accretion disks drag on the binary companion which is on its way to coalesce with the central object. A merger would most certainly be accompanied by electro-magnetic waves due to the presence of the disk, a fact which is impossible for point like mergers. I present results obtained in this intriguing topic of effects of disks drag on the signal variation, especially when extreme mass ratio is considered (in order to see major effects). I discuss the statistics of such objects and argue about their observability.

H0.5-0001-18 TESTING THE EQUIVALENCE PRINCIPLE IN SPACE AFTER MICROSCOPE

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Tests of the weak equivalence principle can reveal a new force of nature or disprove many models of new physics. The rst such test in space is successfully carried out by the MICROSCOPE satellite in low Earth orbit. Early results show no violation from the Earth for PT and Ti test cylinders with random errors (after about 8 days of integration time) of about 1 part in 1014, and similar systematic errors. The improvement over the best ground tests with rotating torsion balances is by about 10 times in spite of a 70 times worse sensitivity to dierential accelerations thanks to the much stronger driving signal in orbit. The potential of space for orders-of-magnitude improvements is demonstrated. Many lessons can be learned from the success and the limiting factors of MICROSCOPE. We analyze random and systematic errors, show how they compare with their expected values and discuss the key lessons to learn for testing the equivalence principle in space to higher precision.

H0.5-0002-18 FUNDAMENTAL PHYSICS MEASUREMENTS WITH LASER-RANGED SATELLITES

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The key role that laser-ranged satellites - such as the two LAGEOS (LAser GEOdynamic Satellite) - have had in the fields of space geodesy and fundamental physics is well known. They provided a wealth of significant applications and results in geophysics, as well as in the measurements of tiny relativistic effects in the weak-field and slow-motion (WFSM) limit of Einstein's theory of general relativity (GR). In this regard, these achievements have been reached thanks to two very important ingredients: i) the quality of the tracking observations of the orbit of the satellites, guaranteed by the powerful Satellite Laser Ranging (SLR) technique, and ii) the quality of their overall dynamical model implemented in a software code. Moreover, today GR has to be considered a fundamental pillar of space geodesy and of geophysics in general: the use of atomic clocks on-board a navigation satellite or on-ground, are just two important examples, among many. Indeed, terms like "relativistic metrology", "relativistic geodesy" and "relativistic celestial mechanics" are very frequent in the literature; in fact they are pertinent and represent bridges among fields wrongly considered separated in the past. SLR is one of the techniques that constitute the Global Geodetic Observing System (GGOS). In the near future it is expected, within the GGOS activities, an improvement of one order of magnitude in global accuracies in the observational as well as the theoretical components of space geodesy. This implies improvements in measuring accuracies, in reference frames realization, in modelling, in the stations network geometry and, consequently, into the accuracies involved in fundamental physics measurements using space geodesy techniques. However, in order to reach these ambitious objectives with a fruitful contribution from the existing satellites, as the two LAGEOS and the more recently launched LARES, several improvements are necessary in their precise orbit determination (POD). For instance, under this point of view, an hot topic is constituted by the knowledge of the so-called center-of-mass correction for these satellites, that directly impact the range determination of the satellites, i.e. the precision of their normal points, and correlates with the so-called range bias of the Earth-bound tracking stations. One more very important aspect that deeply affects the POD of the satellites is represented by a reliable modelling of the subtle thermal effects produced by the visible solar radiation and the infrared radiation emitted by the Earth's surface. These are the Sun Yarkovsky-Schach effect and the Earth-Yarkovsky effect. Their complexity arises from two main aspects: i) the knowledge of the temperature distribution on the satellite surface, and ii) the knowledge of the satellite attitude, i.e of its spin vector evolution.

In this talk, the main activities of the LAser Ranged Satellites Experiment (LARASE) will be described. The LARASE research program is funded by the Italian National Institute for Nuclear Physics (INFN) and it is a collaboration between different institutions. The main goal of LARASE is to provide accurate measurements for the gravitational interaction in the WFSM limit of GR by means of the very precise laser tracking of geodetic satellites orbiting around the Earth. In particular, LARASE aims to improve the dynamical model of the current best laser-ranged satellites in order to perform a refined POD of their orbit. This represents a first step towards new refined tests and measurements of GR in the field of the Earth and of a most profitable use of the orbit analysis of the considered satellites for space geodesy and geophysics. The current results of LARASE in terms of development of new models for the non-gravitational perturbations acting on the two LAGEOS and LARES satellites, their POD and new measurements of relativistic effects on their orbit will be shown, together with an accurate evaluation of the error budget due to the main systematic sources of error.

H0.5-0003-18 GALILEO FOR SCIENCE PROJECT (G4S): ECCENTRIC GALILEO SATELLITES FOR GENERAL RELATIVISTIC INVESTIGATIONS.

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On August 22nd 2014, Galileo satellites 205 and 206 were launched on wrong orbits. If the injection of the two satellites on wrong highly eccentric orbits (e=0.256 then reduced after recovery maneuvers to 0.156) jeopardized the full operation of two satellites for navigation civilian purposes; on the other hand it provided the unique opportunity to have satellites fully suitable for scientific investigations. Satellites with so eccentric orbits can be exploited indeed for investigations in the field of General Relativity and Gravitation. Gravitational red-shift (GRS), Schwarschild perigee precession (Schw) and Lense-Thirring gravitomagnetic drag (L-T) are the main General Relativistic effects that could be measured with unprecedented accuracy today thanks to the twin satellites. The project GALILEO for Science (G4S) is a joint ESA and ASI effort, which has the primary goal to measure such GR effects. Furthermore, the satellites can be the first space facility for the establishment of a pure Relativistic Positioning System (RPS). Finally bounds on alternative theories of gravity can be settled exploiting the observations of the twin satellites. For the measurements of the above mentioned GR effects we do need to construct a very refined surface model of the GALILEO satellites and conceive proper effective analysis strategy just to minimize the systematic uncertainties due to their very long periodic perturbations. For what regards the analysis strategy we plan to use both Lmicrowaves and Laser Ranging observations. Regarding this last technique, we propose a tailored periodic scheduling of the campaigns which will help us to single out the contributions of each Non Gravitational perturbation (NGP): Sun radiation pressure,thermal thrust and Earth's Albedo.

H0.5-0004-18 DIRECT MULTIPIXEL IMAGING AND SPECTROSCOPY OF AN EXO-EARTH WITH A SOLAR GRAVITATIONAL LENS TELESCOPE

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Nature has presented us with a very powerful “instrument” that we have yet to explore and learn to use. This instrument is the Solar Gravitational Lens (SGL), which results from the ability of the gravity field of the Sun to focus light from faint, distant targets. In the near future, a modest telescope could operate on the focal line of the SGL and, using the enormous magnification power of the Lens, could provide high-resolution images and spectroscopy of a habitable exoplanet. We present the imaging properties of the SGL, when the image occupies many pixels in the region near the optical axis. We discuss a mission to the SGL focal region that could provide us with direct, multi-pixel, high-resolution images and spectroscopy of a potentially habitable Earth-like exoplanet. Based on our initial studies, we find that such a mission could produce (1,000×1,000) pixels images of “Earth 2.0” at distances up to 100 light years with spatial resolution of 10 km on its surface, enough to see its surface features. The same instrument would be able to conduct a very high-resolution spectroscopy. We address some aspects of mission design and spacecraft requirements, as well as capabilities needed to fly this mission in the next two decades.

H0.5-0005-18 MOONLIGHT'S AND INRRI'S FOR LUNAR AND MARTIAN MISSIONS

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Since its foundation, dating back to 2003, one of the most important objective of the INFN's SCF_Lab has been the development, design, manufacturing, and qualification for space flight of an 'innovative' LRA (laser retroreflector array) of CCRs (cube corner retroreflectors) especially intended for laser ranging operations in the Earth-Moon system; in fact, the innovation is the use of a single, large retroreflector for lunar laser ranging from MLRO (Matera Laser Ranging Observatory) for precision tests of general relativity. The SCF_Lab Team, with support by ASI, is reaching the aforementioned goal, and is going to fly to the Moon two LRAs, namely MoonLIGHT (Moon Laser Instrumentation for General relativity High-accuracy Tests) and INRRI (INstrument for landing-Roving laser Retroreflector Investigation). MoonLIGHT is a LRA, which makes use of a single CCR; it has got a unique and original design, aimed at compensating for the detrimental effect of lunar librations on the precision of lunar laser ranging to the Moon. INRRI is the microreflector array developed by INFN for laser ranging interrogations, from an orbiting laser down to the surface of any suitable planet, satellite, or minor body of the solar system; it has already got space heritage, and it was space qualified for the needs of interplanetary martian missions of two Agencies: ESA's ExoMars EDM 2016 and NASA's InSight 2018. This paper describes INFN's unprecedented payloads, their range of possible uses, and their space qualification process for TeamIndus and Moon Express 1 missions to the Moon, which are both scheduled for 2018/2019. The microreflector may in fact be used also for martian applications, which will be commented, following integration of LaRRI (Laser RetroReflector for InSight) on board the NASA InSight Mars lander. The use of MoonLIGHT for precision tests of General Relativity will be also commented, given its next deployment on our natural satellite.

H0.5-0006-18 UPDATES FROM INPOP EPHEMERIS: FROM FUNDAMENTAL PHYSICS TESTS TO LUNAR INTERIOR PROBE

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We present here, our published results obtained with the latest version of the Planetary and Lunar ephemeris - INPOP17a [1]. The lunar part of this solution is fitted to LLR data (1969- 2017) with constraints imposed on the lunar gravity field coefficients using estimates derived from the GRAIL mission [2]. The post-fit residuals obtained with INPOP17a reach 1.15cm for the recent and most accurate LLR datasets. We take advantage of this accurate model by performing tests of the Universality of Free Fall (UFF) of the Earth-Moon system in the gravitational field of the Sun, in an attempt to find signatures arising from a differential acceleration of the test bodies. We compare our estimates with other LLR analysis groups and show no violation at the $(3.8 \pm 7.1) \times 1014$ [3]. Additional results to be presented include, sensitivity of the UFF violation estimates to various fluid core sizes and the sensitivity of lunar dynamical model parameters to the principal axis PA rotation of the GRAIL solution. The latter as a first attempt to account for incompatibilities found between GRAIL-derived gravity field solutions and LLR estimates [4,5]. Furthermore, new estimates are presented that includes recent 6 months of high accuracy IR LLR data set from Grasse station [6] obtained in 2018.

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H0.5-0007-18 THE SOLAR LENSE-THIRRING EFFECT ON MERCURY AND THE PERSPECTIVES OF MEASURING IT WITH BEPICOLOMBO

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We analytically calculate the time series for the perturbations $\Delta\rho$ (t), $\Delta\dot{\rho}$ (t) induced by a general disturbing acceleration A on the mutual range ρ and range-rate $\dot{\rho}$ of two test particles A, B orbiting the same spinning body of mass M, angular momentum S, equatorial radius and oblateness J2. We apply it to the general relativistic Lense-Thirring effect, due to the primary's spin S, and the classical perturbation arising from its quadrupole mass moment

J2 for arbitrary orbital geometries and orientation of the source's symmetry axis $\hat{S}$. The

Earth-Mercury range and range-rate are nominally affected by the Sun's gravitomagnetic field to the 10 m, 10^{-3} cm s–1 level, respectively, during the extended phase (2026-2028) of the forthcoming BepiColombo mission to Mercury whose expected tracking accuracy is of the order of ~ 0.1 m, 2×10^{-4} cm s–1. The competing signatures due to the solar quadrupole J20, if modelled at the σJ0 10^{-9} level of the latest determinations based on the MESSENGER data analyses, are nearly 10 times smaller than the relativistic gravitomagnetic effects.

H0.5-0008-18 REALISTIC DETECTION OF GRAVITATIONAL EFFECTS VIA OPTICALLY DRIVEN DISPERSION FORCE PARAMETRIC AMPLIFIERS

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The measurement of lengths and times of the unprecedented accuracy anticipated in next generation relativistic metrology experiments naturally indicates the possibility to access regimes in which "gravitation and quantum electrodynamics are both central to the outcome." [1, 2] This prospect has already led to suggestions that highly sensitive measurements of dispersion forces,

[3] such as the Casimir force [4, 5] or the Casimir-Polder force, [6, 7] will yield information about the effects of spacetime curvature on the quantum vacuum. Although both predictions of this type, including via proposed "Gravity Probe-C"-like missions, [8] have yet to be verified, attention has also been focused, in more recent times, on identifying possible effects on dispersion forces due to the existence of spacetime fluctuations. Direct observation of a gravitational Casimir effect in the laboratory would require demonstration of gravitational wave reflectors, which remains a theoretical speculation. [9] The author has proposed investigating fluctuations of the standard electrodynamical Casimir effect due to gravitational waves. [10] In this case, estimates based on already demonstrated approaches for Lifshitz-Casimir dispersion force detection in real materials suggest that optical parametric amplification strategies might succeed in the detection of astrophysical and cosmological stochastic gravitational wave backgrounds. [11, 12] In this presentation, we shall briefly review the fundamentals of Casimir force physics as it applies to this particular application, propose possible future space-based experimentation, and present an epistemological and ontological framework for the interpretation of possible results regarding the ultimate structure of spacetime. [13] Finally, nanotechnology application of Casimir force cavities to gravitational field measurements in space will be discussed.

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H0.5-0009-18 XHPS: A MODULAR APPROACH FOR THE HIGH PRECISION MODELING OF SATELLITE FORMATIONS FOR GEODETIC AND FUNDAMENTAL PHYSICS APPLICATIONS

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Within the scope of the German collaborative research center "Geo-Q", merging on-ground and space-based geodesy, the need for a high precision simulation tool for the investigation of performance analysis for different kinds of space-based geodesy missions has been identified. A generic tool is beneficial for upcoming and operational missions as it allows for flexibility in the implemented mission scenario. Here the generation of mock data can be used a) to optimize and verify data evaluation procedures and b) to analyze and identify error sources within the science signals. However, in order to realize a sensible agreement between the implementation and a real satellite in orbit, thorough details have to be implemented such that all aspects influencing the real satellite operations are covered. In terms of the modeling, this implies not only a considerably realistic and complete implementation of the gravitational field and all non-gravitational disturbance effects (such as Solar, infrared, Albedo and thermal radiation pressures, atmospheric drag etc.) but also precise modeling of the satellite system, the sensors and the actuators, and their couplings. This includes a model of the satellite shape, noise and coupling models for the sensors, thermal flow models as well as a detailed approach on the implementation of the attitude control.

Besides the obvious relevance for existing mission concepts, such a tool is also crucial for the evaluation of the performance of future mission concepts. By generating a "virtual satellite" (or several at the same time) in virtual space, any mission scenario can be analyzed with respect to the chosen science goal and optimized with respect to orbit, formation, a number of spacecraft and sensor requirements.

Originated from HPS, an orbit propagator developed by the Center of Applied Space Technology and Microgravity (ZARM) at the University of Bremen in Germany in cooperation with the Institute of space systems (DLR-IRS) of the German Aerospace Center, the eXtended High Performance satellite dynamics Simulator (XHPS) has been developed during the first phase of Geo-Q from 2015 - 2018. The tool combines high precision data types with accurate implementation of the satellite system and sensor characteristics. The involved methods have strong generic characteristics and are applicable to a broad range of satellite geodesy and fundamental physics mission layouts. In particular multi-satellite scenarios including the interaction between different spacecraft can be simulated. As an example, we show the reproduction of GRACE Level 1B data using XHPS, namely the dynamic state of the satellite and sensor readouts. Furthermore, we introduce the upcoming work towards the implementation of GRACE-FO including the laser ranging interferometer and the analysis of next-generation geodesy mission scenarios.

H0.5-0010-18 AN ASTROMETRIC NETWORK FOR SCIENCE AND ASTRONAUTICS

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The high-precision catalog that will be available from the Gaia mission opens the opportunity to improve on the astrometric tracking and orbit determination of different types of artificial satellites. Such technique has been explored for at least some 25 years with performances ranging from $\sim$ 100 m to tenths of meters, depending on the approach and observing conditions.

A novel implementation of the technique, relying on large angle, high precision astrometry from ground applied to geostationary satellites and other near-Earth space objects observed from two or more telescopes, would allow an accuracy of a few $10^{-}2$ m with 1-meter-class telescopes and a field of view of some arcminutes. The potential benefits for satellite orbit control and navigation systems depend on the number and position of the contributing telescopes, as well as on the target sample.

This idea, although based on proven technologies, represents a novel measurement concept on a planet-wide scale. We discuss the possible applications of a permanent network of automated telescopes for satellite orbit tracking to astrophysics (direct link between Terrestrial and Celestial Reference Frames) and Fundamental Physics.

H0.5-0011-18 THE RELATIVISTIC GEOID: DEFINITION AND APPLICATION

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One of the fundamental tasks of geodesy is to determine the Earth's geoid from gravity field measurements. Within a Newtonian framework, the definition of the geoid combines the Newtonian gravitational potential and the potential related to centrifugal forces that act on the rotating Earth. Modern relativistic geodesy needs to incorporate a relativistic theory of gravity to fully exploit the technological capabilities and for an undoubtedly correct interpretation of specific high-precision measurements.

We present a definition of the geoid that is based on the formalism of general relativity without approximations; i.e., it allows for arbitrarily strong gravitational fields. For this reason, it applies not only to the Earth and other planets but also to very compact objects. We define the geoid as a level surface of a time-independent redshift potential. Our definition is operational because the level surfaces of a redshift potential can be realized with the help of standard clocks, which may be connected by optical fibers. Therefore, these surfaces are also called "isochronometric surfaces." We deliberately base our definition of a relativistic geoid on the use of clocks since we believe that chronometric geodesy offers the best methods for probing gravitational fields with highest precision in the future. However, we also point out that our definition is mathematically equivalent to a definition in terms of an acceleration potential, i.e., that our geoid may also be viewed as a level surface orthogonal to plumb lines.

We comment on the quantitative and qualitative differences between the conventional and relativistic concept. For particular spacetimes, we illustrate the application of our definition and show how conventions and the arbitrariness left in the comparison of respective notions influence the results.

H0.5-0012-18 LARGE SCALE ATOM INTERFEROMETERS FOR GROUND AND SPACE RELATIVISTIC METROLOGY

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The past decades has seen dramatic progress in our ability to manipulate and coherently control the motion of atoms. This exquisite control offers the prospect of a new generation of force sensors of unprecedented sensitivity and accuracy, from applications in navigation and geophysics, to tests of general relativity or study of highly-entangled quantum states. The spectacular sensitivity or matter-wave interferometers can be used for very precise measurements. It is for example possible to measure the acceleration of gravity with an accuracy of 1 part per billion, the rotation of the Earth with an accuracy better than 1 millidegree per hour and detect minute changes in gravity caused by mass displacements. These devices are so precise that they are used today as reference for fundamental constants (mass, gravity), and are powerful candidates to test general relativity on ground, underground or in space.

The future of matter-wave inertial sensors goes far beyond lab-based inertial sensors. While these experiments are typically quite large, require a dedicated laboratory, and are designed to operate well only in environments where the temperature, humidity, acoustic noise is tightly constrained, many efforts have been put in designing compact, robust and mobile sensors. The development of this technology lead to a new generation of atomic sensors that have been operated in airplanes and rockets, that are commercially available and could be the next generation of navigation unit.

This paper will review the recent experimental results with free-fall dual species interferometer, where two atomic species, 39K and 87Rb, are used to verify that two massive bodies undergo the same gravitational acceleration regardless of their mass or composition. We will present the recent progress in measuring the Eotvos parameter which compared the gravitational acceleration measured by two atomic species, and discuss how precision atom interferometry can be used to perform long-term, drift-free integration even in the harsh environment of a plane or a satellite, and thus provide a new tool for precision measurement and navigation. We will also review, large-scale differential gravitational measurement is using an array of Atom Interferometers (AIs) configured to differentiate Newtonian Noise, geodetic signal and GW detection. In this gravitation antenna, each of the AIs measures the local gradient of gravitational acceleration and the correlation between distant sensors enables to cancel out fluctuations of the terrestrial gravitational forces. With the foreseen cold atom technology developments in the next decade, strain sensitivities down to 10-19 in the 0.1-10 Hz band are within reach, offering interesting complementary observations to optical GW detectors operating at other frequencies.

H0.5-0013-18 AN APPROACH FOR THE GLOBAL-WISE ONE-STEP TIME AND FREQUENCY TRANSFER

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GNSS geodetic techniques have been widely used for time and frequency transfer. Among different approaches, they could be grouped into two types: pseudo-range based and carrierphase based. Pseudo-range approaches are implement for real-time applications but with low accuracy due to big Pseudo-range noise, and carrier-phase approaches have much higer accuracy but are normally realized in post-processing with a latency from several hours to weeks. In this paper, we proposed an algorithm based on GNSS network solution, which uses high accuracy carrier-phase data and can be implement for real-time data analysis. We applied this method using regional and global GPS networks for time and frequency transfer. We also demonstrate the benefits of this new approach for the one-step process for global-wise time and frequency tranfer, where all timing laboratories could be connected and combined.

H0.5-0014-18 PERSPECTIVES FOR ATOM INTERFEROMETERS IN SPACE

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Atom interferometry can be utilized for the measurement of rotations, accelerations and for tests of fundamental physics. In these devices, typically three laser light pulses separated by a free fall time coherently manipulate the matter waves which resembles the Mach-Zehnder geometry in optics. Atom gravimeters demonstrated an uncertainty of few 10^{-8} m/s2, atom gradiometers showed a noise floor of 5 10^{-9} $s^{-}2$ $Hz^{-1/}2$, and dual atom gravimeters tested the universality of free fall to parts in 10^{8}.

Further improvements of atom interferometers are anticipated by the integration of novel source concepts providing condensed and collimated atomic ensembles, which enables an extension of the free fall time and enhanced techniques for coherent manipulation. The QUANTUS collaboration pioneered these techniques and exploited the unique features of microgravity in drop tower experiments and in a sounding rocket mission. The latter demonstrated the first Bose-Einstein condensate in space. All these activities serve as pathfinders for applications in space.

This contribution will outline capabilities of atom interferometers, anticipated improvements, and the perspective for future space missions as tests of the universality of free fall and gradiometry for earth observation based on atom interferometery.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) due to an enactment of the German Bundestag under grant numbers DLR 50WM1551-1558, 50WP1431, 50WP1700, by the Deutsche Forschungsgemeinschaft in the framework of the SFB 1128 geo-Q, and by “Niedersächsisches Vorab” through the “Quantumand Nano-Metrology (QUANOMET)” initiative within the project QT3.

H0.5-0015-18 GENERAL RELATIVISTIC GEODESY - BENEFIT AND CHALLENGES

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Owing to the ever increasing precision of new instruments for practical geodesy like atom interferometers, clocks, and lasers, it is possible to measure the gravitational field with a precision never achieved, also on a global scale. This goes along with the necessity to employ General Relativity in the theoretical modelling of the measurements and of the gravitational field of the Earth.

In this talk, after first reminding at the basic tasks of geodesy, the new instruments will be described and it will be explained how they are of use for geodetic purposes and how they complement the existing instruments. Due to the inclusion of General Relativity the framework of geodesy has to be adapted accordingly. Therefore, in the second part of the talk the corresponding new general relativistic notions for geodesy like the geoid, height, leveling, elipsoid, etc. are described and compared with the usual notions in the traditional Newtonian framework. The third part of the talk then concentrates on the remaining challenges in setting up a fully relativistc framework for practical geodesy. The challenges to be addressed are, among others, the definition of the geoid in a time-dependent environment, the procedure of levelling in the framework of General Relativity, how one can measure the geoid with satellites, what is the full general relativistic gravitational field of the Earth, what kinf of measurements with satellites can tell us about the complete gravitational field of the Earth, how the measured gravitational field is related to the mass distribution of the Earth, or what is the relativistic ellipsoid. It will finally be pointed out that such precision measurements may also be used for improved tests if General Relativity.

H0.5-0016-18 CLOCKS IN SATELLITE NAVIGATION

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Clocks play a fundamental role in satellite positioning, based on GNSS. The basic measured quantity is the travel time of light from the satellites to the receivers requiring clocks at both ends. The ingenious concept of global satellite navigation however allows the epoch-wise synchronization of all clocks which leads to the paradoxical situation that, although GNSS bases of precise travel time measurements, no ultra-stable clocks are required. For geodetic applications of GNSS today either all satellite and receiver clock offsets are estimated epoch-wise with re- spect to an arbitrary reference clock or clock parameters are eliminated by double-differencing of observations which is equivalent. Driven by navigation the satellite clocks get more and more stable. The hydrogen masers onboard Galileo satellites and the Rubidium clocks onboard GPS Block IIF satellites show an excellent performance, offering the potential for further exploita- tion of this stability. As an example the presentation will demonstrate the impact of clock modelling on precise GNSS orbit determination and discusses further applications.

H0.5-0017-18 PORTABLE OPTICAL LATTICE CLOCKS FOR CHRONOMETRIC LEVELLING AND SPACE APPLICATIONS

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With their supreme accuracy and precision, optical clocks are highly interesting as tools to sense gravity or for precision test of fundamental physics on ground and in space.

The first aspect is related to chronometric levelling, where the difference frequency between two clocks measured via e.g. an optical fibre link is related by the relativistic redshift to the potential difference between both clocks. This opens-up a new tool for geodesy that provides high special resolution and avoids accumulation of measurement errors, as in classical levelling. Here, transportable optical clocks will provide the flexibility required by geodesy to choose measurement sites. We will present the

evaluation of a transportable strontium-87 lattice clock that is installed in an air-conditioned car trailer for operation in field campaigns. With this clock, we have reached a fractional frequency uncertainty of 2×10−17, which corresponds to a height resolution of 10 cm. This resolution is achieved after 8000 s of averaging. The application of this clock for field campaigns will be discussed.

The second apparatus we will discuss originates from the Space Optical Clock consortium, which has the goal to prepare a space mission with a Sr optical lattice clock. The setup is optimized for compactness and low power consumption to provide design guidelines for spaceworthy constructions. Presently, the clock is operated with the boson 88Sr. By comparison against PTB's 87Sr laboratory clock, we have measured the isotope shift between 88Sr and 87Sr with an uncertainty of about 12 mHz.

This work is supported by DFG (CRC 1128), EU-FP7 (Marie Curie ITN FACT) and the ESA-funded project iSOC.

H0.5-0018-18 SPACE-BORNE GRAVIMETRY WITH CLOCKS

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The US/German GRACE and European Space Agency GOCE satellite missions have shown the importance of sustained space-borne gravimetry for observing and understanding mass transport in the Earth system, which can be considered an essential climate variable. For the near future, i.e. the 2017-2022 time frame, continued observation is foreseen by the Grace Follow-On mission. For the more remote future, i.e. after 2022, GRACE-II and a Next Generation Gravity Mission are under study and/or proposed by the US and the European Space Agency. All these missions rely on the very precise observation of the inter-satellite distance, referred to as low-low satellite-to-satellite tracking (ll-SST). For the very long term, i.e. beyond 2030, additional observation concepts are being considered, including satellite gravity gradient cold-atom interferometry and the use of ultra-precise atomic clocks. This paper revisits the fundamental equations for atomic clocks in relation to among others gravity. Moreover, an assessment is made of the feasibility of using ultra-precise space-borne atomic clocks for observing Earth's time variable gravity field by means of an efficient error propagation tool. It is shown that very strict and challenging requirements need to be met for using clocks for space-borne observation of the local potential height. Especially the velocity of the space-borne clock needs to be known with extreme high precision. High precision knowledge about the velocity of the satellite provides more accurate information on the gravity field than the use or orbiting clocks. However, clocks with high long-period stability may be advantageous in orbit determination, as the behavior of the clock can be estimated over a longer arc than its translational state.

H0.5-0019-18 VLBI NETWORKS AND FIBER OPTIC LINKS USED TO COMPARE REMOTE ATOMIC CLOCKS

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Very Long Baseline Interferometry experiments require an extremely precise synchronization between the atomic clocks keeping the time and frequency standards at radiotelescope observatories. Recently the availability of fiber optic links from the a few radio observatories and their national metrological institutes has made possible the streaming of extremely stable frequency standards via optical atomic clocks (even two order of magnitudes better than Rubidium or Hydrogen maser standards). In this talk I will present the infrastructure of the Italian Link for Frequency and Time (LIFT) and a few results of the MetGesp project obtained as part of the efforts to create a common clock between two of the antennas of the VLBI Italian Network. Finally I will describe how the VLBI technique can be used to accurately compare atomic clocks located at very distant (a few hundred km) sites as a valid and competitive alternative to satellite-based techniques such as GPS or Two-way Satellite Frequency and Time Transfer.

H0.5-0020-18 ABOUT THE RESULTS OF TESTING MODERN GLOBAL GEOPOTENTIAL MODELS BY COMPARING THE MODEL DATA AGAINST INDEPENDENT GROUND DATA ON THE TERRAIN OF THE WESTERN SIBERIA

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Results of our study of modern global models of Earth's gravitational field, obtained from observations of space gravimetric missions CHAMP, GRACE and GOCE, are briefly outlined. Spectral analysis using the harmonic coefficients of modern global geopotential models is performed. As a result, estimates of resolution and accuracy of the investigated models were obtained. Testing of accuracy of modern global geopotential models is performed by comparing the model data against independent ground-based determinations of quasigeoid heights along with gravimetric measurements conducted on the territory of Novosibirsk region. The results of our study allow us to conclude that the standard methods employed to improve the resolving power and accuracy of Earth's gravitational field models, have reached their own limitations in both technical and methodological aspects of their applications. Therefore, development of new technological approaches and methodological principles is required for further improvement of Earth's gravitational field approximation. This implies creation of new concepts and techniques in studying gravitational field of the Earth. Keywords: CHAMP, GRACE, GOCE, ground gravity data

H0.5-0021-18 GEO-Q - RELATIVISTIC GEODESY AND GRAVIMETRY WITH QUANTUM SENSORS

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The Collaborative Research Center (CRC) 1128 "Relativistic Geodesy and Gravimetry with Quantum Sensors" - or short geo-Q - studies and uses modern quantum physics to develop and utilize innovative experimental devices and measurement techniques, and to develop new theoretical and modeling methods for high precision recovery of the Earth's gravitational field in the next decade and beyond. It focuses on the development of atomic gravity sensors, laser interferometry for satellite gravimetry and optical clocks. The contribution will give an overview about the fundamental research conducted within geo-Q and its applications in geodesy.

H0.5-0022-18 COLD ATOM INTERFEROMETERS USED IN SPACE (CAIUS) FOR MEASURING THE EARTH'S GRAVITY FIELD AND PREPARATORY LABORATORY ACTIVITIES

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In the past decades, it has been shown that atomic quantum sensors are a newly emerging technology that can be used for measuring the Earth's gravity field. Whereas classical accelerometers typically suffer from high noise at low frequencies, cold atom interferometers are highly accurate over the entire frequency range.

The first airborne gravity survey during the ESA Cryovex/KAREN 2017 campaign using this technology was conducted by DTU and ONERA. The survey started with a return flight along a profile from Akureyri to Snæfellsnes, for which the reproducibility of the instrument's measurements was better than 4.5 mGal in terms of standard deviation. A gravity survey over the glacier Vatnajokull was then realized during three days flying. The measurements did not show any drift and their accuracy was found to be a few mGal, leading to the conclusion that the world's first airborne campaign using an absolute CAI gravimeter was a full success.

In space, there are two ways of using that technology for measuring Earth's gravity field. The first is a gravity gradiometer concept that has a high common mode rejection, which greatly relaxes the drag-free control requirements compared to the GOCE mission. The second is to deploy quantum accelerometers for correcting low frequency errors of electrostatic accelerometers that are used in a low-low satellite-to-satellite ranging concept for measuring non-gravitational accelerations. We will present for both concepts the expected improvement in measurement accuracy and the expected improvement of Earth gravity field models, taking into account the different types of measurement (e.g. single axis vs. three axes, integration time, etc.) and different mission parameters such as attitude control, altitude of the satellite, lifetime of the mission, etc.

Additionally, we outline the planned mission preparatory laboratory activities that aim at exploiting synergies between fundamental physics missions (week equivalent principle, gravitational redshift), planetary exploration and Earth observation missions.

H0.6-0001-18 INERTIAL ULTRA-COLD ATOM SENSORS IN WEIGHTLESSNESS

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Quantum technology based on cold-atom interferometers is showing great promise for fields such as inertial sensing and fundamental physics. However, the best precision achievable on Earth is limited by the free-fall time of the atoms, and their full potential can only be realized in Space where interrogation times of many seconds will lead to unprecedented sensitivity. Various mission scenarios are presently being pursued, which plan to implement matter-waves inertial sensors to detect gravitational waves, to measure the Earth gravity field or to test fundamental physics such as the Equivalence Principle.

We developed a cold atom sensor experiment adapted to microgravity platforms, especially the ZERO-G plane. To achieve a test of the Universality of Free Fall, we realize the first onboard operation of simultaneous 87Rb -39K interferometers in the weightlessness environment produced during parabolic flight. The large vibration levels (10−2 g/Hz1/2), acceleration range and rotation rates (5 deg/s) during flight present significant technical challenges for atom interferometers. By hybridizing each atomic sensor with a common mechanical accelerometer, we achieve a sensitivity of 3.4 10−5 g per shot-more than 1600 times below the ambient vibration level onboard the aircraft. We demonstrate the capability of our dual-quantum sensor by measuring the Eötvös parameter with systematic-limited uncertainties of 3.0 10−4 during microgravity. This constitutes the first quantum test of the equivalence principle in a free falling vehicle. Our results can be extended to the trajectory of a satellite for future Space missions. We also achieved a simultaneous 87Rb-39K interferometer on ground with a long term stability on the differential acceleration measurement around 5 10−8g, limited by the fall of the atom clouds. To increase the interrogation time and the sensitivity, a ZERO-G simulator has been installed in our laboratory and allows our experiment to be in free fall during 500 ms every 12 seconds, to achieve highly repeatable measurements in microgravity. We expect to increase our short-term sensitivity by two orders of magnitude, and consequently reach a long-term measurement of the Eötvös parameter at the level of 10−11.

To benefit from the free fall of the experiment completely, it is necessary to produce atoms clouds with a reduced velocity dispersion. To reach this goal, we put 87Rb atoms in an optical

dipole trap supplied by a compact fiber laser compliant with onboard applications and decrease the optical power on a very controlled way to obtain evaporative cooling. Preliminary results of ultra-fast evaporative cooling (less than a few seconds) onboard the ZERO-G plane allowed us to reach a regime of temperature compliant with an interrogation time of the order of one second. This method and technology will be tested on the ZERO-G simulator as well.

H0.6-0002-18 COMPACT COLD ATOM SYSTEMS - PROSPECTS FOR SPACE APPLICATIONS

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The magneto-optic trap (MOT) is the workhorse behind virtually all cold neutral atom experiments. It is based on the viscous damping obtained from laser cooling and a restoring force guiding atoms towards the zero-point of a magnetic field. This constitutes a trap for neutral atoms and they are held there at a temperature typically of order 1 mK. A sufficient number of atoms can be collected from a thermal vapour to form the basis for a large number of experiments including precision measurements such as atomic clocks and atom interferometry. The potential has been recognised for extending the use of these cold atom sources to space-based applications such as space-qualified atomic clocks and timing devices (incl. GNSS), remote sensing (incl. gravity measurements), deep-space navigation and tests of fundamental principles of physics. A key requirement for this would be the development of robust technologies to support extended and autonomous operation of what has so far mainly been complex and labour intensive laboratory-based experiments. This includes lasers and optical technologies as well as associated vacuum systems and signal processing and control electronics. The magneto-optical trap that is presently in use in hundreds of experiments across the world is essentially the same as that used in the first demonstration more than 30 years ago. While being remarkably robust the standard system remains bulky and requires alignment of multiple laser beams. Here we report on a programme that is developing microfabricated diffraction gratings as core elements for simplifying the MOT setup [1]. This enables single-beam laser cooling free of regular alignment and is a key step in reducing the size and weight of cold-atom systems. Additionally, this approach opens avenues for realising compact vacuum systems, which offers further reductions in the overall power requirements. We demonstrate how this technique provides performance in terms of atom number and temperature comparable to that of the conventional MOT configuration. The system has been realised both in a single and a double-chamber setup. In the case of the latter a microfabricated diffraction grating optimised for a 2D MOT configuration was used to inject atoms into an adjacent chamber equipped with a grating for a 3D MOT. This forms the starting point for ongoing work on rapid creation of a BEC for space applications. By rapidly switching off the MOT magnetic field the grating setup has been demonstrated to produce atomic ensembles at 3μK [2]. We report on the use of such samples in a compact atomic microwave clock based on coherent population trapping.

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H0.6-0003-18 BECCAL - QUANTUM OPTICS WITH BOSE-EINSTEIN CONDENSATES AND MIXTURES ABOARD THE ISS

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The joint NASA-DLR Bose-Einstein Condensate and Cold Atom Laboratory (BECCAL) will be a multi-user, multi-purpose facility aboard the International Space Station (ISS). BECCAL is designed to be a versatile toolbox for a multitude of experiments with ultra-cold Rb and K atoms, and their mixtures in regimes and timescales inaccessible on ground. The absence of gravitational sag and the method of matter-wave lensing enable experiments on ultra-long time-scales and unreached fidelity.

The system will be based on the design of drop tower and sounding rocket experiments QUANTUS and MAIUS including an atom chip for efficient evaporation and excellent control of the quantum degenerate atomic clouds. The setup will provide an abundance of time-dependent potentials including magnetic, RF-dressed as well as redand blue-detuned optical potentials. This will serve as a platform to realize experiments in matter-wave optics, physics of quantum degenerate gases, their mixtures, and atom interferometry to test fundamental principles of physics, e. g. to test Einstein's Equivalence Principle.

We present an insight on possible experiments and their expected performance in BECCAL.

This talk presents work of the NASA-DLR funded BECCAL cooperation. The BECCAL project is a collaboration of LU Hannover, U Ulm, HU Berlin, FBH Berlin, JGU Mainz, DLR Institute of Space Systems Bremen and ZARM at U Bremen. It is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under the grant numbers 50WP1431 and 50WP1700.

H0.6-0004-18 COLD ATOM INTERFEROMETRY: FROM GROUND TO SPACE

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Atom interferometry is now proven to be a very efficient technique to achieve highly sensitive and absolute inertial sensors. As a matter of fact gyroscopes or gravimeters based on this technique by using cold atoms have already been developed reaching state-of-the-art performances. This kind of instruments should allow significant advances in fields such as navigation, geophysics or fundamental physics and appear also very promising candidates for future satellite missions for gravity field mapping or testing the Einstein's general relativity (Equivalence Principle, Lense-Thirring effect).

Our work focuses in particular on the development of cold atom instruments for onboard applications dedicated to gravity field measurements from mobile platforms such as boats, aircrafts or satellites. We will present ongoing developments at ONERA in this context and in particular recent results obtained in collaboration with DGA, SHOM and DTU concerning the elaboration of a gravity map from a ship and an aircraft using an absolute cold atom gravimeter. The presentation will show also the first steps we take toward a future space geodesy mission, conducted in collaboration with TUM and ESA, aiming to hybridize a cold atom instrument with a state-of-the-art space electrostatic accelerometer.

H0.6-0005-18 MATURING SPACE-BASED PRECISION METROLOGY WITH QUANTUM GAS STUDIES ABOARD THE ISS

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Precision atom interferometers (AI) in space are expected to become an enabling technology for future fundamental physics research, with proposals including unprecedented tests of the validity of the weak equivalence principle, measurements of the fine structure and gravitational constants, and detection of gravity waves and dark matter/dark energy. We will discuss our preparation at JPL to use NASA's Cold Atom Lab facility (CAL) to mature the technology of precision, space-based, AIs. The focus of our flight project is three-fold: a) study the controlled dynamics of heteronuclear Feshbach molecules, at temperatures of nano-Kelvins or below, as a means to overcome uncontrolled density-profile-dependent shifts in differential AIs, demonstrate unprecedented atom-photon coherence times with spatially constrained AIs, use the imaging capabilities of CAL to detect and analyze spatial fringe patterns written onto the clouds after AI and thereby measure the rotational noise of the ISS. The impact from this work, and potential for follow-on studies, will also be reviewed in the context of future space-based fundamental physics missions.

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

H0.6-0006-18 POINT SOURCE ATOM INTERFEROMETRY FOR INERTIAL NAVIGATION AND PRECISION MEASUREMENTS

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Atom interferometers are being developed for applications like navigation and geodesy as well as for testing fundamental physics, where they may help answer important outstanding questions. Most of these applications will ultimately require portable instruments, and balancing performance and simplicity is an ongoing challenge. As a potential path forward, we evaluate the technique of point source atom interferometry (PSI) [1]. With PSI, the Raman $\pi/2$ π $\pi/2$ pulse sequence is applied to a ballistically expanding cloud of cold atoms. Because of the correlation between final position and atom velocity, a spatial sinusoidal fringe pattern arising from rotations is imprinted on the atom population at the end of the pulse sequence. By imaging the fringe pattern, the PSI technique simultaneously measures acceleration in the propagation direction of the Raman lasers and rotation in the plane perpendicular to that direction. This simple experimental geometry makes the technique promising for miniaturization and hence portable applications. We have previously demonstrated a PSI gyroscope, which used a vacuum volume of 1 cm3 [2]. We will present our ongoing work on optimizing and characterizing the system.

[1] Dickerson et al., Phys. Rev. Lett., 111, 083001 (2013) [2] Hoth et al., Appl. Phys. Lett., 109, 071113 (2016)

H0.6-0007-18 THE SPACE ATOM LASER - A CAL FLIGHT EXPERIMENT

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Up to now atom-laser experiments have been performed in earth-bound laboratories, where the dominant force acting on the outcoupled atoms is gravity, which results in a directed and accelerated beam of atoms leaving the condensate. Here we propose to enter a completely new regime for the atom laser by taking advantage of NASA's Cold Atom Laboratory (CAL): thanks to the microgravity conditions on the ISS it is possible to create a unique shell-like atom laser which slowly expands away from the initial BEC driven only by the repulsive interaction between the atoms. This phenomenon can be exploited to establish a nearly isotropic source for ultra-cold atoms in microgravity.

We present a scheme based on radio-frequency outcoupling that enables the generation of a slowly expanding shell of atoms featuring an isotropic momentum distribution even if the initial BEC was trapped in an elongated anisotropic trap. This output is achieved by resonantly outcoupling at the very edge of the BEC with relatively small coupling strength in order to establish a spatially well-localized and state-selective outcoupling process.

In order to prepare for the CAL flight campaign, we report on our recent progress towards a realistic modeling of atom-laser experiments in microgravity taking into account higher-order contributions to the Zeeman effect and fluctuations of the number of particles and the Rabi frequency as well as varying magnetic fields. In this way we identify a promising parameter regime for a successful realization of the space atom laser with CAL.

H0.6-0008-18 AN ULTRA-HIGH VACUUM SYSTEM FOR THE MAIUS-2/3 ATOM INTERFEROMETER ON A SOUNDING ROCKET

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During the two sounding rocket missions MAIUS-2 and MAIUS-3, it is planned to perform sequential and simultaneous dual-species atom interferometry with Bose-Einstein condensates of

Potassium-41 and Rubidium-87. The microgravity environment offers experiments on timescales that are not possible on ground. To perform long lifetimes of the BEC, a pressure 5·10−10

mbar needs to be reached and maintained in the vacuum chamber. During ascent of the rocket, vibrational loads of 1.8 g RMS in the frequency range of 20-2000 Hz and accelerations of up to 13 g are applied to the vacuum system and the payload. During re-entry and landing static loads can reach a level of up to 50 g. The ultra-high vacuum system presented in this talk is designed to withstand these loads while maintaining the vacuum quality. Sealing technologies and pumping concepts as well as used commercial parts, needed to be tested and qualified. This talk presents the ultra-high vacuum system of the MAIUS-2/3 payload and its vibration and qualification tests at the shaker test facility at the Center of Applied Space Technology and Microgravity (ZARM) in Bremen.

H0.6-0009-18 ACCELEROMETERS FOR FUNDAMENTAL PHYSICS AND SOLAR SYSTEM EXPLORATION

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In the last decades the role of space-qualified high-sensitivity accelerometers — devices which measure tiny accelerations acting on spacecraft due to non-gravitational forces — has increased considerably. Today their use is a first-choice option in all the cases — as fundamental physics

— where small dynamical effects must be accounted for a good outcome of the mission. In this talk the accelerometers developed by the Experimental Gravitation Group of IAPS-INAF are presented, focusing on their concept, design, performance verification and calibration strategies. Their main applications in fundamental physics tests, as well as in the exploration of the Solar System, are discussed, with an outlook to the near-future.

H0.6-0010-18 LISA TECHNOLOGIES FOR OTHER PURPOSES: ONGOING DEVELOPMENT OF EXTREMELY PRECISE AND STABLE OPTICAL SYSTEMS

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The Laser Interferometer Space Antenna (LISA) mission has pushed the state of the art of high precision and stability optics further than ever before. Some of the concepts and technologies can be re-purposed to the benefit of other industries and science endeavors. A modular and integrable optics system built from conventional engineering materials has been in development and is steadily moving ever closer to LISA like stability levels. This system will be capable of interferometry, metrology, optical communication and will include: monolithic piezo actuated steerable optic mounts, optical bench, and a metal-to-glass structural interface. Further experiments are planned to demonstrate nano-meter angular resolution of the steering mirror and pico-meter optical path stability in the 0.1 Hz to 1 Hz LISA band. A compact and lowcost shaker table for space-flight qualification tests of experimental LISA technology has also been in development. This hardware could bring preliminary flight testing in-house to save time and money compared to off sight evaluation. The shaker table will give other institutions the opportunity to enjoy more cost effective and partially in-house flight qualification of their experiments or even small satellites. Motivated by space science metrology needs the optical system is designed to be compact, low cost, and highly configurable which makes it relevant to a diverse range of applications beyond LISA which may require such scientific instrumentation.

H0.6-0011-18 DESIGN OF A CUBESAT PAYLOAD TO TEST A MAGNETIC MEASUREMENT SYSTEM FOR SPACE-BORNE GRAVITATIONAL-WAVE DETECTORS

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Space observatories for gravitational radiation such as LISA are equipped with dedicated onboard instrumentation capable of measuring magnetic fields with low-noise conditions at millihertz frequencies. The reason is that the core scientific payload can only operate successfully if the magnetic environment meets certain strict low-frequency requirements. With this purpose, a simplified version of the proposed magnetic measurement system for LISA has been developed for a six-unit CubeSat, which will make it possible to improve the technology readiness level (TRL) of the instrument. The special feature of the experiment is that the magnetic sensors integrated in the payload are magnetically shielded to low-frequency fluctuations by using a small cylindrical permalloy enclosure. This will allow the in-flight noise characterization of the system under the CubeSat orbit environment. Therefore, a CubeSat platform will offer the opportunity to measure the capability of the instrument and will guide the progress towards the improved magnetic measurement system for LISA. This talk describes the principal characteristics and implementation of the CubeSat payload.

H0.6-0012-18 OPTICAL IODINE FREQUENCY REFERENCES FOR SPACE

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Highly stable frequency references are an essential component for several space experiments and missions in the field of global navigation satellite systems (GNSS), Earth observation and geodesy as well as for tests of fundamental physics e.g. gravitational waves detection and special relativity. Here we present our latest efforts in development and qualification of absolute optical frequency references based on Doppler-free saturation spectroscopy of molecular iodine, where a laser is stabilized onto one of the hyperfine transitions near 532 nm using modulation transfer spectroscopy. This wavelength can be conveniently obtained by frequency doubling a 1064 nm laser source which is baseline e.g. for LISA and GRACE-FO missions. In conjunction with their high long-term stability and low complexity, optical iodine clocks are a promising candidate for use on future space missions. In collaboration with the Humboldt-University of Berlin and the Laboratory of Enabling Technology at Airbus Defence and Space GmbH in Friedrichshafen, three spectroscopy units have been realized with emphasis towards space compatibility. A setup on elegant breadboard level (EBB) using a 30 cm long iodine cell in triple pass configuration has been integrated on a thermally and mechanically stable 55 x 25 cm^2 glass ceramic base plate [1], as well as a more compact setup on engineering model level (EM) realized on a 38 x 18 cm^2 fused silica base plate, where a squared iodine cell in 9-pass configuration is used to reduce overall dimensions while preserving absorption length [2]. Similar frequency instabilities in the 10–15 domain at integration times between 10 s and 1000 s could be shown with both of the setups, whereas the EM unit was

additionally subjected to thermal cycling and vibrations. As a major step towards space, a spectroscopy unit for use on a sounding rocket mission scheduled in May 2018 has been developed and realized [3]. Optimized in terms of compactness and ruggedness, a 15 cm long tube cell in double pass configuration and all necessary optical components have been integrated on a 24.6 x 14.5 cm^2 fused silica base plate.

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H0.6-0013-18 THE ISA ACCELEROMETER IN VIEW OF BEPICOLOMBO LAUNCH

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The BepiColombo Italian Spring Accelerometer (ISA) is a component of the dedicated suite of instruments which will perform the so-called Radio Science Experiments in order to study gravitational field, internal structure and rotational state of the planet Mercury, and to verify important predictions of the general theory of relativity. Its main role is the measurement of non-gravitational accelerations acting on the surface of the Mercury Planetary Orbiter spacecraft, thereby enabling to work on a virtually drag-free satellite. In this talk the concept, design and development of the instrument are reviewed, along with its main scientific products. The development and testing of the data processing procedures, as well as the definition of the instrument operations for the various mission phases, are also presented.

H0.6-0014-18 PERFORMANCE OF THE DAMPE IMAGING CALORIMETER IN SPACE

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The Dark Matter Particle Explorer, primarily designed to directly measure high energy electrons (positrons, gamma rays) in cosmic radiation, was launched successfully on Dec 17th, 2015, and, since then, it is in continuous data taking. The calorimeter of the DAMPE apparatus has been designed to measure the energy of incident particles and identify electrons (positrons) from protons (antiprotons) with high efficiency and rejection power. It is a total absorption 3D BGO imaging calorimeter, which comprises 308 BGO crystal logs. In this work we present the on orbit performance of the calorimeter, including the measured energy reconstruction and identification capabilities. The calorimeter provides a proton rejection factor of 105 while keeping a high efficiency in selecting electrons and positrons. We also show that, after two years operation in space, the calorimeter is still performing nominally.

H0.6-0015-18 A NOVEL APPROACH FOR TRACKING PARTICLES IN SPACE

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In the last decades new silicon detector technologies were developed for and applied to particle tracking in different research fields, namely high energy physics, nuclear physics, radiation physics, dosimetry and medical physics. Nonetheless, tracking high energy particles in space continues exploiting microstrip detectors, based on a concept of late 80s. An important problem is rising, since future space applications will require better performances, e.g. lower thickness and sub µm spatial resolution tracking over O(100)m2 areas. Monolithic Active Pixel Sensors, based on commercially-available CMOS technology, offer an interesting solution for this scenario. They are O(µm) sized pixel with integrated readout, allowing on-chip zero suppression and being at the same time suitably radiation hard and cost-effective. Studies on MAPS suitability for space applications are presented, taking as a reference the case of ALPIDE, developed at CERN for the ALICE Inner Tracking System Upgrade, and proposed for the High Energy Particle Detector of the Second China Seismic Electromagnetic Satellite.

H0.6-0016-18 RESEARCH ABOUT TEMPERATURE CONTROL SYSTEM FOR THE CABIN OF THE SCIENTIFIC BALLOON

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Currently, the scientific balloon has achieved good development and applied in a wide range, especially for scientific exploration in extreme regions. However, the payload requires very limited environment. Too high or too low temperature is not good for the normal operation of the equipment. Too high temperature may even cause equipment failure. Therefore, the temperature control inside the cabin is essential. This article studies temperature control for the cabin of a scientific balloon by statistics the heating power of the payload and designing a set of control scheme to ensure that the temperature was within the required range. The comprehensive performance of the heating power of the payload, the heating equipment and the cooling fan were simulated by software ANSYS. Through the analysis of the distribution of temperature field and velocity field on different cross section, the pattern of the gas flow and heat transfer in the cabin are obtained. Based on the simulation results, the design of the cabin and the location of the thermal payload can be further optimized. Finally, we also tested the analysis results on a scientific balloon, the test results and analysis of the results are basically the same, indicating that the control scheme is feasible. The work provides a practical reference for the temperature control of cabin for scientific balloon and stratospheric airship.

H0.6-0017-18 THE EPD INSTRUMENT CONTROL UNIT

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The EPD experiment aims to measure the composition, spectra, timing and distribution functions of suprathermal and energetic particles. The main scientific topics to be addressed include the sources, acceleration mechanisms, and transport processes of these particles. This experiment is an instrument suite consisting of several sensors measuring electrons, protons and ions over a broad energy interval (2 keV to 15 MeV for electrons, 3 keV to 100 MeV for protons and few tens of keV/nuc to 450 MeV/nuc for ions), that is part of the Solar Orbiter payload. Solar Orbiter is the first medium-class mission of ESA's Cosmic Vision 2015-2025 Programme. All operations of the instrument are handled by the EPD Instrument Control Unit (ICU), which is composed of a Common Data Processing Unit (CDPU) and a LVPS (Low Voltage Power Supply). The CPU of the experiment is based on a LEON2 architecture (a SPARC V8 implementation) running the RTEMS real time operating system. The main purpose of the ICU is to control and communicate the sensors (EPT, HET, SIS and STEP) with the spacecraft. Communications between EPD and the satellite are performed via a SpaceWire links. Data acquisition from the sensors is performed via a UART/LVDS 115200 bps interface. In this work, we describe the ICU of the experiment and the general software scheme.

H0.6-0018-18 A NOVEL THEORETICAL MODEL FOR THE FAMOUS QUANTUM PHYSICS PARTICLE - WAVE DUALITY EXPERIMENT AND GENERALIZATION OF THE SCHRODINGER EQUATION: IMPLICATIONS FOR SPACE EXPLORATION.

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A novel theoretical model for the famous quantum physics particle - wave duality experiment: implications for space exploration.

The famous Thomas Young double -slit diffraction experiment for light, proving the wave nature of light, was performed in 1803, far before the advent of quantum physics in the 20th century. Nonetheless, this old experiment remains at the heart of understanding quantum mechanics, as was noted by Richard Feynman. It introduces such unusual concepts as non-locality of a particle in a micro world and a dualism of particle-wave nature.

There were many attempts undertaken to elucidate the results of this experiment. Some were even based on the “wavy” structure of space itself, and on the concept that the particles are influenced by that “wavy” nature of the ambient environment. Other interesting interpretation is a multi-universe model. But there are many arguments against this multiverse theory. Despite the wide usage of the quantum mechanical effects, to-date there is still no consistent, complete explanation of this most famous experiment in quantum physics.

An absolutely novel approach and corresponding consistent theoretical model will be presented to explain the results of this important quantum physical double-slit experiment in its entirety. The model is non-linear, time-dependent and multi-phase. For this particular case, a particle wave duality will be elucidated using an experiment with an electron /electron gun. Nevertheless, the results are applicable to other plasma particles, also to photons, atoms, sub-atomic and other particles of the micro world. The results of my theoretical model are also consistent with the results of the Delayed Choice Quantum Eraser Experiment (1999). This experiment can be considered a modified initial double-slit experiment.

The famous long-standing Schrodinger equation will be generalized by a novel boundary value problem. This new mathematical approach will help to better describe and elucidate the reality of a micro world.

The ramifications for the space exploration will be be discussed as well.

H0.6-0019-18 THERMAL DESIGN OF A QUANTUM OPTICS EXPERIMENT ABOARD THE ISS

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Bose-Einstein Condensate - Cold Atom Laboratory

Bose-Einstein Condensate - Cold Atom Laboratory (BECCAL) is a high precision quantum optics experiment about to fly on the International Space Station (ISS). BECCAL is a bilateral collaboration established between NASA and DLR. The facility shall satisfy the needs of both the American and German scientific community concerning cold atoms physic.

Proper thermal stabilization of any high precision experiment is crucial to its operation. Here, the requirements are further complicated by having to fit the constraints of the ISS. This contribution will cover a summary of the occurring thermal loads and present a concept of the Thermal Control System (TCS).

The predecessors to BECCAL are the sounding rocket campaigns MAIUS (MAteriewellen Interferometrie Unter Schwerelosigkeit - Matter wave interferometry in microgravity). MAIUS was developed by a German consortium and produced the first BEC in space. Consequently BECCAL inherits many systems and components from MAIUS with planned novel features. BECCAL shall be housed in a quad locker and a single locker inside an EXPRESS (Expedite the PRocessing of Experiments to Space Station) rack on the ISS. For this reason the payloads structure and the TCS have to be adapted.

BECCAL consists of three main systems: The laser system, the control electronics and the physics package. Especially the electronic components and the laser induce high thermal loads to the structure. In addition, most of the electronic and laser components require a narrow temperature range and a limited temperature gradient during operations. The lasers, for instance, require a frequency and power stabilization during operation to allow for an ideal performance. Therefore, the TCS has to stabilize the micro optical bench of the lasers to ± 0.1 K. Considering the high electrical powers averaging 850 W with a peak power of up to 1.13 kW in close proximity to the lasers, thermal stabilization has to be designed carefully to meet the payloads requirements.

The ISS provides multiple options for thermalizing installed payloads. Two of which are considered for BECCAL: A water cooling cycle in a Moderate Temperature Loop (MTL) and a ducted air cooling via the Avionic Air Assembly (AAA). The Rack provides two interfaces to the MTL with quick connectors. A maximum of 500 W cooling is possible with one interface. The AAA allows up to 200 W cooling for each payload position.

Within this contribution, these restrictions and the challenging thermal requirements of the experiments subsystems will be discussed and the current design of the TCS presented.

H0.6-0020-18 MEMORY LAYOUT FAULT TOLERANCE TESTING OF APPLICATION SOFTWARE ON-BOARD EPD INSTRUMENT CONTROL UNIT

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The Space Research Group (SRG) of the University of Alcalá is in charge of the development of the Instrument Control Unit (ICU) for the Energetic Particle Detector (EPD) on-board Solar Orbiter along with the corresponding boot (BOOTSW) and application software (ASW). Because of the proximity of the Sun, from the Solar Orbiter perspective, it is mandatory to look out for permanent memory errors resulting from a Single Event Latch-up (SEL) failures in application binaries stored in EEPROM and its SDRAM deployment areas. In order to better manage this process when a SEL happens, each one of the two ASW images stored in EEPROM is internally organized in a particular memory layout described by descriptors and a set of code/patch segments. This paper describes the EEPROM ASW binaries organization and the exhaustive runtime testing procedure in order to ensure that all possible fault pair in ASW binaries; memory location and faulty bits, is tested. This exhaustive verification has been accomplished by the use of a LEON2 Virtual Platform (Leon2ViP) with fault injection capabilities developed by the Space Research Group (SRG). Leon2ViP has been boosted with external scripting capabilities. This batch mode allow the definition of very complex fault injection scenarios and is especially useful in order to integrate the virtual platform in a continuous development and testing environment to achieve a complete test run automation. Thus, it has been possible to carry out a complete assessment of the effectiveness of the EEPROM memory layout fault tolerance mechanism stated in the system specification and to get feedback for their enhancement and correction.

H0.6-0021-18 ELECTRODE BREAKDOWN ANALYSIS IN NEAR SPACE

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In recent years, research on near space has drawn increasing attention and enterprises and research institutions from various countries have invested a great deal of manpower and resources into this field. Due to the special environment in near space, the electrode breakdown phenomenon of the electronic and electrical equipment in near space is different from those of ground, aviation and aerospace. Corresponding standards have been set to limit the electrode distances in situations of ground, aviation and aerospace. But in near space, the standards are not very clear. Electrode breakdown phenomenon refers to that the current it created between the positive and negative poles in the circuit due to the breakdown of particles in the air. The key to explaining electrode breakdown is Paschen's Law, which is related to the pressure, voltage, electrode distance and temperature. This article studies the electrode distance limitation in near space, including the electrode distance limitation of solar cells and high voltage battery packs under different conditions of high temperature, high voltage and low pressure, and verifies it with ground tests. The research in this article is of great significance by providing basis for the design and manufacture of near space electronic and electrical equipment in the near future.

H0.6-0022-18 STUDY ON THE SYSTEM PLAN OF INTELLIGENT RECONSTRUCTION BASED ON CARRIER ROCKET

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Abstract:the technology of intelligent reconstruction of carrier rocket is self-repair and intelligent regeneration according to the system state, which does not rely on manual intervention, does not rely on hardware disassembly. It independently identifies the system state, which completes the rebirth of the inherent functions and regeneration of new functions. The reasons of system reconstruction include passive reconstruction based on changes in the inner state and active reconstruction based on changes in the external environment. The technology of reconfiguration that covering a complete technology ecological chain, relates to the testing, fault mode recognition, fault diagnosis, fault management, software architecture, reconfiguration decision making technology etc. According to the characteristics of rocket system, this paper put forward the plan of reconstruction scheme of launch vehicle system with hierarchical fault processing and reconstruction. Key words:carrier rocket,fault management,intelligent reconstruction.

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LR.1-0001-18 GRAVITATIONAL WAVES AND ASSOCIATED EMISSIONS

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On 2017 August 17 the dazzling discovery of GW170817, a binary neutron star merger with an electromagnetic (EM) counterpart, marked the start of a new era in multi-messenger astronomy.

In this talk I will review what we have learned from GW170817, starting from the prompt detection of an associated gamma-ray burst by Fermi and Integral. I will then emphasize the key role of the massive space- and ground-based follow-up effort that unveiled the properties of GW170817 in all bands of the EM spectrum. Finally, I will discuss what questions remain open after GW170817, and highlight future prospects for joint gravitational wave and EM observations of the transient sky.

LR.1-0002-18 DAMPE AND ITS LATEST RESULTS

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Dark Matter Particle Explorer (DAMPE), the first Chinese astronomical satellite, was launched into a Sun-synchronous orbit at an altitude of about 500 km on 17 December 2015. DAMPE is a high-energy particle detector optimized for observations of cosmic ray electrons and gammarays up to about 10 TeV. In this talk I'll introduce the on-orbit performance of the detector, the calibration, and the latest results on cosmic rays and gamma-rays of DAMPE.

LR.1-0003-18 AKATSUKI REVEALS VENUS ATMOSPHERE DYNAMICS

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Akatsuki Reveals Venus Atmosphere Dynamics

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Since its orbit insertion in December 2015, Akatsuki has been providing new discoveries on the Venusian atmosphere, which is known for thick clouds and the super-rotation with angular speeds up to several tens of times as the solid planet. This talk will focus on dynamical aspects revealed from imaging at multiple wavelengths. Venus is covered with clouds that extend from about 45 to 70 km altitude. Images at the near-infrared "atmospheric window" wavelengths visualize the silhouette of lower-to-middle layer clouds. From Akatsuki's near-infrared images, it was found that a jet-like feature emerged and lasted over several months near the equator, which had never been observed previously. Also found are large-scale vortices presumably due to dynamical instability. These results suggest that winds in the lower and middle cloud layers are much more variable than have been thought. Ultraviolet imaging has long been used to observe winds at the cloud top. However, with novel two-wavelength imaging and cloud tracking with high accuracy, major advances have been provided from Akatsuki. We have succeeded in evaluating angular momentum budget regarding the super-rotation for the first time. Also found are hemispheric asymmetry that developed for a period of time and the existence of long-lasting overall vertical shear at the cloud top. Akatsuki's midinfrared imaging revealed that huge interhemispheric stationary gravity-wave signatures appear around the cloud top over low-latitude highlands when they are in local afternoon. This finding provided an unexpected probe of near-surface atmospheric conditions, since its formation depends on near-surface winds and static stability. It will provide a useful constraint for the study of the persistency of super-rotation. Long-term monitoring at UV from 2006 to 2017, including Venus Express observations, exhibits significant decadal variations of solar energy depositions at the cloud top level, which should affect atmospheric circulation. In fact, cloud-top super-rotation rate varied consistently. In combination with general circulation modelling and theoretical works, Akatsuki is expected to renew our understanding of the atmosphere of Venus.

LR.1-0004-18 A 25-YEAR RECORD OF GLOBAL MEAN SEA LEVEL CHANGE: WHAT HAVE WE LEARNED?

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A 25 Year Record

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G. T. Mitchum, and J. Willis

The 25-year record of global sea level change from satellite altimetry is one of our most valuable climate data records of how the Earth is responding to anthropogenic warming. But what have we learned from this record? This presentation will summarize our current understanding of sea level change based on the satellite altimeter record. One important fact we have learned from these observations is that the 25-year altimeter record occurs during a remarkably unusual time in the 100+ year sea level record. As a result, we must ask ourselves how this affects our interpretation of the altimeter record - are the changes we are observing short term or long term? Sorting out the natural and anthropogenic climate signals is a continuing challenge as we move in.

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Panels (P)

COSPAR 2018
42ND ASSEMBLY | 60TH ANNIVERSARY

PANELS (P)

COSPAR CAPACITY BUILDING INITIATIVE: A REVIEW OF THE LAST 15 YEARS AND HOW TO FACE THE NEXT 10 (PCB.1)

PCB.1-0001-18 THE LAST 8 YEARS OF THE COSPAR CAPACITY BUILDING

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In this talk I will describe the purpose of this COSPAR initiative, and I will summarise the activities that the Panel on Capacity Building carried out in the last 8 years, the period during which I acted as chairperson. In particular, I will describe the expansion of the programme, both through a significant increase of the number of workshops we organised and the number of fellowships we awarded per year, and the involvement of new areas within the COSPAR remit.

PCB.1-0002-18 CROSS-DISCIPLINARY CAPACITY BUILDING IN SPACE WEATHER

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Over the last 4 years, a series of Capacity Building Workshops in the cross-disciplinary subject of Space Weather has been initiated in the framework of COSPAR's Panel on Capacity Building. The first workshop took place in 2016 in Kamchatka, Russia led by IKIR RAS and the second will take place later in 2018 in Sao Jose dos Campos, Brazil led by INPE's Embrace Programme. This presentation will describe efforts undertaken to date in order to develop a format which combines scientific excellence with operational awareness and practices. Current experience will be presented along with possible future directions. Opportunities presented by increasingly available web technologies to reach a wider audience, while maintaining the integrity and quality of the courses themselves, will be discussed.

PCB.1-0003-18 IRI CAPACITY BUILDING WORKSHOP - AN ORGANIZER AND STUDENT PERSPECTIVE

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The International Reference Ionosphere (IRI) is a joint project of the Committee on Space Research (COSPAR) and the International Union of Radio Science (URSI) with the goal of developing and improving an international standard for Earth's ionosphere. IRI is well established and widely used and in 2014 was elected as the ISO standard for ionosphere (ISO

= International Standardization Organization). Good performance, easy use, and open accessibility have made IRI a catalyst for ionospheric science in many developing countries and an excellent topic for COSPAR's Capacity Building Workshops (CCBW). IRI already had a long tradition of bi-annual workshop with 60-100 participating experts. Combining this expert meeting with a training program for students has turned out very beneficial for students and experts. The students get a full week of lectures and hands-on study followed by, in many cases, their first participation and presentation at an international science meeting. This, on the other hand, also makes it easier to find good lecturers because they were planning to come to the IRI Workshop anyway. Lecturers and participants in the expert meeting may find good candidates for open graduate and post-doc opportunities to work on their science projects. During the first week training the students will work in groups of 4 or 5 on a specific ionospheric modelling problem and present their results during the second week expert meeting. They are encouraged to continue their collaboration after the workshop and are invited to publish their results in a special issues of Advances in Space Research dedicated to ionospheric modelling and data assimilation. We will present experiences from the 2015 and 2017 IRI CCBWs from the organizer and student perspective.

PCB.1-0004-18 COMMENT ABOUT CAPACITY BUILDING WORKSHOP "CRYSTALLOGRAPHY FOR SPACE SCIENCES" CO-ORGANIZED BY IUCR-COSPAR-IAU IN PUEBLA, MEXICO, 2016

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COSPAR, the International Union of Crystallography and the International Astronomical Union together organized a very successful International School/Workshop on Crystallography for Space Sciences, within the frame of COSPAR Capacity Building Workshop (CBW). It was held in Puebla, Mexico in April 17-29 2016. The aim of the Workshop was to prepare a selected number of participants for the next generation of projects in search of a deeper knowledge and understanding of extraterrestrial minerals and rocks, either large solid bodies or interstellar dust particles, using in-situ and remote analytical techniques. The workshop hosted about 30 PhD students, postdocs and young staff members from Central and South America. They were trained in modern crystallographic techniques in the fields of diffraction, imaging, spectroscopy and remote sensing. They learned from the world class experts about the formation of mineral growth patterns in the early Earth, our Moon, Mars and other planets and moons, meteorites and interstellar dust, as well as relevance of crystals with origin of life and detection of primitive life forms. During the workshop, the students analyzed and discussed data from the missions Discovery and Curiosity as well as the forthcoming Exomars mission. Portable difractometers and spectrophotometers designed for these missions were used during field trips for remote analysis of volcanic rocks. Possibilities of organizing similar CBW on other continents will be discussed

PCB.1-0005-18 THE COSPAR CAPACITY BUILDING WORKSHOP AT MEKELLE UNIVERSITY IN ETHIOPIA

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This talk summarizes the experience in organizing the COSPAR Capacity-Building Workshop "Coronal and Interplanetary Shocks: Analysis of Data from SOHO, Wind, and e-CALLISTO" in Mekelle University, Ethiopia. The main objective of the COSPAR Capacity-Building Workshops is to encourage the scientific use of space data by scientists in developing countries. In particular, in view of the large number of extensive archives of data from past and current space missions, and the ready access to these and the associated analysis software via the internet, the typical workshop aims to provide a highly practical training in the use of one or more of these, based on current missions. In line with this objective, a two-week workshop introduces data analysis of space-based white-light coronagraph observations and radio spectral observations from space and ground to study shocks driven by coronal mass ejections. In particular, the wealth of data accumulated at the CDAW Data Center at NASA Goddard Space Flight Center from the ESA/NASA Solar and Heliospheric Observatory (SOHO) mission, NASA's Solar Terrestrial Relations Observatory (STEREO), NASA's Wind and Advanced Composition Explorer (ACE) missions are used. In addition, ground based radio data from the e-CALLISTO network and the Radio Solar Telescope Network (RSTN) around the globe are used for the study. Context information from NOAA's GOES mission and NASA's Solar Dynamics Observatory (SDO) missions are also used. This workshop enables scientists and students in developing countries where the eCALLISTO instruments are deployed to use their data in conjunction with space data to study Earthaffecting solar transient phenomena.

PCB.1-0006-18 EXPERIMENTAL TRAINING AND CAPACITY BUILDING: EUROMOONMARS WORKSHOPS AND FIELD SIMULATIONS 2016-2018

Bernard H. Foing, bernard.foing@esa.int ESA/ESTEC, Noordwijk, Netherlands EuroMoonMars Team (2016-2018)

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A. Lillo (1,2,4), A. Kołodziejczyk (5), C. Heinicke (2,3,7), M. Harasymczuk (5), M. Krainski (1), A. Zaklynsky (2,8), A. Sitnikova (2,8), A. Izotova (2,8), A. Neklesa (2), J. Preusterink (2,9) & ILEWG EuroMoonMars 2016, 2017 & 2018 support teams, 1)ESA/ESTEC, Postbus 299, 2200 AG Noordwijk, NL, 2)ILEWG, 3)Vrije Universiteit Amsterdam, 4)ISAE Supaero, 5)LunAres Space Garden, Poland, 6) SGAC, 7)ZARM, 8)ArtScience Interfaculty The Hague, 9)Kopernicus Observatory

The ILEWG/COSPAR EuroMoonMars programme conducted in 2016-2018 a series of workshops and field analogue missions where students and professionals all over the world became one space crew. Young professionals joined the team as scientists, engineers or as education/outreach experts in process of simulating real life and work on the MoonMars ExoHab and ExoLab laboratories, and in order to develop experience, training and capacity building.

Goals: The EuroMoonMars mission simulations in ESTEC 2017 and 2018 set a few key goals:

First of all the participants had been developing and testing equipments, experiments, investigations, and procedures.

Secondly they developed their own communication protocol between the Mission Control Center, the ExoLab and the ExoHab from both technical and verbal sides aimed to standardize and facilitate the communication.

Thirdly, they performed evaluation of ergonomics of all units and the equipment needed to complete the mission.

And finally, samples were collected from the surface for analysis in the MoonMars labs.

All above was the subject of a training program in the process of learning astronaut's daily performance.

PCB.1-0007-18 COSPAR CBP: GOOD, BETTER, BEST - NEVER LET IT REST

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The Capacity Building Programme is considered today one of the flagships of COSPAR activities. It started in 2001 as a tentative project to widening expertise in space science and promoting the use of data archives from space missions in developing countries. A first period of settling down went on for 8-9 years, led by Prof. Willmore, in which the initial concepts were refined, the usefulness of the workshops confirmed and an associated Fellowship created. A second period, marked by a continuous expansion followed, this time with a Panel heading the Programme, in which the different main space science disciplines were represented. This year is perhaps a good moment to reflect on what can be done better, what is still missing in the Programme, and how we can use the impending Panel reorganisation to renew and expand our objectives, and so maybe initiate a new era of the CBP. Under these premises, I would like to present and discuss some ideas concerning: a) ways to better evaluate the impact of the Programme, b) a larger interaction between the diverse space disciplines represented in it, and c) an extension of the Programme with the aim of motivating younger students to move in the direction of space sciences in developing countries.

PCB.1-0008-18 A STUDENT'S VIEW OF THE COSPAR WORKSHOPS

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This slot is reserved for short talks by former participants to COSPAR Capacity Building Workshops who attend the Assembly.

PANELS (P)

YOUNG SCIENTIST IN THE CLASSROOM (PE.1)

PE.1-0001-18 YOUNG SCIENTIST IN THE CLASSROOM (I)

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Young Scientist in the Classroom (I)

PE.1-0002-18 YOUNG SCIENTIST IN THE CLASSROOM (II)

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Young Scientist in the Classroom (II)

PE.1-0003-18 YOUNG SCIENTIST IN THE CLASSROOM (III)

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Young Scientist in the Classroom (III)

Panels (P)

Young Scientist in the Classroom (PE.1)

PE.1-0004-18 YOUNG SCIENTIST IN THE CLASSROOM (IV)

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Young Scientist in the Classroom (IV)

PE.1-0005-18 YOUNG SCIENTIST IN THE CLASSROOM (V)

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Young Scientist in the Classroom (V)

Panels (P)

Young Scientist in the Classroom (PE.1)

PE.1-0006-18 YOUNG SCIENTIST IN THE CLASSROOM (VI)

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Young Scientist in the Classroom (VI)

PE.1-0007-18 YOUNG SCIENTIST IN THE CLASSROOM (VII)

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Young Scientist in the Classroom (VII)

PE.1-0008-18 YOUNG SCIENTIST IN THE CLASSROOM (VIII)

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Young Scientist in the Classroom (VIII)

PE.1-0009-18 YOUNG SCIENTIST IN THE CLASSROOM (IX)

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Young Scientist in the Classroom (IX)

PE.1-0010-18 YOUNG SCIENTIST IN THE CLASSROOM (X)

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Young Scientist in the Classroom (X)

PE.1-0011-18 YOUNG SCIENTIST IN THE CLASSROOM (XI)

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Young Scientist in the Classroom (XI)

PE.1-0012-18 YOUNG SCIENTIST IN THE CLASSROOM (XII)

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Young Scientist in the Classroom (XII)

PE.2-0001-18 SPACE GENERATION EDUCATION PROFILE

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Discussions on best practices for education are trending topics in all generations. How can we better prepare future generations? But the 21st century is bringing opportunities and challenges that are shifting towards a more demanding and deep change in our educational systems. Discussions about how to rebuild educational systems are taking place all around the world and space exploration, data handling, digital skills are some of the keywords helping steer the wheel towards the skills for the future. Space Exploration is a very rich topic that gracefully accommodates several concepts from different disciplines and is at the same time interesting and motivating for students. Space can also be the trigger to a more open schooling where discussions among local community stakeholders become part of the education process of their young members, preparing them to become critical thinkers and literate decision makers. In this presentation we intend to share with the audience some best practices taking place in Europe that are helping reshape how we collaborate with schools and how Space is having a major role.

PE.2-0002-18 ROBOTICS PROGRAMMING COMPETITION SPHERES, RUSSIAN PART. FIVE YEARS EXPERIENCE

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“Spheres” such name was done to Russian part of the Zero Robotics project which is a student competition devoted to programming of SPHERES (SPHERES-Synchronized Position Hold Engage and Reorient Experimental Satellites are the experimental robotics devices which are capable of rotation and translation in all directions, http://ssl.mit.edu/spheres/), which perform different operations on the board of International Space Station. Competition takes place online on http://zerorobotics.mit.edu. The main goal is to develop a program for SPHERES to solve an annual challenge. The end of the tournament is the real competition in microgravity on the board of ISS with a live broadcast. The Russian part of the tournament has already five years history for high school students and two years for middle school but the problems, organization and specific are useful for the other educational projects especially for the international ones. We introduce the history of the competition, its scientific and educational goals in Russia and describe the participation of Russian teams in 2014-2018 tournaments. Also we discuss the organizational problems.

PE.2-0003-18 HOW TO TEACH ASTRONOMY TO ILLETERATE KIDS

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We founded the association Ephemerides 4 years ago. Its first goal was to teach astronomy to people living in marginalized places in the Paris region. In 2018 we started to organize astronomy activities in Mali, a West African country where only 23.1% of teenage girls go to secondary school. In our presentation we will share our experience and the different challenges we faced.

PE.2-0004-18 ASTRONOMY AND SPACE SCIENCE ON THE SCHOOL - AN OUTREACH PROJECT FOR ELEMENTARY AND HIGH SCHOOL STUDENTS OF BRASILIA

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This project aims to develop interdisciplinary actions, articulated and convergence in the field of education, dissemination and popularization of science and technology in Brasilia-DF, the Federal District of Brazil. These actions are also been carried out at DF surroundings areas. Since 2015 linked convergent actions are focused on the development of space science and astronomy teaching with hands on experimental activities. Workshops, short basic astronomy courses, expositions and planetarium show are been carried out by a team of professors, graduate and under graduate students from University of BrasiliaUnB. At the same time upgrade actions are been done in order to modernize The Luiz Cruls Astronomical Observatory located at the far campus of UnB, named Fazenda Água Limpa. It is now a Center for research and space science dissemination and popularization not only for students but also for the whole community of Brasilia. Working toghether with the Physics Institute of UnB we have the recently created a Museum of Science and Technology of Brasilia, temporarily located at the UnB campus. The Museum is responsible for contac with schools and Brasilia community and for the organization of the activities of the Science on the School Project.

Science on the School is an educational, scientific and cultural proposal was approved and financed by the brazillian national research council (CNPq) and by the Science and Technology Reseach Foundation of Brasilia. Besides science dissemination for the brazillian society the project is also developing theoretical and experimental research in the area of Space Science and Astronomy. The project also aim to transform the Museum in a strong Science Education Center for the Brazil central region population, It is going to be a cultural environment and leisure for the Federal District and surrounding areas of Brasilia.

In this work we will describe the coordinate actions of the Astronomical Observatory and of the Museum destinated to public communication of up to date advances of science and technology.

In their facilities will be possible to conceive, plan, develop, encourage and support scientific activities (playful and interactive) in schools and communities of Brasilia and surrounding areas, focusing on different aspects of space science and astronomy and their relationship with society through investigative practices involving, particularly students and teachers of basic education and the community in General. The project is acting even in the promotion of events, courses, workshops and scientific-cultural experiences, production of radio and TV programs aimed at promoting initiation into Science and environmental awareness on basic education.

PE.2-0005-18 THE ARGUMENT FOR USING QUALITY SCIENTIFIC LEVEL EQUIPMENT IN PRIMARY SCHOOLS FOR AUTHENTIC ASTRONOMY ACTIVITIES TO INCREASE KNOWLEDGE OF AND IMPROVE ATTITUDE TOWARDS SCIENCE.

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This presentation reports on the ability of primary school students to use scientific level telescopes efficiently. It outlines impact that participation in authentic science activities can have on student knowledge of and attitude towards science.

Modern, relatively cheap automated telescopes and imaging software has made transient object searches a valuable addition to research based activities conducted by professional astronomers. This provided an opportunity to use transient object searches as a tool for authentic science in the classroom. The students located and imaged astronomical transient objects, such as near Earth asteroids. It is an exciting field of modern research where discoveries can have real life implications, such as discovering potentially hazardous near Earth asteroids.

The ability of primary school students to understand complex concepts is generally underestimated. This activity followed ten and eleven year old students from a primary school classroom in Western Australian as they successfully used three different research level telescopes. Each telescope had a different system of operation, yet the students were able to locate known asteroids and plan and execute a search for ones yet to be discovered.

PE.2-0006-18 NEW METHODS OF TEACHING ASTRONOMY AND SPACE SCIENCE IN NEPAL

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Pokhara Astronomical Society (PAS) has introduced new techniques in teaching astronomy and space science in Nepal with more practical approach since 2012. We are helping students to construct refracting telescopes from PVC pipes and using it to observe the night sky which is contributing to bring remarkable interest in studying astronomy in middle school. Similarly in high schools we have organized series of webinars with renowned scientist from different parts of the world. We have screened documentaries of space activities; and are helping students to use online robotic telescopes by using internet. This eventually is creating more interest in students to study science and particularly astronomy and space science in their higher studies. The use of mobile apps and different satellite tracking website have helped students to determine the location of space objects and has generated curiosity in students for the detailed study of them. Students are learning practical methods of weather forecasting. New generations of students are now learning the uses and benefits of space based technology also from outside of the curriculum. We have organized numerous talk show programs to spread the awareness of space education in the different parts of the country. We are now reaching thousands of students with different proceedings to popularize astronomy and generating interest to pursue higher education in this subject. As well as creating the scientific awareness and understanding among others who are not choosing science in their higher studies. This paper highlights the means of advanced and practical approaches of teaching astronomy and space science over traditional approach.

Key Words: Nepal, PVC Telescope, Space Based Technology, Space Science, Practical Methods

PE.2-0007-18 ASTRONOMY EDUCATIONAL OUTREACH PROGRAM IN NEPAL.

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Education of basic space science and astronomy is nominal in Nepalese society. Institutionalization's of it providing space science education are few in number. No space agency is in existence till. Yet, the development in space science and technology is very much essential in raising our living standard.

The coverage of astronomy education to students and public is very less. Only 20%, 25% and 30% of the entire course contains the few topics on astronomy on secondary, undergraduates and graduates level. However some research works on astronomy are carried out by Tribhuvan University at central and state level. The gap in the astronomy education are fulfilled by some existing astronomy clubs like PAS by conducting educational outreach programs like, Night sky observation and hands on activities through constellation models, Solar motion, Star clock whereas for the public conducting by the series of night sky observation as well as the awareness programs on several astronomical phenomenon like eclipses. These types of activities create a lot of interests to the school students and reduce the superstition beliefs prevailing in the society. So this paper discussed the major beliefs prevailing in the society and the major steps taken by clubs to eliminate the beliefs. In addition importance of the educational outreach conducted outside the program to enhance the astronomy education will be highlighted.

Key Words: Educational Outreach, Hands on Activities, Public

PE.2-0008-18 THE NASA/IPAC TEACHER ARCHIVE RESEARCH PROGRAM (NITARP): 12 YEARS OF WORKING WITH HIGH SCHOOL TEACHERS

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NITARP, the NASA/IPAC Teacher Archive Research Program, gets teachers involved in authentic astronomical research. We partner small groups of educators with a professional astronomer mentor for a year-long original research project. The teams echo the entire research process, from writing a proposal, to doing the research, to presenting the results at an American Astronomical Society (AAS) meeting. The program runs from January through January. Applications are available annually in May and are due in September. The educators' experiences color their teaching for years to come, influencing hundreds of students per teacher. This submission will review the NITARP program, including lessons learned.

PE.2-0009-18 ATTEMPTS TO BRING TRAINED TEACHERS IN THE SCHOOLS OF NEPAL

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To develop space activities and to industrialize astronomy, base of space education in the high schools must be very effective. This paper highlights the present scenario of space education and discusses the syllabus of astronomy in the different education level of Nepal. Astronomy is included in the curriculum of science book of middle school and high school which contains very few contents of solar system, constellations, galaxy, black holes and formation of stars. There are no any degrees for higher studies in astronomy as a separate department in any universities of Nepal. This paper also highlights the space activities and national level programs conducting in Nepal to support astronomy education. With the rise of many astronomical clubs and societies in the different regions of Nepal, astronomy education has been more effective in the recent time. Galileo Teacher's Training Program is being organized in the different parts of Nepal since 2011 by Global Hands on Universe in cooperation with local astronomy clubs. The attempts to bring more trained and skilled teachers in the classroom by the government and non-government agencies are now gradually increasing. The competition of private schools and their capacity building workshops to their teachers to attract more students is also playing active role to shape the school education effective. The challenges, prospects and the practice of effective astronomy education prevailing in Nepal will be discuss.

Key Words: Nepal, Astronomy Education, GTTP, Trained Teachers

PE.2-0010-18 EDUCATIONAL OUTREACH ACTIVITIES OF TEAM PULI SPACE TECHNOLOGIES IN INDIA

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Educational Outreach activities have an important role to play in our quest for Space exploration in not only inspiring the youths and students to choose space science as a career but also to educate the general public to make them aware about the mysteries of the Universe and the efforts being taken by the humans in bringing the applications of space technology in various daily life on Earth. Team Puli Space Technologies, an Ex-Google Lunar X-Prize Competitor Company from Hungary has marked its presence in India during several occasions at Educational Outreach events. The company motto to Moon and beyond is flagship sentence to inspire the young kids. The connection of the word "Puli" with India is not new. In 2015 an Indian movie named "Puli" was released much before Team Puli Space Technologies got to make its presence in India with the Educational Outreach events. The word Puli is from Tamil language which means Tiger. Most recently in the month of September, a Water Rocket Launch event was conducted in India where Team Puli Space Technologies got its presence with the Team Puli Logo marked on the Water Rocket. The successful launch of the water Rocket with team Puli Logo on it signifies that the Team Puli Space Technologies will have journeys to the outer space in the coming time with its ongoing project Puli Rover will become an additional source of inspiration to lift off in quest for exploration of Moon,Mars and beyond. The Educational outreach activities have not only helped in making people aware about the works of Puli Space Technologies in India particularly school and college students but also encouraged and motivated the young students to participate in space science activities during the events and inspired them to look up space technology as a career perspective. Before Team Puli Space actually starts its trip to Moon and beyond such educational outreach events will definitely help the Team Puli Space to make presence in different parts of the world through the various and establish the presence of the Hungarian flag as one of the forefront leader in the quest for Space exploration for the benefit of mankind on Earth.

PE.2-0011-18 SPACE RESEARCH INSTITUTE (IKI) EXHIBITION AS AN EDUCATIONAL PROJECT

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The Exhibition “Space Science: Part and Future” in Space Research Institute (IKI) was opened in 2007 in commemoration of the 50th anniversary of the first man-made satellite launch. It covers the latest and the most important findings in space research, shows instruments which are used in space exploration, and presents past, current, and future Russian science missions. Prototypes of space instruments developed by Russian specialists and mockups of spacecraft and spaceships flown to space are displayed, together with information posters, describing space missions, their purposes and results. The Exhibition takes a great part in school space education. Its stuff actively works with schoolchildren, undergraduate students and also makes a great contribution in popularization of space researches. Moreover the possibility to learn about scientific space researches first-hand is priceless. We describe the main parts of the Exhibition and forms of it work and also describe the collaboration with other museums and educational organizations.

PE.2-0012-18 31ST JANUARY LUNAR ECLIPSE, HYDERABAD - A REPORT OF NS ASTROCLUB SPONSORED EVENT

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The lunar trifecta, combination of a super moon, a total lunar eclipse and a blue moon watching event was organised by the NS Astroclub. The club has been organising such celestial and sky gazing events from time to time. Such a rare celestial wonder in India was one of its kind. A report of the event is presented.

The first glimpse of eclipse was visible from 18:10, 72 degrees ENE onwards till the eclipse ended at 21:39. Total duration was 3hours, 29 min approx. Necessary preparations were planned and put in place for the D-Day - Telescope with tripod, Astro binoculars, Astro Camera, stop watch, flash lights.

Students were prior informed of the event and the response was enthusiastic. It was heartening to see the onlookers who for the first time let go of their traditional beliefs and watched this mega event. This time even the weather gods supported us with clear skies, although it was a very chilly night. Beforehand, a short ppt presentation was made by our subject expert on the fundamentals and the process of observing the event, the different phases of the eclipse. This proved a lot informative as the students were made to realise what they would be seeing and the interpretations. High tea was arranged. Further necessary precautions in observations were emphasised.

The students and others gazers circled up and started to observe the celestial event as it unfolded first time in 35 years where a blue moon had synched up with a supermoon and a total lunar eclipse. All students were bubbling with euphoria when they sighted the blood red moon during the peak of the eclipse and awed at the various shades of red, followed later on with the different phases of eclipses. Using the astro cam, pictures of the event were shot. After the totality the partial eclipse was witnessed by the audience. The session ended with the culmination of the penumbral eclipse and the crowd was mesmerised, most of them witnessing this event for the first time, a timeless moment inscribed permanently in the mind.

PE.2-0013-18 ATTEMPTS TO BRING TRAINED TEACHERS IN THE SCHOOLS OF NEPAL

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To develop space activities and to industrialize astronomy, base of space education in the high schools must be very effective. This paper highlights the present scenario of space education and discusses the syllabus of astronomy in the different education level of Nepal. Astronomy is included in the curriculum of science book of middle school and high school which contains very few contents of solar system, constellations, galaxy, black holes and formation of stars. There are no any degrees for higher studies in astronomy as a separate department in any universities of Nepal. This paper also highlights the space activities and national level programs conducting in Nepal to support astronomy education. With the rise of many astronomical clubs and societies in the different regions of Nepal, astronomy education has been more effective in the recent time. Galileo Teacher's Training Program is being organized in the different parts of Nepal since 2011 by Global Hands on Universe in cooperation with local astronomy clubs. The attempts to bring more trained and skilled teachers in the classroom by the government and non-government agencies are now gradually increasing. The competition of private schools and their capacity building workshops to their teachers to attract more students is also playing active role to shape the school education effective. The challenges, prospects and the practice of effective astronomy education prevailing in Nepal will be discuss.

Key Words: Nepal, Astronomy Education, GTTP, Trained Teachers

PE.2-0014-18 SEEKING AN INTEGRATIVE VISION OF THE PLANET AND MAN IN BRAZILIAN BASIC EDUCATION THROUGH THE TEACHING OF SPACE SCIENCE IN SCHOOLS AND NON-FORMAL SPACES

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Brazilian education is governed by the National Curricular Parameters (PCNs). These, in principle, favor an integrative view among several areas of knowledge. However, they are not always fully developed, partly due to deficiencies in teachers training, among other problems.

The group of Astronomy and Astrophysics (GAIA) of PUC Minas develops activities of teaching and dissemination of science, in the Museum of Natural Sciences of PUC and in other spaces.

Through teaching materials prepared by the Brazilian Space Agency (AEB), the group proposes activities to instigate students' interest in space science as a way to solidify the experience of scientific literacy, reinforcing the implementation of the PCNs. These activities include space science training courses for teachers, courses and lectures for students, hands on experiments and workshops, observation of the sky, planetarium sessions, and rocket launching competition between schools. All this aims to give an integrative vision of the planet and civilization in order to create a more conscious, egalitarian and just society. An idea of a planetary civilization.

PEDAS.1-0001-18 WISE IR OBSERVATIONS OF BREEZE-M ROCKET BODIES AT GEO

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In 2010, NASA's Wide-field Infrared Survey Explorer (WISE) observed the entire sky from low Earth orbit in four infrared (IR) bands simultaneously (3.4, 4.6, 12, 22 microns). Although WISE was originally launched to investigate more distant astronomical sources, its orbit and scanning strategy serendipitously allowed for a large number of resident space objects (RSOs) to be detected in its images. The WISE IR bands measure reflected sunlight and thermal emission from RSOs, and the simultaneous four-band observations allow us to correlate RSO reflective and thermal properties. We investigate different populations of objects in the geosynchronous orbit (GEO) regime. Calibrated IR colors and magnitudes of ILS Proton Breeze-M rocket bodies are presented along with those of Titan rocket bodies and debris as well as active geostationary satellites. Preliminary results show that Breeze-M rocket bodies appear photometrically distinct from Titan rocket bodies but similar to cylindrical geostationary satellites. We discuss possible reasons for these differences.

PEDAS.1-0002-18 LIGHT CURVE ANALYSIS OF NON-OPERATIONAL GLONASS SATELLITES

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Knowledge of attitude dynamic of debris objects is crucial concerning the foreseen active debris removal missions. It also allows researchers to better understand the natural forces that govern the attitude motion of the objects. In this regard, 70 non-operational GLONASS satellites have been observed by the Astronomical Institute of the University of Bern (AIUB) for several years. Non-resolving optical observations of these objects was performed using the 1-meter telescope ZIMLAT located at Swiss Optical Ground Station and Geodynamics Observatory Zimmerwald in Switzerland. The resulting light curves were analyzed to obtain the apparent rotation periods and phase diagrams. Here we discuss our analysis of the temporal evolution of the rotation rates and of the signatures in the light curves.

PEDAS.1-0003-18 PROJECT LEDSAT: USING LEDS TO IMPROVE ORBITS AND ATTITUDE DETERMINATION OF LEO SATELLITES

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Project LEDsat is an international effort to investigate the use of Light Emitting Diodes (LEDs) for applications on satellites in Low Earth Orbit (LEO). These applications include improved orbit determination by making the satellite visible even in Earth shadow, distinguishing satellites by using different flash patterns on satellites in simultaneous launches of multiple satellites, attitude determination, and telemetry.

Optical observations are often used for determining the orbit of uncooperative spacecraft and space debris and they provide the possibility to significantly improve the Two-Line Elements (TLE) orbital parameters estimation with a small set of optical data. However, a comparison between optical and other positioning data is not easily available for the uncooperative nature of the observed objects. LEDSAT will offer a unique opportunity to compare the optical orbit determination results to the on-board Global Positioning System (GPS) receiver data and to the laser ranging measurements allowed by on-board retro-reflectors, hence providing the chance to verify, improve and cross-correlate the optical stand-alone orbit determination techniques for space debris.

An Italian student team from Sapienza Space Systems and Space Surveillance Laboratory (S5Lab) at Sapienza - University of Rome

is developing the 1-Unit Cubesat LEDSAT. The satellite project is realized within the European Space Agency Fly Your Satellite! Programme, that will offer a satellite launch opportunity for the International Space Station in late 2019, in addition to technical support for the satellite development process. The satellite mission consists in testing a Light Emitting Diodes (LED) -based payload as calibration target for the current methodologies and techniques for optical-based orbit determination of space objects.

A student team from the University of Michigan is developing a 3U CubeSat LED mission called PHAROS. Initial efforts here are centered on a balloon payload to test visibility of LEDs, trajectory information from LEDs and other sources, and attitude determination of the payload. The primary goal is to verify the optical link budget used for future spacecraft missions.

We will review the current status of both of these missions, and how lessons learned will benefit knowledge of the increasingly congested LEO environment.

PEDAS.1-0004-18 HIGH ALTITUDE BALLOON DEMONSTRATION OF OPTICAL TRACKING AND ATTITUDE DETERMINATION FOR SATELLITES

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Here we present one part of an international effort to investigate the use of light emitting diodes (LEDs) for orbit determination and spacecraft identification by flight testing the concept on a high altitude balloon payload (HAB). The increasing number of spacecraft being launched into low Earth orbit (LEO) calls for new techniques for tracking, orbit determination and spacecraft identification.

The Michigan eXploration Laboratory (MXL) is a research laboratory run out of the University of Michigan Aerospace Engineering Department. MXL has flown 7 CubeSats and 29 HABs as technology demonstrations and science missions in collaboration with organizations such as NASA-JPL, NSF and SRI International. MXL will demonstrate the combined use of LEDs and a network of optical and radio ground stations to augment current LEO tracking abilities while still maintaining low cost through the use of existing ground station infrastructure and inexpensive hardware. This autonomous and robust tracking capability could enhance on-orbit satellite conjunction prevention and space situational awareness. Here, we describe a high altitude balloon flight mission to verify these concepts.

There are three facets to the demonstration: an LED balloon payload, an optical ground station network, and a radio ground station network. The LED balloon payload has been designed via an optical link budget that accounts for losses through links in the onboard battery of the communications system, the LEDs themselves, as well as the atmosphere and the ground telescope. The purpose of this mission is to prove the validity of our optical link budget in a real flight scenario, which derives the intensity of

the signal obtained given a specific telescope's parameters and LED input power. The radio ground station receives GPS telemetry data via APRS beacons that will provide feedback for a remote telescope that we will use to track the balloon payload. Once we are able to obtain stable tracking of the payload, we will use the optical ground station to detect and receive payload telemetry such as brightness and rotation rate. This telemetry will be post-processed to derive two closely interlinked datasets: attitude and light intensity, which will be compared to truth data collected on-board with gyroscopic sensors. This data and analysis is critical for the design of an optical tracking and attitude determination CubeSat mission.

PEDAS.1-0006-18 ALGORITHMS FOR AUTOMATED ANORMALY DETECTION OF GEO OBJECTS USING SPACE-BASED NON-RESOLVED OPTICAL OBSERVATIONS

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Ground-based non-resolved optical observations have been known to provide researchers with valuable information about satellite status. In order to cover all the objects in the GEO belt, at least three observatories are needed across the world. Instead of building overseas sites, one alternative option is to launch a space-based detector for characterization, which can also get rid of atmospheric effects. To reduce data transmission, we are designing algorithms that automate the process of rapidly characterizing objects from non-resolved optical data. Simulation tests have shown that our algorithms can achieve automated object identification and photometry. Via in-situ data processing of the lightcurves, unnormal status of the objects, including tumble rates, error pointing and miss tracking, can be detected and reported to ground sites, impelling the satellite manager to conduct a fine tracking of the concerned targets. Such algorithms, while deployed in future intelligent detectors, may become a great addition to the current capacity of debris measurements.

PEDAS.1-0007-18 PASSIVE OPTICAL SYSTEM FOR SPACE DEBRIS SURVEILLANCE AT NRIAG

- EGYPT

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As the number of space debris growths with time around the Earth, the collision probability between space debris and active satellites increases. In order to avoid a collision, it is necessary to monitor space debris. In the absence of an optical monitoring system in the Middle East and North Africa, National Research Institute of Astronomy and Geophysics (NRIAG) has been established the passive optical system for space debris surveillance which consists of an optical telescope attached with a highly sensitive camera with a field of view in the range of (3.4 x 2.3). According to this system, we can detect objects with a diameter about 10 cm which can cause major damage to active satellites. The primary goal of the optical system is to obtain and preserve physical and orbital information of space debris by purely optical means. To overcome the limits of optical observation, we have included in the International Scientific Optical Network (ISON) through scientific cooperation. The NRIAG team started a test operation in September 2017. A group of LEO space debris and satellites such as FENGYUN 1C DEB, CFESAT and COSMOS 2251 have been successfully observed using its NORAD Two-Line Element Sets (TLEs).

PEDAS.1-0009-18 LABORATORY SIMULATION OF MULTI-SITE SPECTRAL MEASUREMENTS OF A THREE-AXIS STABILIZED GEO SATELLITE

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Spectral analysis has been playing a significant role in revealing the material composition of space objects. Compared to observations from a single site, simultaneous multi-site observations are supposed to provide more convincing results. This paper introduces a six degrees of freedom platform used for parallel physical simulating the actual lighting and observing geometry of space objects. Spectral measurements and analysis of a three-axis stabilized GEO satellite model, observed from three ground sites, are presented and yield two significant outcomes. First, spectral data collected by sites of adjacent latitudes share similar way of variation related to time, indicating an analogous combination of illuminated surfaces. Second, by examining the specific spectral features' appearing time during different observations, the attitudes of the satellite's body and panel can be roughly estimated. Such evidence implies the great potential of multi-site spectral measurements in determining the attitudes of space objects.

PEDAS.1-0010-18 VALIDATION OF THE MASTER MODEL

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The Institute of Space Systems of the TU Braunschweig is currently developing the latest version of the European MASTER model. MASTER is the European reference model for the description of the space debris environment. It allows the calculation of a high-resolution particle flux on oriented satellite surfaces on Earth orbits. The model is based on the simulation of a large number of historical single events that released space debris. The descriptions of the release and the debris properties are based on statistical models. The orbital debris distribution is based on the higher orbit mechanics. There have been important improvements in this source modeling. The resulting populations must be validated with historical and current measurements. This validation is a very elaborate process in the development of the model. On the one hand, it is about the validation of the object population in the large size regime by observational data. For this the software PROOF is used. It compares the detections of simulated observations with actual measurement campaigns. Both, optical and radar measurements can be simulated. On the other hand, it is about the validation of the small sized particle population using impact data on retrieved satellite hardware. Here, the simulated particle flux is compared with the actually measured number of impacts. This paper shows examples of validating the new version of the MASTER model. The process of validation will be explained. The procedure is identical to the validations of previous versions of the MASTER model. The revised historical population will be re-validated. New results are presented taking into account data from current measurement campaigns. It will be illustrated with selected examples how the simulated results match the measured data.

PEDAS.1-0011-18 ENVIRONMENTAL ESTIMATION ON SUB-MILLIMETER-SIZE DEBRIS UTILIZING IN-SITU MEASUREMENT DATA

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Space debris smaller than 2 mm, which cannot be tracked nor detected by ground-based observations, may cause a fatal damage on a spacecraft. To understand the environment of such sub-millimeter-size debris sufficiently, in-situ measurements and modeling should be conducted. Therefore, IDEA the project for In-situ Debris Environmental Awareness, which aims to detect sub-millimeter-size debris using a group of micro satellites, has been initiated at Kyushu University. To estimate the debris environment based on in-situ measurements from the project, this paper proposes an environmental model that estimates the population of sub-millimetersize debris utilizing the date, time and location at impact on a measurement satellite. The proposed environmental estimation is based on an algorithm of a particle filter, considering the natures of orbits on which debris can be detected by the in-situ measurement satellite. This paper also evaluates the proposed model with a simulation using MASTER-2009, which is the environmental model developed at European Space Agency. Comparison between the debris population predicted by MASTER-2009 and the simulated estimation verifies that the proposed model can estimate the debris environment. Collision flux estimated by the proposed model is also evaluated to predict the impact rate into the measurement satellite. It is concluded, therefore, that the estimation model proposed and evaluated in this paper can provide a better definition of sub-millimeter-size debris environment with in-situ measurements.

PEDAS.1-0012-18 UNCONTROLLED RE-ENTRIES OF SIZABLE SPACECRAFT AND ROCKET BODIES: A POTENTIAL THREAT IN THE AIRSPACE AND ON THE GROUND

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More than 24,000 cataloged orbiting objects have re-entered so far into the Earth's atmosphere since the beginning of the space age. The associated returning mass, close to 30,000 metric tons, was mainly concentrated in intact objects, i.e. spacecraft, platforms and spent upper stages, accounting for nearly 29% of the re-entered objects. Over the last ten years, from 2008 to 2017, almost 440 large intact objects (80 spacecraft and 360 rocket bodies) have re-entered without control, with a total mass of about 900 metric tons (150 and 750 metric tons for spacecraft and spent upper stages, respectively). Therefore, approximately 90 metric tons belonging to large intact objects would have, on average, re-entered the Earth's atmosphere each year, and a mass fraction between 5% (4500 kg) and 15% (13,500 kg) might have crossed the airspace and hit the ground. In spite of a not negligible amount of mass suspected to have survived re-entry, and of at least fifteen events, from 2008 to 2017, in which spacecraft and rocket bodies components were retrieved, trivial damages to property occurred and no case of personal injury was confirmed. However, even if the risk related to the re-entry of manmade space objects is still extremely low, it cannot be commonly accepted as being inevitable. Moreover, it cannot be excluded that uncontrolled re-entries of sizable space objects might become of greater concern in the future, as a consequence of the increased use of space and growing population density on the ground.

After an overview of the most critical historic re-entries events, the attention will be focused on the re-entries of massive objects occurred without control during the last decade, highlighting:

1) the relative relevance of spacecraft versus rocket bodies (typically, the re-entry of large spacecraft catches more media and people attention than the re-entry of an equally, or even more massive, upper stage); 2) the re-entry frequency; 3) the distribution in inclination; 4) the potential risk due to a large returning mass (such as the NASA's Upper Atmosphere Research Satellite, the Russian cargo ship Progress M-27M, the Russian-Ukrainian second stage of the Zenit-3 launcher), or the presence on board of a significant amount of highly toxic propellants (as was the case of the Phobos-Grunt probe). For a number of re-entry events eyewitnesses sightings were reported and/or pieces of debris were recovered (as for debris from the RussianUkrainian Zenit-3 second stage 2015-074C, landed in Vietnam at the beginning of January 2016, or the Composite Overwrapped Pressure Vessel of the Vega's upper stage AVUM 2012-006K, recovered near Oddanchatram, India, in November 2016).

Hence, lessons learned from past uncontrolled re-entries of enough massive bodies suggest that, even if still small compared to other commonly accepted risks related to the lifestyle, or workplace and household safety, the risk for aircraft, or people and property on the ground, of being hit by falling orbital debris cannot be absolutely neglected. Moreover, it should not be ignored that also space vehicles intended for a controlled re-entry at the end of their mission may sometimes suffer failures, compromising the success of the planned de-orbiting strategy. This is, for instance, the case of the Chinese space station Tiangong-1. There are also large upper stages, with masses of about 4 metric tons or more, which still mostly re-enter without control.

PEDAS.1-0013-18 DETERMINATION OF HARMFUL SPACE DEBRIS USING TWO COLLISION CALCULATION ALGORITHMS

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This paper investigates which debris are highly dangerous to exacerbate the future orbital environment based on the outcomes of an orbital debris evolutionary model with two different algorithms of collision risk assessment. One is "Two-Sphere Overwrap" collision risk assessment, which focuses on the geometrical relation between the orbits of the two colliding objects, calculates the collision risk on the assumption that the objects are closest to each other at the intersections of the orbital planes at an interval of one year. The other is "Cube" collision risk assessment, which focuses on the relative positions of the two colliding objects, calculates the collision risk when both objects are inside a cube with a side of 10 km at an interval of 5 days. The previous study by the second author (Dr. Zemoura) identified harmful debris to be removed based on the outcome of an orbital debris evolutionary model with the "Two-Sphere Overwrap" collision risk assessment. As a result, it was found that there are removal debris with short-term environmental improvement effect and removal debris with long-term environmental improvement effect. This paper identifies harmful debris to be removed based on the outcome of the same orbital debris evolutionary model but with the "Cube" collision risk assessment. Finally, this paper compares harmful debris to be removed between the previous and present outcomes and investigate how the harmful debris to be removed change as the collision risk assessment changes.

PEDAS.1-0014-18 DESIGN OF A BAU SCENARIO INCLUDING CURRENT TRENDS IN THE SPACE MARKET

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Since the beginning of space exploration, the amount of space objects and especially space debris in Earth orbits has almost steadily increased. Consequences are a rise up of collisions (e.g. Sentinel 1-A in 2016) and collision avoidance maneuvers, and satellite protection requirements. Thus, a stabilization of the space debris environment is desirable. For this purpose it is necessary to know which parameters influence the space debris environment and their importance.

To gain insight into the possible evolution of the space debris environment, long-term projections can be performed. These projections take into account all major space debris sources, like launches, explosion and collision events, and sinks, such as atmospheric drag, post mission disposal (PMD), and active debris removal (ADR). The long-term simulations are generally performed for time-frames of 200 years wherefore the final results contain large uncertainties. Nevertheless, by varying single modelling parameters, their impact on the long-term evolution can be ascertained, which then can be used to deduce measures towards a sustainable space environment. A starting point for these simulations is generally a business-as-usual (BAU) scenario. In this scenario, it is assumed that all parameters, that are governed by mankind, are perpetuated like in the past. This includes launch rates and any kind of mitigation measures, such as PMD, passivation, and collision avoidance as well as the possibility to perform ADR. As spaceflight is undergoing a significant change due to an increasing number of launches of small satellites and launches from private companies and the ascending likelihood of so-called mega-constellations, currently used BAU scenarios have become outdated. Therefore, this paper presents the development of a new BAU scenario, together with a parametric variation based on this scenario.

The first step in the development of a new BAU scenario is the estimation of future launch rates. For this purpose the launches of the past are categorized by launch countries, to be capable of mapping effects on single categories, e.g. the end of the Soviet Union or the entry of China into the space age. Private companies and satellites with a mass lower than ten kilogram are sorted in own categories. The received rates are then extrapolated to the future, utilizing a formula for logistic growth that is often used in biology to calculate bacterial growth. Contrary to usually used logarithmic extrapolation, this formula can map processes of saturation. Other parameters derived from past behaviour are PMD and passivation rates, and the number of explosions. Due to the direct extrapolation of data from the past, the created BAU scenario shows, in contrast to most of the other long-term simulations, a realistic possibility of the future space debris environment as it is indicated by current space flight activities.

Based on the new BAU scenario, a parameter study is performed in which the launch traffic (including the possibility to launch mega-constellations), passivation and PMD levels, collision avoidance performance, and the use of ADR are varied. A comparison between the different simulations of the parameter study enables to assess the importance of single parameters. Furthermore, the costs of each scenario are analysed to identify the efficiency of the various measures for an improvement of the future space debris environment.

PEDAS.1-0015-18 CHARACTERIZATION OF LOW EARTH ORBIT SPACE OBJECTS USING MULTIPLE MODEL ESTIMATION

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Recent decades have seen the proliferation of man-made objects in Earth orbit, prompting the construction and maintenance of catalogs to predict potential collisions and ensure the safety of operational space assets. Although much of the emphasis in cataloging has been placed on estimating and predicting translational states and uncertainties, it is essential to additionally characterize parameters related to the size, shape, attitude, and material composition of space objects in order to accurately model their behavior and ascertain their origin and intent.

It is possible to extract features and estimate size, shape, and attitude parameters from resolved images, such as those obtained from space-based platforms in proximity operations or from powerful ground-based sensors imaging large objects. However, the majority of data collected for space situational awareness is produced by lower resolution ground-based sensors tracking small objects, which yields unresolved targets. Under these conditions, it is not generally possible to directly estimate the desired parameters, though useful information is still available from a combination of active and passive radiometric, photometric, spectral, and polarimetric sensors. This information can be exploited through the use of multiple model estimation techniques to characterize additional space object parameters.

Recent work has explored a variety of multiple model filters for object characterization, including multiple model adaptive estimation (MMAE), adaptive likelihood mixtures (ALM), and hierarchical mixture of experts (HME), primarily as applied to objects in geosynchronous orbit. This paper examines the relative performance of these techniques as applied to objects in Low Earth Orbit (LEO), which poses additional challenges in terms of visibility and sparseness of data availability. In addition, objects in LEO are subject to significant non-conservative perturbing forces such as atmospheric drag and lift, increasing the importance of accurately characterizing non-translation state parameters. Test cases evaluate the performance of the filters processing simulated optical measurements from a ground station in Canberra, Australia.

PEDAS.1-0016-18 HIGH AREA-TO-MASS RATIO OBJECT CHARACTERIZATION USING MACHINE LEARNING

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High area-to-mass ratio (HAMR) objects at high altitudes have complex dynamical behav- ior due to their low mass compared to their high cross-sectional area exposed to the nongravitational forces. HAMR objects are observed by ground-based optical sensors because it is not only more efficient but also less costly compared to radar observations. However, dim light curves and complex dynamics of HAMR objects due to the attitude-orbit coupling challenge the optical surveys of ground telescopes to detect, track, and catalog them. The capability of characterizing such objects from astrometric, photometric, spectral, and polarimetric data without applying compute-intensive calculations is essential to promote the Space Situational Awareness (SSA).

Optical observations are sensitive to the material properties, size, shape, and attitude state of the space objects. It is possible to extract such features of the objects by fusing astrometric, photometric, spectral, and polarimetric data through the use of machine learning approaches. Although different varieties of multiple model adaptive estimation (MMAE) techniques are proposed to be used for the characterization of resident space objects (RSO), they are computationally expensive, and this makes them impractical for the optical surveys of HAMR objects. Machine learning models can provide near-real-time (NRT) predictions once they are trained. Recent research that applies machine learning methods to characterize the space objects uses continuous and dense astrometric or photometric data, and this makes it trivial for machine learning models to fit the data. However, the observational data are sparse due to the visibility challenges in the optical surveys.

This paper studies the practicality of using two different machine learning methods, namely Extreme Gradient Boosting (XGBoost) and Deep Neural Networks (DNN), to characterize HAMR objects from sparse astrometric, photometric, spectral, and polarimetric data. The training data are simulated data by using attitude-orbit coupled dynamics and high fidelity force modeling. The training data are divided in to train, development test and test datasets to test the generalization capability of the trained machine learning model.

PEDAS.1-0017-18 A COLLISION IN A CUBESAT CONSTELLATION

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Cubesats which are centimeters sized-satellites will represent a large part of the space objects population in the years to come. As the issue about space debris is growing, we need to define tools to study the impact of a fragmentation inside of a constellation composed of cubesats, a new low cost architecture that drastically reduce the access to space. We did a simulation by using the data of the European project QB50 which is led by the Von Karman Institute in Belgium. QB50 consists in a constellation of 50 cubesats that will orbit in one orbital plane to study the lower thermosphere (90-320 km). We made a virtual collision between a cubesat of the constellation with an other one which is not part of the constellation. Here we present our results about the evolution of the debris generated and their impact on the remaining cubesats. By using several representations of the relative motion we introduce the first tools adapted to the case of a fragmentation inside a constellation of satellite.

PEDAS.1-0018-18 OPTIMAL RE-ENTRY TIME PREDICTION OF RESIDENT SPACE OBJECTS FROM HIGHLY ELLIPTICAL ORBITS

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About 5% of the catalogued resident space objects (RSO) around Earth are in highly elliptical orbits (HEO). The forecast of the distribution and lifetime of uncontrolled RSO is essential for carrying out stable and safe future space operations. With low perigee and high apogee, large uncontrolled RSO in HEO pass through high spatial density regions and are a potential source for increasing debris population. When RSO survive the re-entry disintegration process at the end of their lifetime, the resulting debris fragments may endanger terrestrial life. Re-entry time estimation of decaying HEO objects is a key area of debris mitigation and remediation.

The dynamics of the motion in HEO is governed by the influence of luni-solar gravity, atmospheric drag and oblateness of the Earth. The combination of atmospheric drag, varying with upper atmospheric density due to solar activity, and luni-solar perturbations alter the perigee altitude leading to lifetime variation from several weeks to decades. The orbital evolution and lifetime estimation of HEO objects are sensitive to the initial conditions which should be optimized for obtaining accurate re-entry time. Two initial parameters with significant uncertainties are the ballistic coefficient (B) and eccentricity (e). B, which varies with RSO's attitude during atmospheric passage, depends on the drag coefficient and RSO's area to mass ratio. e is uncertain since semi-major axis is easily computable from the orbital period.

The usage of complex perturbation models in nonlinear Newtonian equations of motion abets computational difficulties in obtaining accurate state vector. Using Kustaanheimo-Stiefel (KS) regularization method, linear differential equations of a harmonic oscillator with constant frequency is obtained and extended to perturbed motion. A regularized numerical orbit propagator (KSROP), with constant step-size, in terms of KS regular elements is developed. The Sun and the Moon ephemeris are computed using Plataforma Solar de Almería and a series expansion algorithms, respectively. An oblate atmospheric model using density scale height varying with altitude for drag and zonal harmonic terms up to J6 for oblateness effects, are considered.

In the present study, re-entry prediction of HEO RSO is treated as an optimal estimation problem. Two-line element sets of few RSO are used with SGP4/SDP4 theory to obtain initial osculating orbital elements. Optimal estimates of B and e are found using response surface methodology with genetic algorithm. KSROP is used to propagate the optimal initial parameters. Re-entry times are predicted with low error (<5%) when compared with actual data.

PEDAS.1-0019-18 THE DYNAMICAL PLACEMENT OF MEGA-CONSTELLATIONS

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An emerging concern for the Earth's orbital environment is the robustness of the current debris mitigation guidelines, which were based on the continuation of space traffic at the rates observed in the 1990s. Largely governed by geopolitical and economic factors, space traffic has always been subject to considerable fluctuations, however recent trends point to a significant increase of traffic in the low-Earth orbit (LEO) region. Companies such as SpaceX, OneWeb, and Boeing have each submitted ambitious satellite mega-constellation proposals to the FCC. The implementation of these mega-constellations involves the introduction of thousands of satellites to the LEO environment to provide low-latency broadband internet to the entire world. A permanent debris-control scheme, based more on remediation than mitigation, will have to be developed well in advance of the critical orbit-clogging point predicted by the Kessler Syndrome.

We investigate the effects of the proposed SpaceX and OneWeb constellations on the sustainability of LEO, as well as the efficacy of possible passive satellite removal techniques; particularly, the exploitation of dynamical instabilities caused by resonant perturbations. The results of this study are intended to serve as a baseline for the selection of orbital parameters for the proposed LEO and MEO mega-constellation satellites, which satisfy mission requirements and employ a passive decommission ideology.

Methods utilized here are based on lessons learned in the investigation of the chaos and stability of the navigation constellations in medium-Earth orbit (MEO) (see, e.g., Rosengren et al. 2017, DOI 10.1093/mnras/stw2459, and references therein). In order to better understand the governing dynamics of the individual satellites of these mega-constellations, the principle effects of atmospheric drag, solar radiation pressure, J2 (Earth oblateness), and lunisolar perturbations are investigated. Furthermore, the main resonances acting in the LEO region are mapped to give an idea of the possible chaotic regions affecting LEO satellites and the stability of the proposed disposal orbits.

The results of this case study provide insight into the stability and lifetime of satellite orbits in the LEO environment, aiding satellite constellation designers in the selection of initial and disposal orbital parameters. The optimal selection of these parameters will ensure the stability of satellite orbits throughout constellation life cycles and prevent decommissioned satellites in disposal trajectories from interfering with active satellites.

PEDAS.1-0020-18 BAYESIAN ORBIT UNCERTAINTY ESTIMATION USING LASER RANGING AND TLE DATA

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Orbit uncertainty quantification is of utmost importance in space surveillance and tracking (SST). One of the most prominent use cases is conjunction assessment of operational satellites and potential collision targets like space debris. Estimating orbit uncertainty of such uncooperative objects is typically a data-sparse problem. This is due to the large object population and the limited availability of tracking sensors. Amongst them, laser ranging is a promising concept to complement future SST activities as it has several advantages over radar tracking. It is not only considerably cheaper but also about one order of magnitude more accurate. A major challenge is that orbit uncertainty grows and becomes non-Gaussian during long propagation intervals between successive measurements. Moreover, observability issues may arise in view of ill-distributed tracking geometries. These challenges call for non-Gaussian modeling of orbit uncertainty and data fusion with Two-Line Elements (TLEs), where the advantages of accurate but sparse tracking data and abundant but inaccurate TLEs are combined.

Therefore, we present the first application of a Gaussian mixture filter to assimilate real laser ranging and TLE data for uncertainty estimation of space debris in low-Earth orbit (LEO). While the a-priori uncertainty is derived from historical TLEs, real laser observations are processed in Bayesian state updates. To obtain the required statistical information of TLEs, we apply an uncertainty estimation method accounting for the new way of TLE generation, which has been gradually introduced in recent years. Process noise is primarily governed by atmospheric density mismodeling in LEO. We model these errors as a modified version of the stochastic Ornstein-Uhlenbeck process, which takes account of temporal correlations. A state space representation of this process is derived to facilitate covariance propagation for the individual Gaussian components.

Finally, we evaluate the potential of our approach based on parameter and sensitivity studies using data from a recent tracking campaign. In doing so, we compare our results with those obtained from a Particle Filter (PF), an Extended Kalman Filter (EKF) and batch least-squares (BLS) adjustment. While the PF serves as a benchmark provided that a-priori uncertainty and process noise are adequately tuned, the EKF demonstrates limitations due to Gaussian uncertainty modeling. Comparisons with BLS solutions provide insight into the benefits of process noise modeling.

PEDAS.1-0021-18 MODELLING ATMOSPHERIC DENSITY INDUCED UNCERTAINTY IN ORBIT PREDICTIONS

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One of the main tasks of a space objects catalogue is to support routine space operations with accurate orbital information and associated uncertainties. Uncertainties associated with an estimated orbit are provided through a covariance matrix, which in turn is used in estimating the probability of collision between the satellite of interest and other orbiting space objects. The estimate of collision probability is only as good as the quality of the input that is the covariance matrix. In order to make appropriate decisions during space operations, the realistic covariance matrix plays an important role. Therefore, a method for estimating realistic covariance will be significant within a space object catalogue maintenance system.

Generally, the batch least square orbit determination (BLSQ-OD) procedure is used in maintaining a space object catalogue. With this procedure, the estimated orbit and the confidence of estimation is obtained by fitting the modelled orbit to a given set of observations. Thus, the estimated covariance matrix mainly depends on the number of observations, length of the observation arc, and the time distribution of observations within the arc. The covariance associated with the estimated orbit in a BLSQ-OD does not take into consideration the quality of the force models used within the propagator. Generally with the BLSQ-OD process the estimated covariance matrix is optimistic. This tight covariance might not provide realistic information about the uncertainty associated with the orbit determination and prediction. Hence, it is required to include all the uncertainties within the estimated and propagated covariance, which are: 1. Uncertainty within force models 2. Uncertainty within the method of propagation 3. Uncertainty within the observation set.

The present study will target uncertainties associated with atmospheric density modelling and an empirical method to estimate them along the prediction arc lengths.

The LEO altitude atmospheric densities are both spatially and temporally correlated. To estimate or to include an uncertainty of such a system is a non-trivial task. In this study an interpolated Gauss-Markov process (smoothed Brownian motion) is used to approximate the uncertainty within the density models, and later a time power series is used for approximation. The order and powers of the polynomial are estimated by solving the Hill-Clohessy-Wiltshire equations with stochastic accelerations. The second part will discuss the process noise approximation for estimating the observation uncertainty together with the BLSQ-OD estimated covariance matrix. Later, results from the application of the method over real observation data sets are presented and discussed.

PEDAS.1-0022-18 AN ENSEMBLE KALMAN FILTERING APPROACH FOR ATMOSPHERIC DENSITY ESTIMATION USING ORBITAL DEBRIS

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A key requirement for accurate trajectory prediction and space situational awareness is knowledge of non-conservative force effects on space object motion. These effects vary temporally and spatially, driven by the underlying behavior of space weather. Existing trajectory prediction algorithms adjust space weather models based on calibration satellite observations. However, lack of sufficient data and mismodeling of non-conservative forces cause inaccuracies in space object motion prediction, especially for uncontrolled debris objects. The uncontrolled nature of debris objects makes them particularly sensitive to the variations in space weather. Our research takes advantage of this behavior by utilizing observations of debris objects to infer the space environment parameters controlling their motion.

The hypothesis of this research is that it is possible to utilize debris objects as passive, indirect sensors of the space environment. We focus on estimating atmospheric density and its spatial variability to allow for more precise prediction of Low Earth Orbit (LEO) object motion. The estimated density portion of the estimated state is parameterized as a grid of values, distributed by latitude and local sidereal time over a spherical shell encompassing Earth; the position and velocity of each debris object is also estimated. This work builds upon our previous work in which an Ensemble Kalman Filter (EnKF) is used for assimilation of space object measurements to estimate density. More specifically, this research demonstrates the advantage of estimating the full density state at each measurement time, as opposed to a single density element closest to the debris object. One advantage of a fully extended state is that the uncertainty corresponding to each density element is available at all measurement times via the covariance, which allows for an observability analysis using the accumulated information matrix. A localization scheme is derived from the initial density state ensemble and applied in the filter measurement update to leverage density state correlations.

We investigate the validity of the hypothesis by comparing estimated and true density fields in an appropriate simulation. Synthetic measurements are generated by propagating space objects through a complex density field defined by the NRL-MSISE model to serve as truth. The truth model is sensed indirectly via noise-corrupted observations of space object motion (range, range rate, and angles) that are assimilated in the EnKF to produce an estimate of the true density field. The filter initially assumes the Jacchia Reference Atmosphere density model. This approach simulates a real world scenario in which a filter is initialized with a complex density model that differs from the true density field reflected in the measurements. For performance comparison, the scenario characteristics (number of objects, orbit diversity, measurement cadence, etc.) are based on a sensor tasking campaign executed for the High Accuracy Satellite Drag Model project.

The EnKF analysis details spatial comparisons between the true and estimated density fields, and quantification of the improved accuracy in debris object motion predictions due to more accurate drag force models from density estimates. This research focuses on LEO object motion, but if successful, the approach could also be extended to other orbital regimes for refinement of magnetic field and solar radiation models.

PEDAS.1-0023-18 ATMOSPHERIC REENTRY PREDICTIONS FROM TLE LONG TIME SERIES. APPLICATION ON THE TIANGONG-1 REENTRY DURING SPRING 2018.

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The long term evolution of orbital parameters of a trajectory is efficiently driven following semi-analytical approaches. Software such as STELA designed to check the compliance of storage orbits with the IADC guidelines propagate time series of mean orbital elements very quickly, with an accuracy level that does not significantly suffer from the averaging approach. By propagating the mean variational equations jointly to the equations of motion, it is even convenient to adjust the mean model to data sets, such as TLE times series, even over long or very long time scales.

We propose in this paper to investigate to what extent TLE time series can be used jointly to STELA to give an insight into the reentry epoch of a low altitude orbit, by adjusting the trajectory to the available data. We analyse the impact of the number of data, their spread, and the latency before the event, through some charts to be seen as abacus. The method is applied to the chinese station Tiangong-1 that is about to re-enter the atmosphere soon, but which is still flying the Earth when submitting this abstract. But, in the presentation, we will use the time of reentry only as a reference, and we will investigate in these abacus the impact of the atmospheric density and solar activity models.

As a consequence, we focus also in this paper on the ballistic coefficient and the area-to-mass ratio that have to be evaluated jointly to the initial (mean) state vector of the satellite. For most of space debris, their a priori-value is frequently far from the one leading to the best compatibilty between the theory and the observations. This paper is also a great opportunity to present our method to calibrate these coefficients. Other examples as the Chinese station are also provided, with ballistic coefficients that are also available through as a database hosted by IMCCE at Paris Observatory.

PEDAS.1-0024-18 LIFETIME ANALYSIS IN LAUNCH WINDOW MAPS: DESIGNING SATELLITE ORBITS FOR DEMISE

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For the investigation of the Earth's magnetosphere and interplanetary space, satellites with orbits of large semi-major axis and large eccentricity are often used. While end-of-life (EOL) disposal options are well established for missions in low-Earth orbits (atmospheric decay) and the geosynchronous belt (near circular graveyards), existing mitigation guidelines do not fully regulate the whole, usable circumterrestrial orbital space, such as these highly eccentricity orbit (HEO) science missions; e.g., NASA's Magnetospheric Multiscale Mission (MMS) and ESA's INTErnational Gamma-Ray Astrophysics Laboratory (INTEGRAL). The non-negligible collision risks posed by these LEO-GEO transiting spacecraft has motivated both theoretical study and practical implementation.

The solution to the space debris problem, from LEO to GEO, can be found only by coupling a deep understanding of the circumterrestrial phase space with satellite mission analysis and design. For future missions, the EOL options have to be clearly identified during the early phases of the design, taking into account orbital interactions and environmental evolution. This more holistic vision parallels that of ESA's Clean Space initiative, fostering innovative techniques and tools in orbital dynamics to novel spacecraft design and manufacturing to reduce the space industry's environmental impact. We emphasize here the new paradigm of self removal of satellites through natural perturbations (passive disposal), and discuss how lifetime estimates can be incorporated into launch window constraints to ensure the future demise of the satellites.

For the science missions described above, the time of launch, and therefore the location of the orbit in space, must be chosen to satisfy a number of limiting constraints. In such launch window studies, the orbital lifetime is likely a factor to ensure the satellite exceeds the nominal mission time, but its reduction or control is hardly a consideration. For the purposes of space debris mitigation and remediation, we propose incorporating lifetime predictions as a fundamental mission constraint. Doing so will not only ensure that the missions will have predictable behaviors over both the nominal (and possibly extended) mission, thus avoiding an Interstellar Boundary Explorer (IBEX)-like situation, but that the satellites will eventually meet their demise through atmospheric reentry (without the need to make future significant orbital adjustments, à la INTEGRAL).

We have developed an extensive set of computational tools (regularized formulations of special perturbation theory and semi-

analytical averaged models) for the exploration and simulation of the dynamics of Earth-satellite orbits, accounting for gravitational and non-gravitational perturbations. Here we apply these capabilities towards lifetime predictions of HEOs, and adapt this to launch window analyses. Such dynamical assessments could have a profound and tangible influence on constellation design, perhaps attacking the debris problem at its source.

PEDAS.1-0025-18 PARAMETERIZATION OF HIGHLY ECCENTRIC ORBIT

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In this report, we present a new way to parameterize the Highly Eccentric Orbit (HEO). The new parameterization is introduced to overcome the difficulty in propagating the HEO in restricted scenarios. By restricted scenarios, we mean the space debris where the HEO objects are numerous or the onboard environment where the hardware capability is limited.

In the restricted scenarios, it is time-consuming to use the numerical propagation since the large eccentricity requires the propagator to adaptively change the step size to obtain a good balance between accuracy and speed. Even so, propagation at the perigee is inevitably slow, not to mention that frequent adapting the step size itself comes at the cost of efficiency. The storage for HEO ephemeris is also a concern. Due to the fast motion at perigee, the ephemeris has to be saved at a reasonably small step size at perigee.

Analytical solution is another popular option in such scenarios, among which SGP is always used by many agencies. However, the analytical approach faces a critical problem with HEO, where the large eccentricity renders the expansion (with respect to the mean anomaly) highly inaccurate or even invalid. Many approximations applied to nearly circular orbits do not hold either in these circumstances and the neglected higher-order terms (with respect to the eccentricity) have to be reconsidered. All these restrictions compromise the current analytical solutions in the application of HEO.

There have been some earlier researches, providing alternative presentations of the orbits of the space objects, including HEO objects or debris. One effective approach is to follow the broadcast ephemeris in satellite navigation (GPS, Galileo, BeiDou) that uses certain numbers of parameters to fit the propagated orbit based on known variation pattern of the orbital elements. These parameters, together with predetermined model, are used to compute the orbit or position at real time. This approach always involves frequency analysis or Fourier analysis, to find the contributing periods. The limit of this approach on HEO is that, since the HEO objects move non-uniformly and it is not easy to model the orbit variation with simple combinations of various frequencies. To model the orbit using combinations of cos(ωkt) and sin(ωkt) could require a large number of terms.

In our approach, we start modeling the orbit from the underlying dynamics. Recognizing that the orbital element actually varies with respect to the true anomaly f, instead of the mean anomaly (or equivalently the time). The orbit variation is modeled in the form of summation of cos(kf) and sin(kf), together with other possible terms including linear or quadratic terms and/or monthly or semimonthly periods. The tricky part of this approach is about how to solve for the true anomaly when recovering the orbital elements from the fitting parameters. We use a recurrence approach to determine the true anomaly at the beginning of the orbit calculation and with the determined f time series, the other elements can be determined as well.

Preliminary tests show that it is easy to obtain high accuracy with this method, without having to include too many frequencies in the model. This new parameterization is feasible in terms of both the orbit accuracy and the data storage of fitting parameters.

PEDAS.1-0026-18 CHARACTERISTIC AND DISTRIBUTION OF TLE ORBITAL PROPAGATION ERRORS

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The TLE catalog is a global public data source of space objects, and is widely applied for space missions, collision risk assessment, etc., but orbit accuracy is not available. Historical TLE and GPS precision ephemerides of CHAMP and GRACE are collected and compared to assess TLE orbital propagation errors. Evolution over time and spatial distribution of the errors are discussed, especially characteristic of the system biases. The biases can reach the level of kilometers, and are correlated with geographical locations. Removing system biases from orbit uncertainties will significantly improve orbit accuracy and provide credible collision risk assessment.

PEDAS.1-0027-18 DEVELOPMENT OF A HIGH-SPEED, RAREFIED PLASMA WIND TUNNEL FOR IONOSPHERIC AERODYNAMICS RESEARCH

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Spacecraft orbiting in Low Earth Orbit (LEO) undergo complex and poorly understood interactions with their environment leading to large uncertainties in predicting orbits and an associated risk of collision with other satellites and space debris. The drag of orbiting spacecraft represents one of the largest sources of error for orbit determination. Spacecraft drag in LEO due to neutral particle interactions has been studied in detail, and significant reductions in uncertainties of spacecraft drag coefficients can be attributed to an improved understanding and modeling of gas-surface interactions. However, the interaction of the orbiting spacecraft with the charged particle environment in the ionosphere and the resulting perturbation to their orbit is less well understood. Research is underway at UNSW Canberra to enable the prediction of the orbits of near-Earth space objects with significantly greater fidelity - for the modeling of environment interactions - than currently possible. This is being achieved through an astrodynamics research program that closely couples physics-based supercomputer simulations of the complex plasma-spacecraft interactions in LEO (ionospheric aerodynamics) and benchmarkquality ground-based experiments as well as in-orbit flight experiments to address the research challenges associated with the development of enhanced space-situational awareness capability.

The work described in this paper provides insight into the development of a ground-based experimental plasma flow physics capability, applicable to ionospheric aerodynamics research. To enable this, a magnetically filtered hollow cathode plasma source has been coupled to a vacuum chamber (diameter 1m, length 2m) to simulate the high energy/low density charged particle interaction environment experienced by spacecraft orbiting in LEO. A plasma diagnostic suite consisting of a Langmuir probe to measure the plasma density and electron temperature, and a retarding potential analyzer to determine the ion energy have been employed to characterize the plasma flow properties. Plasma source operating parameters can be adjusted to vary plasma flow properties and thus enable scaling studies.

Charged drag measurements for grounded and negatively charged flat plate and cylinder test objects have been conducted successfully using a nano-Newton thrust stand. The ion current collected by the test objects was also recorded as a proxy for direct ion momentum exchange due to ions hitting the test objects' surface. Differences in the trends for total force and ion current measurements were observed with increasing negative surface potential. This can be attributed to indirect ion momentum exchange with the test objects. The latter effect is related to the electrostatic interaction between the streaming ions and the electrostatic sheath surrounding the charged test object. The resulting force counteracts, i.e. reduces, the direct charged force/drag (from ions hitting the surface) imparted on the charged test object. The experimental data corroborate previous findings from numerical simulations and clearly demonstrate the significance and complexity of charged aerodynamics effects for LEO plasma-body interactions.

PEDAS.1-0028-18 ESA ACTIVITIES ON COMBINING RADAR, OPTICAL, AND SLR OBSERVATIONS FOR SST: ANALYSIS ON THE INFLUENCE OF REALISTIC COVARIANCE ON CORRELATION

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The integration of the SST software components and the verification of their end-to-end functionalities and performance when dealing with real data will provide ESA with the necessary technical tools to independently conduct tests at large scale to routinely perform surveillance of space debris hazards. Within the SST Core Software, developed under ESA's SSA Programme, the observations are processed using Data Processing Chain (DPC) to maintain the catalogue of space objects. The main sources of input to the DPC are observations obtained through different sensors, external catalogue, and other third party data.

The current and future observation test campaigns are aimed at collecting a sufficient sample of real data from all SST sensor technologies: radar, passive optical telescopes, and satellite laser ranging (SLR). These data are used to validate the SST Core Software, to validate other software tools under development, and to populate a temporary test catalogue. The observation planning has been split according to the altitudes covered, into a LEO and a MEO/GEO part. The LEO campaign is planned to involve both of ESA's test-bed radars: the monostatic (MSSR) at Santorcaz, Spain and the bistatic (BSSR) at Palaiseau, France, together with the Austrian SLR station in Graz. The MEO/GEO campaign will involve the use of passive optical sensors including ESA's Test-Bed-Telescope and two other telescopes for survey activities (ZimSMART in Switzerland and Starbrook located in Cyprus and operated by the UK), and three telescopes for tracking (Deimos' DeSS Tracker2 in Spain, ESA's Optical Ground Station (OGS) at Tenerife,

Spain, and Zimlat in Switzerland).

The observations are needed to be correlated, linked with each other, or with the catalogued object. The accuracy of the correlator depends on several factors, such as quality of observations, quality of ephemerides, uncertainty associated with the ephemerides, etc, while covariance associated with a catalogued object plays an important role on false association of the observations. To ensure the optimal performance from the correlator, the data provided to the correlator must be to its maximum accuracy.

In the current presentation we intend to summarize the observation campaigns, discuss correlation results obtained from using different methods of covariance propagation, and conclude with an overview on future directions on improving the DPC to handle all sensor data.

PEDAS.1-0029-18 COMPARISON SPACE SELECTION TO ACHIEVE EFFICIENT TRACKLET TO OBJECT ASSOCIATION

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A major challenge when maintaining a space object catalog is the proper association of new measurements to already cataloged objects. Optical observations are typically associated by comparing the modelled observation with the measured one. The modelled observation is generated from cataloged object states by propagating them to the epoch of observation and transforming them from state space, e.g. orbital elements, to the observation space, e.g. right ascension and declination. In addition to propagating the states, their propagated uncertainty distribution is transformed to observation space as well. Statistical distance metrics, such as the Mahalanobis distance, are then evaluated to test whether the observation originated from the cataloged object or not. These distance measures often assume that the uncertainty can be represented with a Gaussian distribution. Assuming that the catalog state uncertainty is properly represented by a Gaussian, it can still be deformed during the propagation in time and the transformation to observation space. The uncertainty of the catalog state is typically much larger than the one from new measurements (only a few arc seconds for optical telescopes) and is therefore more affected by transformation distortions. It is therefore beneficial to perform the comparison in a space advantageous for the state representation. In the case of radar observations, this can be achieved by the use of object centered curvilinear coordinates. However, optical observation arcs do not provide enough information to directly map them into such a space. Instead, they can be projected into a state space, e.g. assuming the same radial distance as the tested catalog object. In this presentation, we will analyze the effect of the comparison space selection on the cataloging performance, i.e. we will systematically test if it is beneficial to compare directly a series of angles, angles and angular rates, or to do the comparison in a object centered frame.

PEDAS.1-0030-18 ON THE PRACTICAL EXPLOITATION OF PERTURBATIVE EFFECTS IN LOW EARTH ORBIT FOR SPACE DEBRIS MITIGATION

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This paper presents the results of a numerical evaluation of the natural lifetime reduction in Low Earth Orbit, due to dynamical perturbations. The study considers two values for the area-tomass ratio, a nominal ratio which resembles a typical value of spacecraft in orbit today, and an enhanced ratio which covers the surface augmentation. The results were obtained with two orbit propagators, one of a semi-analytical nature and the second one using non-averaged equations of motion. The simulations for both propagators were set up similarly to allow comparison. They both use the solar radiation pressure and the secular terms of the geopotential (J2, J4 and J6). The atmospheric drag was turned on and off in both propagators to alternatively study the eccentricity build up and the residual lifetime. The non-averaging case also covers a validation with the full 6x6 geopotential. The results confirm the findings in previous publications, that is, the possibility for de-orbiting from altitudes above the residual atmosphere if a solar sail is deployed at the end-of-life, due to the combined effect of solar radiation pressure and the oblateness of the Earth. At near polar inclinations, shadowing effects can be exploited to the same end. The results obtained with the full, non-averaging propagator revealed additional de-orbiting corridors associated with solar radiation pressure which were not found by previous work on space debris mitigation. The results of both tools will be compared for specific initial conditions. For nominal values of area-to-mass ratio, instead, it is confirmed that such an effect is negligible.

The paper then puts the findings in the perspective of the current satellite catalogue. It identifies space missions which are currently close to a resonance corridor and shows the orbit evolution within the resonances with a significantly shorter residual orbital lifetime. The paper finishes with a discussion on the exploitation of these effects with regards to the long-term simulation of the space debris environment and the operational considerations.

PEDAS.1-0031-18 SPACE DEBRIS DEFLECTION AND DE-ORBIT TO EARTH BY TUNED, INFLATED MIRROR BALLOONS

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The growing Space debris danger poses a hazard to all satellite survival and even to future astronauts safe flight in orbit. We suggest a novel solution based on two main procedure: 1) A preliminary location in all future satellite mission of a safe (final) inflatable balloon mirror, whose role it is to inflate at the end of the satellite life in case of a need of any soon (months) landing. The balloon size is related to the satellite mass by a simple law: for instance a mini satellite mass (about 10 kg) might needs a ten meter size ballon. 2) A more complex capture of already present debris in orbit requires a main cleaner "Mother satellite" that will reach as many as possible fragments in almost collinear nearby trajectories at comparable speeds. The Mother satellite station once along the debris fragment cluster will eject at each differential speeds a secondary "children" mini or nano satellites approaching each tuned single debris target. Once single satellite will approach the fragment at a small speed it capture it by an elastic net trap, linked and bounded to a inflatable mirror balloon whose size is correlated to the corresponding debris mass. The solar photon pression will hit and skim these spherical mirrors in a way pushing and forcing toward the Earth center the debris while in sunny side. The force it is weak but it is able to bring (for instance a 10 kg mass and a 10 meter radius balloons) in a few months the debris a few hundred kilometers below toward the Earth atmosphere. Below 800 km altitude the same diluted terrestrial atmosphere will act by its friction even much more efficently and faster than the same solar pressure. This is leading to a faster capture and deorbit of the debris. At 600 km the atmosphere friction it is 10 times larger (while at 400 hundred km it is 100 times larger) than solar pressure. Therefore the balloons role is ruling in deorbit debris from low height, while solar pressure on the large balloon areas at highest (above thousand km) altitude orbit. Effect of combined radiation pressure and aerodynamic forces at different altitudes is calculated. An evaluation of balloon radius required in relation to debris mass is provided, and of the corresponding payload.

PEDAS.1-0032-18 ACTIVE DEBRIS REMOVAL FROM ORBIT USING DRAG INDUCER CUBESATS (DICS)

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Debris in useable orbits around the Earth has been increasing at an alarming rate over the last two decades with the increase in population of satellites particularly in LEO. The no. of tracked debris objects in space has almost doubled since 2005 as a result of Fengyun-1C and Iridium/Cosmos incidents. Active Debris Removal (ADR) is one of major areas of space research. The amount of non-operational objects in vicinity of valuable space assets significantly enhances the risk of collision. Applications for ADR include depopulation of non-operational space objects in usable orbits and development of collision detection and avoidance systems for future satellites. The work involves comparative study of debris classification techniques and selection of removable debris using ADR. An in-depth review of drag inducing mechanisms currently under study for ADR by space research organizations worldwide. This paper presents a novel approach in ADR research by using a master satellite in orbit with packs of single and 2-unit CubeSats stored inside. Such a system effectively allows us to establish an inventory of propeller devices in space. Small tumbling objects which cannot be accurately modelled by using ground-based instruments will be assessed and profiled in real-time from master satellite. Once the real-time characterization of debris is performed, Drag Inducer CubeSats (DICs) are ejected in the direction of target object. After the ejected satellite captures or tethers itself to the target debris, sails stowed in CubeSat are deployed perpendicular to the flight path of debris consequently increasing the drag coefficient. This causes the target debris to slow down and reenter Earth's atmosphere resulting in a burnout thus removing it from the orbit. Furthermore, preliminary system design budget of parent spacecraft with short to midrange lifetime will be presented. System level budgeting will involve preliminary structural, electrical, data-handling and propellant subsystem budgeting with focus on storage and in-orbit ejection/latching-on mechanism of Drag Inducer CubeSats. System budgets evolve concurrently after the comparative study of ADR method is concluded.

PEDAS.1-0034-18 ANALYSIS ON THE ACTIVE REMOVAL OF HIGH-RISK OBJECTS

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Space Debris and its impact on the near-Earth space environment has become a serious problem for active satellites. While modelling and observing make up a large portion of the discussion on how to limit the debris, the order of 'high risk objects' and the impact of an active removal is just as essential. High risk objects are can be ranked according to their mass, size and collision probability. Among the countless studies on their actual order according to risk probability, rocket bodies of the SL-16 and SL-8 type always rank high within the top 200. While some authors argue to actively remove the heavier SL-16 first, others debate for a multiple SL-8 removal within one mission. They have the advantage to orbit in close vicinity, a removal would limit the available impact area. The presented work compares, how the removal of SL-16 or multiple SL-8 would impact the space environment on the long term. A mission analysis is performed to collect the SL-8 fuel efficient, or in other words to find rocket bodies close enough to each other to be removed within one mission. An order of ranking for the removal for the SL-16 is presented, the comparing analysis follows this order. Both approaches are compared according to their expenditures and outcomes.

PEDAS.1-0035-18 LASER ABLATION FOR SPACE DEBRIS MITIGATION: A SYSTEMATIC STUDY

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The increase in the number of artificial objects in orbit around the Earth represents a serious threat to the future utilization of space. The scope and nature of the problem require an international effort. The Trento Institute of Fundamental Physics and Applications (TIFPA) participates in the study of laser ablation for space applications, propulsion and space debris mitigation, in the context of New Reflections program of the Institute National of Nuclear Physics (INFN). An evaluation of the performance of laser ablation for debris removal in Low Earth Orbit (LEO), for different scenarios of ground-based and orbiting system configurations is presented. The results are obtained from a simulation developed in the MATLAB environment, which includes the relevant gravitational (Earth zonal model, solar and lunar gravity) and atmospheric models. Attention is also paid also to laser system features, e.g. pulse duration and intensity, repetition rate and light-material coupling coefficients, as determined from laboratory measurements performed on purpose in Trento. The relative merits of the different configurations are discussed.

PEDAS.1-0037-18 A SENSOR TASKING TOOL TO BUILD-UP AND MAINTAIN A CATALOGUE OF GEOSYNCHRONOUS SPACE OBJECTS

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To protect the geosynchronous region the orbits of all space objects have to be known. Precise and accurate orbits are prerequisite of successful collision prediction. Two different observation types are usually employed: survey, which are performed to expand the catalogue caused by any change of the space object population and follow-up observations to maintain the accuracy and precision of ephemeris data within certain limits for each catalogued object. To perform these observations in the most efficient way, optimized sensor tasking is a key element. This paper presents a sensor tasking algorithm for an optical telescope network providing optimized survey and follow-up observations for catalogue maintenance. The algorithms is based upon genetic optimization of detectability based upon the phase angle and maximizing the information content relative to the orbit improvement. The proposed methodology is effectively balancing survey and follow-up observations. A simulated object population based on the current TLE catalogue is used to illustrate the effectiveness of the sensor tasking algorithms.

PEDAS.1-0039-18 SPACE DEBRIS IN THE NEIGHBORHOOD OF THE OPERATIONAL ARTIFICIAL SATELLITES

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Most of the cataloged objects in Low Earth Orbits are space debris, considering that less than 7% are operational spacecraft. In this work, the orbital dynamics of space debris are studied in the neighborhood of the Brazilian satellites, CBERS and SCD, and around of the ISS - International Space Station. The results show that the collision risk of space debris with the operational satellites studied is high and preventive actions to avoid collisions are necessary.

PEDAS.1-0040-18 SPACE DEBRIS IN LEO REGION: ORBITAL DYNAMICS DESCRIBED BY RESONANT ANGLES

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The Low Earth Orbits (LEO) has an increasing number of space debris justifying the interest in the observation and collision avoidance. The orbital dynamics of several of these objects involve different resonances distributed by the distinct altitudes. In this work, objects in resonant orbital motions in the regions of 14:1 and 15:1 resonances are studied. Using the two-line elements (TLE) of the NORAD, resonant angles are described to develop an analytical model and the time behaviors of the orbital elements. Frequency analysis shows possible irregular motions describing the orbital motions of these objects.

PEDAS.1-0041-18 ATTITUDE STATE STATISTICS FOR LEO ROCKET BODIES

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For space debris remediation, the active removal of rocket bodies attracts a lot of attention, considering the large quantity and harmfulness of rocket bodies. The knowledge of attitude state and state changes of the target objects is required in the pre-early stage of the mission, and get statistics on a large number of samples will be especially helpful for understanding the evolution of attitude motion of rocket body and guiding the target selection for ADR.

Sequential photometric measurements, so called light curves, can be used to inverse the attitude state of space debris, e.g., using continuous glinting epochs in light curve to determine the directions of reflective surface. In our previous work, a new attitude inversion method has developed by using simulated light curves and machine learning. It relies on the features of entire light curve than the glinting points only, so much broader range of light curves of rocket bodies can be evaluated for attitude state inversion, for which the direction of precession axis in space and the tumbling angle and period are the most interesting parameters.

This paper will discuss a statistical analysis of the attitude states of dozens of LEO rocket bodies. Based on the MMT satellite photometric database and the attitude inversion method we developed, the attitude state history and state change rates were determined. The long-term evolution of rotational motion for different types of rockets was discussed and the parameters related to gravity gradient and eddy currents Torques were also evaluated.

PEDAS.1-0042-18 ESTIMATION OF ROTATIONAL MOTION OF CZ-2C ROCKET BODIES

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The rotational motion and its evolution of CZ-2C rocket bodies are estimated based on the ground observational data, which include the laser observational data of two targets and the optical observational data of another one. From the laser observation data, the attitude variation of rocket bodies and its short-term evolution can be obtained. And the long-term evolution of the rotational motion can be estimated from the optical data. The overall rotation law of CZ-2C rocket body can be confirmed through the combination of the two observations.

PANELS (P)

INTERNATIONAL COORDINATION OF SPACE EXPLORATION ACTIVITIES (PEX.1)

PEX.1-0001-18 THE EUROPEAN SPACE SCIENCES COMMITTEE ON INTERNATIONAL COORDINATION FOR SPACE EXPLORATION

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European Space Sciences Committee

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The European space sciences landscape is very diverse as it involves two major intergovernmental organisations (The European Space Agency-ESAand the European Commission-EC) and more than 25 countries that each have their national institutional setting and scientific planning approach. It has therefore always been essential to coordinate space science and exploration programmes throughout Europe and with international partners.

The European Space Sciences Committee (ESSC - www.essc.esf.org) is offering European scientists an independent voice providing advice and guidance on space science matters to ESA, EC, national space agencies, and other stakeholders. The ESSC is not a programmatic nor a political entity; it promotes space science not as a cost but as a high-return investment with a broad and exciting leverage effect on the people and the economy.

Similarly to other international advisory bodies, ESSC offers recommendations and implements other space exploration related activities; it delivers direct consolidated (solicited or proactive) input from the scientific community to programmatic institutions; but is can also represent an anchor for non-European scientific communities to interact and collaborate.

The ESSC has thus kept and developed very strong links with the Space Studies Board of the US National Academies (NAS-SSB), members from both sides of the Atlantic thus affording regular insight on European and US space programmes. These two bodies are also linked in some strategic planning issues and in studies related to Planetary Protection (e.g. on PhobosDeimos categorisation), Mars (Mars Special Regions), space weather or the icy moons of the giant planets. The ESSC has also tight contacts with Chinese, Russian and Japanese space agencies and research organisations.

This international bottom-up approach in space roadmapping has proven to be highly valuable in the past, a relevant example being the Cassini-Huygens mission. In the early eighties, the concept of a joint U.S.-European mission to explore the Saturnian system was delineated during a joint European Science Foundation-US

National Academies workshop, this was the spark of one of the most successful long-lived (2004-2017) planetary exploration missions to date.

A coordinated integrated position on programmatic space matters is key to maximise scientific return. Since the late nineties, the ESSC and its office have conducted studies and evaluations on the ESA Life and Physical Sciences in Space programme (ELIPS) as well as defining a Science-Driven Scenario for Space Exploration or roadmaps in the fields of human space exploration or astrobiology. ESSC has also been very active in providing inputs to the European Commission on the definition of its space strategy and space research work programme. The ESSC contacts with international bodies significantly contribute to the definition and implementation of exploration programmes in their respective countries and demonstrate that common initiatives allow us to promote the inputs from the scientific communities. A network of independent non-programmatic interdisciplinary bodies covering all the regions of the world would certainly improve coordination of space exploration at the global level.

References: all of the documents related to the aforementioned studies can be found at: http://www.essc.esf.org/list-of-publications/

PEX.1-0002-18 NASA'S PLANETARY SCIENCE MISSIONS PRESENT AND FUTURE PLANS

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The exploration of the outer Solar System has recently revealed remarkable information regarding "ocean worlds". With these new discoveries, these worlds have become a focus in the search for possible life elsewhere in the Solar System.

Earlier Mars missions were designed to make discoveries under the theme of "Follow the Water." Progressive discoveries related to evidence of past and present water in the geologic record make it possible for next steps. NASA is currently following an exploration strategy of "Seeking Signs of Life." In addition to landing in a place with past evidence of water, we are seeking evidence of organics which potentially provide habitable conditions. Future Mars missions include NASA's InSight lander and the Mars 2020 rover that will produce rock cores from a geologically diverse sight for potential future return.

Furthermore, OSIRIS-Rex is expected to begin approaching Bennu in August 2018; Psyche and Lucy are in full implementation; and Dragonfly and CAESAR are in Phase A concept study; NASA's Planetary Science Division continues the formulation of the Europa Clipper and the implementation the InSight and MARS020 missions. We also continue work to deliver NASA's contributions to fly on international missions such as ESA's Jupiter Icy Moons Explorer (JUICE) mission.

International partnerships are an excellent, proven way of amplifying the scope and sharing the science results of missions. NASA has always encouraged international participation on our missions and other Space Agencies have reciprocated and invited NASA investigators to participate in theirs. As Director of Planetary Science at NASA, I will continue to seek cooperation with our strong international partners in support of planetary missions.

PEX.1-0003-18 CANADIAN SPACE AGENCY SPACE EXPLORATION UPDATE

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Human Spaceflight, Space Astronomy and Planetary Science define the scope of the Space Exploration branch at the Canadian Space Agency.

The Canadian Space Agency undertakes Exploration activities in partnership and is active in international fora such as the International Space Exploration Co-ordination Group and International Mars Exploration Working Group. CSA is a partner in the International Space Station and the James Webb Space Telescope, and currently supports the Canadian APXS investigation on NASA's Mars Science Laboratory and OSIRIS-REx Laser Altimeter investigation on NASA's OSIRIS-REx New Frontiers mission. Following astronaut selections in 2012 and 2017, Canada has an active astronaut core of four, with David Saint-Jacques scheduled to fly on Expedition 58/59 in November 2018.

This paper presents an update on CSA Space Exploration Strategic Planning group activities and reports on recent studies and analogue activities exploring potential Canadian contributions to flagship international activities such as the Global Exploration Roadmap, Robotic Lunar Exploration and Mars Sample Return.

The CSA SESP is responsible for consultation with the Canadian community on Space Exploration priorities. A summary of the recent report 'Canadian Space Exploration: Science and Space Health priorities for next decade and beyond' will also be discussed.

PEX.1-0004-18 UTILIZING MODERN ADVANCED ROBOTICS SYSTEMS FOR THE IN-SITU EXPLORATION OF THE SOLAR SYSTEM

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With robotic systems on Earth obtaining new capabilities in a staggering speed, there is a golden opportunity to use these capabilities to reach once unreachable spots on large and small bodies in the Solar System to perform in-situ measurements and to gather the most pristine and interesting samples. Therefor DLR intends to use its in-situ heritage and robotic competence for exploration and support the analysis of the potential for life on planetary bodies. Based on DLR's recent efforts for MASCOT, HP3, ROBEX, Kontur-2, its contributions to the CORSAIR proposal and strong institute heritage in planetary science, system competence and advanced robotic systems, DLR proposes the expansion of in-situ science throughout the Solar System. In this paper an overview is given what, in the near future, shall be reachable on Mars and other planets as well as smaller bodies in our Solar System. The paper also addresses the need for international coordination and cooperation in the development of miniaturized payloads like cameras, VNIR-, IR-, UVund Raman spectrometers, temperatureand moisture sensors, lab-on-chip systems for "in-situ wet chemistry", micro sampling and return. The paper also addresses the need for cooperation in the preparation of the next generation of robotic systems for their exploration of caves, caverns, micro-g bodies and other geological, biological and geophysically interesting sites in the Solar System.

PEX.1-0005-18 REPORT TO COSPAR PEX FROM INTERNATIONAL LUNAR EXPLORATION WORKING GROUP (ILEWG) AND MOONVILLAGE WORKSHOPS

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Moon Village Workshops Organisers 2017 - 2018

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The International Lunar Exploration Working Group (ILEWG) was established in April 1995 at a meeting in Hamburg, Germany. As established in its charter, this working group reports to COSPAR and is charged with developing an international strategy for the exploration of the Moon. It discusses coordination between missions, and a road map for future international lunar exploration and utilisa-tion. It fosters information exchange or potential and real future lunar robotic and human missions, as well as for new scientific and exploration information about the Moon. We give a report on ILEWG community activities, refer to COSPAR and ILEWG ICEUM and lunar conferences and declarations [1-18].

Ongoing ILEWG priorities from ICEUM 11 and follow-up events include:

Science and exploration

(recommendations will be discussed at COSPAR B3.1 Lunar science and exploration session)

Technologies and resources

A number of robotic missions to the Moon are now undertaken independently by various nations, with a degree of exchange of information and co-ordination. That should increase towards real co-operation, still allowing areas of competition for keeping the process active, cost-effective and faster.

Lunar landers, pressurized lunar rover projects as presented from Europe, Asia and America are important steps that can create opportunities for international collaboration, within a coordinated village of robotic precursors and assistants to crew missions.

We have to think about development, modernization of existing navigation capabilities, and provision of lunar positioning, navigation and data relay assets to support future robotic and human exploration. New concepts and new methods for transportation have attracted much attention and are of great potential.

Infrastructures and human aspects

It is recommended to have technical sessions and activities dealing with different aspects of human adaptation to space environments, the modeling of sub-systems, microbial protection and use of inflatable technologies

While the Moon is the best and next logical step in human exploration, we should make best use of the space stations as stepping stones for exploration and human spaceflight beyond Low Earth Orbit.

Further research is needed on lunar dust aspects in regard to humans and interaction with habitats. We note high interest in CELSS for Moon and Mars bases, and recommend further research and development.

We recommend the development and use of terrestrial analogues research sites and facilities, for technology demonstrations, comparative geology and human performance research, and public engagement. We endorse the proposal of development of world analogue sites for international Moon-Mars analogue research.

Moon, Space, Society and Young Explorers

We consider that the current legal regime as set out in the Outer Space Treaty and the Moon agreement are satisfactory for current and future missions, but may require further clarification for future exploration. Issues of transparency and security will need to be addressed.

Great things are happening for Young Lunar Explorers, with inspiring missions and hands-on activities as coordinated by ILEWG. Lunar exploration is encouraging students of all ages to pursue higher education.

More possibilities for participatory engagement should be offered to the society for example via interdisciplinary activities with the humanities.

We appreciate the work from COSPAR panel on Exploration PEX that should be shared further.

Continued cooperation should be enforced at all levels. The space community feels strongly that joining the forces of space faring nations to explore the Moon should be seriously implemented, with the views of expanding a Global Robotic Village and building in the long run a Manned International Lunar Base."

ILEWG has further integrated its activities with COSPAR, and developed a series of programmes to allow exchange of data, payload opportunities, collaborations on lunar missions, young lunar explorers grants for research projects, field campaigns and conference participation.

ILEWG has also supported a number of MoonVillage workshops and events in 2016-2018. This will be reported in PEX1 session concerning the international coordination of space activities, and in PEX2 concerning the synergy between human exploration of Moon, Mars NEOS.

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PEX.1-0006-18 INTERNATIONAL COORDINATION RESULTING FROM SCIENTIFIC COLLABORATIONS

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International coordination is achieved in part as a result of existing scientific collaborations and relationships. Scientific collaborations happen at all levels but the ones made from early technical interactions are strong and last a lifetime. There are multiple ways to achieve these collaborations from participating on mission teams or on science and technology study teams to writing joint proposals to co-arranging workshops. There are many examples of these to be found, for example, the Cassini mission was an excellent example of international coordination at all levels and the study teams for the Europa and Ganymede missions that have led to the Juice and Europa Clipper missions are due in part to the relationships built during that mission. If there are no ongoing missions or studies in a particular field, then workshops can play a big role. Consistent interactions and relationship-building are key to promoting trust and cultural understanding, which lead to international collaboration and eventually coordination on a larger scale. One such workshop is the International Planetary Probe Workshop (IPPW), which is now in its 15th year. IPPW is an independent organization, without a permanent governing body. All those who participate in the organizing and award committees do so out of a desire to learn from the annual workshops and to share a week in an exciting location with long-standing associates. Many of the attendees have been to several past workshops. They continue attending to learn about the latest science and technology in the field of planetary probes. As with most ongoing workshops and conferences, a core group of enthusiastic volunteers re-volunteer to serve on committees and devote their own time to planning and conducting our yearly events. The past IPPWs have attracted 2000 professionals and students. In addition, 600 people have benefitted from the Short Courses offered prior to the annual workshops. Student attendance and presentations are encouraged and highly valued and, as a result, the students are highly motivated to stay in the field and often are employed by their more senior attendees' institutions. The workshop has maintained its international theme, with five of the twelve workshops conducted at European centers of planetary probe exploration. These collaborative efforts continue to initiate and build relationships that continue throughout the careers of the participants. Such foundational interactions are key to the larger scale international coordination that countries wish to have.

PEX.1-0007-18 ASTROBIOLOGY AS A GLOBAL ENDEAVOR

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The intrinsically interdisciplinary study of astrobiology is also a highly international enterprise. Scientists from many nations regularly work in field sites, at laboratories, and with space agencies away from their home countries. This interaction is essential to the discipline by enabling the exchange of ideas and expertise, exposure of students and professionals to diverse scientific perspectives and specialties, and providing the potential to access important field sites in many lands both distant and near.

The NASA Astrobiology Institute (NAI), which is part of the Astrobiology Program at NASA, has an almost 20 year history of partnering with astrobiology institutes and other organizations in countries with significant astrobiology interests and activity. These partnerships were envisioned at the inception of NAI to encourage full access to important, even unique, facilities and field locations around the world including in the United States. Although international partnerships of this sort do not involve any exchange of funds between partners, to make these formal ties remain fruitful necessitates long-term commitment from the NAI and its partner institutions. It is a significant investment of effort to maintain engagement, information exchange, and interest in each other's activities and projects. This can be very challenging to accomplish as the individual fortunes of organizations change and the focus may morph over time, but ultimately the results are worth the effort expended.

Broadly speaking, healthy and vigorous international cooperation and exchange on astrobiological topics may help to grow the collaborations that produce new mission concepts, novel science questions, and potentially innovative payloads. Critically, astrobiology has a major scientific stake in the success of diligent and well-crafted planetary protection practices to preserve the scientific integrity of life detection missions. The framework for planetary protection is and has always been an international concern and obligation. Although astrobiology has a good history of international exchange and collaboration, much can still be done to continue this track record into the future to enrich the fundamental science, and mission opportunities in the future.

PEX.1-0008-18 INTERNATIONAL PARTNERSHIPS IN EXPLORATION SCIENCE

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Exploration Science is defined as the science of human exploration of the Solar System, including both science to enable humans to explore as well as the science enabled by human exploration. International interest and participation in Exploration Science efforts, particularly through the Solar System Exploration Research Virtual Institute (SSERVI), has increased exponentially over the past decade, leading to major efforts on a wide range of topics. International partnerships in this arena have the potential for strengthening scientific and human exploration efforts on all sides, leading to a new era of possibilities in robotic and human exploration of our Solar System. This talk discusses a sampling of these efforts, with an eye toward the important discoveries that will enable new approaches in human exploration in the coming decades.

PEX.1-0009-18 INTERNATIONAL COORDINATION OF SPACE EXPLORATION ACTIVITIES

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Panel Chairs: Pascale Ehrenfreund and Chris McKay

Panel speakers: Simonetta di Pippo, Clive Neal, Victoria Hipkin, Jeff Johnson, Chiaki Mukai, Bernard Foing

Ambitious plans to build new space infrastructure, transport systems, and space probes require international cooperation. To create a sustainable long-term space exploration program, space agencies are seeking consensus on priorities, objectives, and approaches. Furthermore, an increasing number of countries and organizations have shown interest in participating in future space exploration efforts. There are currently many independent groups planning activities relating to future space exploration scenarios of the Earth-Moon-Mars space. These address different stakeholders, including national space agencies as well as non-profit and commercial interests. In addition to COSPAR (PEX, PPP), the organizations and working groups that have been most active in recent efforts include the International Astronautical Federation (IAF) through its standing space exploration committee, the International Academy of Astronautics (IAA) which has organized recent "Heads of Space Agencies Summits", the International Lunar and Mars Exploration Working Groups (ILEWG, IMEWG), respectively, and the International Space Exploration Coordination Group (ISECG). Numerous reports and roadmaps have also been proposed by the international science organizations and working groups including the Mars Exploration Program Analysis Group (MEPAG), the Lunar Exploration Analysis Group (LEAG), the US National Academies' Space Studies Board (SSB) with its recent 2014 comprehensive report "Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration" and the European Science Foundation's European Space Sciences Committee (ESF-ESSC). Support from organizations such as the International Institute of Space Law (IISL) and the United Nations Committee On Peaceful Uses of Outer Space (UNCOPUOS) guarantees the incorporation of international space law agreements and the interests of developing countries in the space exploration framework. 2018 will be an important "space year" with the International Space Exploration Federation ISEF in Tokyo, the Unispace +50 event in Vienna, the International Astronautical Congress 2018 in Bremen, and the COSPAR 2018 Assembly in Pasadena. COSPAR, through its Scientific Commissions and Panels provides an international forum that supports and promotes space exploration worldwide. This proposed COSPAR PEX Panel is intended to foster a dialogue with other international space organizations to explore pathways for improving coordination of space exploration activities.

PEX.1-0010-18 INTERNATIONAL COORDINATION OF SPACE EXPLORATION ACTIVITIES

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Ambitious plans to build new space infrastructure, transport systems, and space probes require international cooperation. To create a sustainable long-term space exploration program, space agencies are seeking consensus on priorities, objectives, and approaches. Furthermore, an increasing number of countries and organizations have shown interest in participating in future space exploration efforts. There are currently many independent groups planning activities relating to future space exploration scenarios of the Earth-Moon-Mars space. These address different stakeholders, including national space agencies as well as non-profit and commercial interests. In addition to COSPAR (PEX, PPP), the organizations and working groups that have been most active in recent efforts include the International Astronautical Federation (IAF) through its standing space exploration committee, the International Academy of Astronautics (IAA) which has organized recent "Heads of Space Agencies Summits", the International Lunar and Mars Exploration Working Groups (ILEWG, IMEWG), respectively, and the International Space Exploration Coordination Group (ISECG). Numerous reports and roadmaps have also been proposed by the international science organizations and working groups including the Mars Exploration Program Analysis Group (MEPAG), the Lunar Exploration Analysis Group (LEAG), the US National Academies' Space Studies Board (SSB) with its recent 2014 comprehensive report "Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration" and the European Science Foundation's European Space Sciences Committee (ESF-ESSC). Support from organizations such as the International Institute of Space Law (IISL) and the United Nations Committee On Peaceful Uses of Outer Space (UNCOPUOS) guarantees the incorporation of international space law agreements and the interests of developing countries in the space exploration framework. 2018 will be an important "space year" with the International Space Exploration Federation ISEF in Tokyo, the Unispace +50 event in Vienna, the International Astronautical Congress 2018 in Bremen, and the COSPAR 2018 Assembly in Pasadena. COSPAR, through its Scientific Commissions and Panels provides an international forum that supports and promotes space exploration worldwide. This proposed COSPAR PEX Panel is intended to foster a dialogue with other international space organizations to explore pathways for improving coordination of space exploration activities.

PEX.1-0011-18 SCIENTIFIC GOALS FOR EXPLORATION OF THE OUTER SOLAR SYSTEM

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The 2018 draft goals document of NASA's Outer Planet Assessment Group (OPAG) has been posted for community comment (https://www.lpi.usra.edu/opag/reports/). This document will be a resource for defining technology development and research directions, for mission and instrument science objectives, and for international collaboration. Ultimately this document will guide preparation for the outer solar system portion of the next decadal survey, including mission studies being done in preparation for that survey. There are several major changes from the old (2006; 2015 draft) versions, based on new developments such as the Europa Clipper and JUICE missions, science results from Cassini, New Horizons, and Juno, the Ocean Worlds program and Roadmap to Ocean Worlds (ROW), and studies of an ice giants mission and a Europa lander. In addition, for the first time, this document includes the Kuiper Belt Object (KBO) planets.

One of the unique opportunities in the outer solar system is the chance to explore oceans. The outer solar system is replete with ocean worlds including Europa, Ganymede, Callisto, Enceladus, Titan, and probably Triton, among others. In the inner solar system only Earth has an ocean today, and oceans may be key to understanding the origin(s) and evolution of life. Ocean worlds may be the best places to search for extant life beyond Earth.

Two major planetary systems in our solar system have never had a dedicated spacecraft mission: the ice giants Uranus and Neptune. Voyager 2 flew through each system and gave a scouting report: these are exciting planetary systems. Given their importance to understanding planetary formation and evolution, exoplanets, and potential ocean worlds, as well as the unique environments on display there, exploration of ice giants was a top recommendation in Vision and Voyages, the current Decadal Survey. The recent Ice Giants study noted that preferential launch windows are in the 2029-2034 timeframe. Because of Triton, we favor a Neptune mission as top priority.

For Flagship-class missions, our top recommendation is to complete Europa Clipper. Our top priority for a new start is an Ice Giants mission. Our second new Flagship priority is a mission to search for life on an ocean world, most likely Europa or Enceladus. For New Frontiers class missions, OPAG supports opening competition to all solar system destinations, as recommended by the National Academies in 2008. In particular, we support the continued inclusion of Enceladus and Titan ocean worlds missions along with Io Observer and Saturn probes, and mission concepts to KBO planets. For Discovery class missions, we strongly support efforts that open up the outer solar system to Discovery, such as allowing radioisotope power systems (RPS). Smallsat missions are feasible as add-ons to larger missions to outer planets, and we support continued study and technology development for such concepts, leading to actual flight opportunities. We recommend a space telescope dedicated to planetary science. International coordination will likely continue to be essential for the success of missions to outer planet systems.

PEX.1-0012-18 THE ACTIVITIES OF SMALL BODIES EXPLORATION MISSIONS IN JAPAN AND INTERNATIONAL PARTNERS

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In order to enhance our understanding of the origin and evolution in the early Solar System, it is very important to comprehensively connect small bodies in different evolution stages by exploring as many of them as possible, and to connect the chemical characteristics of target bodies obtained from sample return and/or on-site analyses with their geological features. The international collaborations in the two small body missions in Japan, Hayabusa2 and Destiny+, are known examples of multi-scale solar system science covering from interstellar medium to planetesimals. Hayabusa2, the Japanese C-type asteroid sample return mission, was launched on December 3, 2014 and is scheduled to arrive at the near Earth asteroid Ryugu on July 2018. During its 18-month stay, remote-sensing and lander observations will be carried out. The on-board lander of the Hayabusa2 spacecraft, Mobile Asteroid Surface Scout (MASCOT), was developed by DLR and CNRS. MASCOT includes Camera (Cam), Radiometer (MARA), Hyperspectral microscope (MicrOmega), and Magnetometer (Mag), which will carry out cm - mm scale observations of geology, mineralogy (hydrated minerals, especially), organic chemistry, temperature, thermal inertia (grain size), and magnetism of the asteroid surface, respectively. MASCOT plans to be released for exploring the region that is geologically similar to the 1st sampling site selected based on the remote observation data. The observation data from MASCOT is very important for selecting the 2nd and 3rd sampling sites. Thus, scientists from remote sensing team, MASCOT team, and sample analyses team have been closely work together to decide a landing site selection strategy by sharing the common picture of the multi-scale asteroid science. DESTINY+ (Demonstration and Experiment of Space Technology for INterplanetary voYage Phathon fLyby dUSt science) is a mission to flyby of Geminids parent (3200) Phaethon and in-situ dust analyses, which is planned to be launched in 2022. The science goals of this mission are i) to understand physical and chemical properties and origins of interplanetary dust particles, interstellar dusts and ii) to understand active asteroid Phaethon. The in-situ dust analyzer (DESTINY+ Dust Analyzer, DDA) is a time-of-flight mass spectrometer developed by Stuttgart University, Germany, with heritage of Cassini Cosmic Dust Analyzer (CDA) onboard Cassini. Great advantages of DDA is that flux, masses, velocities, orbits and compositions for the individual dust particles can be obtained. Thanks to DLR's support, application of two DDAs (for cation and anion modes) is currently under consideration. For promoting these international collaborations, Japan Society for the Promotion of Science (JSPS) core-to-core program, encourages young scientists to study at the partner institutions in USA, Switzerland, France, Germany, for several weeks to months. Ultimate goal of this program is to establish the international network of planetary sciences connecting solar system small bodies science with exoplanetology.

PEX.1-0013-18 THE ISECG SCIENCE WHITE PAPER: SCIENCE OPPORTUNITIES ENABLED BY THE GLOBAL EXPLORATION ROADMAP

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The 15 space agencies of the International Space Exploration Coordination Group (ISECG) are discussing an internationally coordinated approach for human and robotic space exploration, as documented in ISECG's Global Exploration Roadmap (GER), i.e. a coordinated international effort to prepare for collaborative space exploration missions beginning with the Low Earth Orbit (LEO) and continuing to the lunar vicinity, the Moon, asteroids and, eventually, Mars.

The ISECG agencies have engaged the scientific community in a coordinated discussion with two goals: 1) promoting the scientific opportunities, and 2) improving the understanding of the priority science questions that can be addressed by near-term human exploration in to the Solar System. The ISECG set up in 2015 an independent Science Advisory Group (SAG) composed of scientists from a variety of nations and diverse science disciplines, and mandated this group to elaborate a Science White Paper to identify the scientific opportunities in nearterm exploration missions beyond LEO, the overarching science themes and their relevance to the GER mission concepts.

The SAG - together with ISECG agencies - organized a thorough consultation of the community using several conferences and dedicated events, starting with an interactive workshop at the European Lunar Symposium in May 2015 and continuing with a COSPAR-ISECG-ESF workshop in Paris in February 2016. The result is that international science communities' perspectives have been incorporated for a broad range of scientific disciplines including planetary and space sciences, astrobiology, life sciences, physical sciences, astronomy and Earth science.

The Science White Paper was published in December 2017 and is structured around the science themes "Understanding Our Place in the Universe" and "Living and Working in Space". The key science aspects also inform the future evolution of mission concepts considered in the GER.

We will present the contents of the Science White Paper, with particular emphasis on the benefits of such a Global Exploration Roadmap enabling scientific exploration.

PEX.1-0014-18 INTERNATIONAL COORDINATION OF SPACE EXPLORATION ACTIVITIES - THE NEXT GENERATION PERSPECTIVE

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International Coordination of Space Exploration Activities

- The Next Generation Perspective

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The Space Generation Advisory Council (SGAC) is a non-governmental organisation based in Vienna, Austria and is also a registered 501(c)(3) organisation in the United States. SGAC works on the international, national and local level to link together university students and young professionals to think creatively about international space policy issues and voice the new generation's point of view on international space policy creations. SGAC has obtained permanent observer status in the United Nations (UN) Committee on the Peaceful Uses of Outer Space (COPUOS) and is a member of the UN Economic and Social Council (ECOSOC), as well as the International Astronautical Federation (IAF).

As Strategic Partnerships Coordinator, I support SGAC's mission to represent students and young professionals to the United Nations, space agencies, industry, and academia. In my role I manage partnerships and sponsorships that enable SGAC to connect with the wider space community. We partner with leading space agencies, corporations and organisations from around the world to nurture the next generation of space leaders.

SGAC recognises the importance of developing strong partnerships with private industry, academia, space agencies, NGO's and other actors of the space community. Through international coordination we foster understanding and advocate progress within the space industry.

SGAC is continuously seeking to identify opportunities that bring the next generation of space leaders into the conversation. International coordination is one of SGAC's key strengths. SGAC is the largest network of students, young professionals and alumni in the space industry. Our global volunteer base of over 13,000 members in 150+ countries worldwide work on a range of space related projects.

SGAC organises events at the international, regional and local levels to bring our members together to discuss and engage with current leaders from space agencies, industry and academia.

Our eight project groups enable our members to shape key topics on space through technical papers, long-term project, policy briefs and recommendations. SGAC advocates for space exploration and inspire others in the next generation to get involved in space-related careers. SGAC provides scholarships that enable our members to participate in space-related events around the world. Finally, SGAC empowers its members with the skills and experiences to become the space leaders of tomorrow.

PEX.1-0015-18 THE FORUM FOR NEW LEADERS IN SPACE SCIENCE: 2014-2018

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The space science community is thoroughly international, with numerous nations now capable of launching scientific payloads into space either independently or in concert with others. As such, it is important for national space-science advisory groups to engage with like-minded groups in other spacefaring nations. The Space Studies Board of the US National Academies of Sciences, Engineering and Medicine has provided scientific and technical advice to NASA for 60 years. Over this period, the Board has developed important multilateral and bilateral partnerships with space scientists around the world. The primary multilateral partner is COSPAR, for which the Board serves as the US national committee. The Board's primary bilateral relationship is with the European Science Foundation's European Space Science Committee. Burgeoning Chinese space activities have resulted in several attempts in past decades to open a dialogue between the Board and space scientists in China. On each occasion, the external political environment was not conducive to success. The most recent efforts to engage Chinese space researchers began in 2011 and have proved particularly successful. Although NASA is currently prohibited from engaging in bilateral activities with China, the Board has established a fruitful dialogue with its counterpart in the Chinese Academy of Sciences (CAS). A joint National Academies-CAS activity, the Forum for New Leaders in Space Science, has been established to provide opportunities for a highly select group of young space scientists from China and the United States to discuss their research activities in an intimate and collegial environment at meetings to be held in both nations. The presentation will describe the current state of US-China space relations, discuss the goals of the joint NAS-CAS undertaking and report on the activities undertaken at the eight Forums held so far.

PEX.1-0016-18 UNDERSTANDING VENUS: AN INTERNATIONAL EFFORT

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Within five years of the dawn of the space age with Sputnik, the Mariner 2 fly-by (1962) and Venera-4 probe's entry (1967) into another atmosphere demonstrated that our nearest neighbor was a world very different from our own home planet. With regular launches from the Soviet Union in the early decades of exploration of Venus and missions launched by NASA, the knowledge about Venus grew significantly. It was only after the COSPAR general assembly held in Philadelphia in 1976 that collaboration began between US and USSR with exchange of data, leading to some small joint efforts with the Pioneer Venus Orbiter and Probe missions (1978-1983) followed by collaboration in planning and carrying out the VeGa mission in 1985 involving many countries.

The nearly two-dozen missions flown to Venus have painted a puzzling picture of Venus. Presently JAXA's Akatsuki orbiter is collecting observations that are adding more questions about the planet. They can be summed up by perhaps just one question: why did Venus evolve so differently from Earth? What we have learnt from the many missions to Venus is that to understand Venus, we need to observe its surface, sample its deep atmosphere, explore its magnetosphere and ionosphere, infer the interior structure and monitor the deep, global cloud cover. Just like Earth is being observed by multiple spacecraft in different orbits, airplanes, ships, automated surface and ocean stations, observing Venus and its environment requires a combination of platforms. Single, focused missions are effective at tackling some of the questions about Venus, but the synergy of near simultaneous and long term monitoring of Venus is needed for a better understanding of the planet.

The International space agencies and scientists have been considering various approaches to exploring Venus through small and large missions. The Venus Exploration Analysis Group (NASA) has developed a Venus Exploration Roadmap and a comprehensive list of goals, objectives and investigations (www.lpi.usra.edu/vexag). Venus science and questions for future missions have been periodically discussed by international Venus scientists at dedicated conferences. Following discussions at such meetings, the International Venus Exploring Working Group was formed during the 2012 general assembly in Mysore India to promote collaboration among the global Venus scientific community and coordination of efforts to explore Venus by the spacefaring nations, which worked so successfully for the VeGa, Venus Express and Akatsuki missions in particular.

At present a collaborative effort limited to Roscosmos and NASA is being conducted by the Joint Science Definition Team assembled to study the implementation approach for Russia's Venera-D mission. It is recognized that Venera-D would represent an important piece of an international Venus exploration strategy. Leading up to and following this step an ongoing effort and additional missions by all space agencies are desirable to address the many un-answered questions. ESA is currently evaluating EnVision, a proposed mission that could carry a small contributed probe (such as those being studied by NASA), allowing for a coordinated and complementary international exploration plan. Such a plan is needed to maximise the returns from future Venus exploration.

PEX.1-0017-18 INTERNATIONAL COOPERATION IN OUTER SOLAR SYSTEM EXPLORATION

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Exploration of the outer Solar System is challenging in terms of cost and mission duration. Some of the most successful missions to the outer Solar System have been international partnerships. An example is the Cassini-Huygens mission - built on a primarily US Saturn orbiter and a probe to the surface of Titan by ESA. Science goals for future missions to the ocean worlds of the outer Solar System will include the search for evidence of life. Such a search would benefit considerably from the ability to return samples to Earth. Two particular issues with an astrobiology sample return from an ocean world are mission duration/cost and the challenge of bringing potentially living organisms to Earth in a fully contained manner that meets the goals of planetary protection and minimizes the possibility of terrestrial contamination. In this paper we consider the illustrative example of a sample return from the plume of Enceladus. As a point design we postulate a joint mission by NASA and JAXA (these are the two agencies that have achieved sample return from targets beyond the Moon) and consider how such a mission could spread mission costs and solve the challenge of safe return.

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PEX.1-0018-18 ROLES FOR COSPAR PPP AND PEX IN FUTURE SPACE RESOURCES GOVERNANCE ACTIVITIES

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The development of space-resource extraction activities has begun. Without a pre-existing framework to govern such activities, it is necessary to examine concepts that may lead to that governance, while ensuring that, to the maximum possible extent, they address existing treaty obligations regarding on-orbit operations and space resource rights. To be successful, these concepts will need to enable, support, and coordinate the steps leading to the use of space resources, while being acceptable to space-faring nations and other interested States. Over the last few years, a group known as The Hague International Space Resources Governance Working Group has developed and is circulating draft "building blocks" for the development of an international framework for the governance of space resource activities. In particular, the Working Group's Building Block 9, "Avoidance of harmful impacts resulting from space resource activities" should be of interest to COSPAR. It specifies that the international framework of space resources governance "should provide that States and intergovernmental organizations authorizing space resource activities shall adopt a precautionary approach with the aim of avoiding harmful impacts, including: a) Risks to the safety of persons, the environment or property; b) Damage to persons, the environment or property; c) Adverse changes in the environment of the Earth, taking into account internationally agreed planetary protection policies; d) Harmful contamination of celestial bodies, taking into account internationally agreed planetary protection policies; e) Harmful contamination of outer space, including the creation of harmful persistent space debris; f) Harmful interference with other on-going space activities, including other space resource activities; g) Changes to designated and internationally endorsed outer space natural or cultural heritage sites; and h) Adverse changes to designated and internationally endorsed sites of scientific interest. The relationship of these points to the Terms of Reference for both the Panel on Planetary Protection and the Panel on Exploration in COSPAR will be the subject of this presentation.

PEX.1-0019-18 THE MOON VILLAGE ASSOCIATION: AN INFORMAL, GLOBAL FORUM FOR COOPERATION AND COORDINATION IN LUNAR EXPLORATION

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The concept of a "Moon Village" (MV) is one that encompasses a wide range of prospective future human activities on the Moon - comprising early landers and orbiters, initial human and robotic exploration missions in the mid-term and eventual ambitious government and commercial operations (including eventual human settlements) In the far-term. During the past year, significant progress has been made to advance the vision of a Moon Village by a new non-governmental organization (NGO), the Moon Village Association (MVA). Working in concert with a variety of existing government and non-government organizations, this progress has centered around identifying, organizing broad-based international teams and beginning to undertake a variety of critical activities. These MVA efforts have included conventional topics such as identifying potential lunar missions and markets, examining options for Moon Village architectures (including high-level interface standards). However, the MVA has also undertaken consideration of cultural issues, cooperation and cooperation among diverse players, formulation of concepts for lunar analogues (both on Earth for the Moon, and on the Moon for missions beyond). This paper will review the core concepts that define the Moon Village, summarize recent progress to realize this vision with special emphasis on the methodology being used by the MVA, and define a notional international MV roadmap. It will conclude with a plan of action going forward.

PEX.1-0020-18 OPTIMISING HUMAN SPACE EXPLORATION STRATEGIES AND POLICIES

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The three central players in human space exploration, understanding those who master the full spectrum of means to explore, are moving along with strategies that seem aimed at different goals, with different tempos and paths. For the United States, the long-term objective is to reach Mars and set up on the Red planet a sustained human presence. For NASA, this should proceed via a Deep Space Gateway (DSG) in cis-lunar orbit, providing the infrastructure as a springboard to Mars, and also using the Moon as a proving ground for a number of indispensable functions essential to long distance travel in the solar system. The strategy for this new course is consistent with the possibility to have the ISS privatised starting in 2025, freeing NASA to concentrate on human space programmes beyond LEO. While SpaceX, for its part, considers that a direct access to Mars is the way to go, regular shuttling from the Earth would support a first step for a permanent presence on this planet. China is taking a quite different approach: continue to learn more by establishing a larger space station, TienGong-3, in the next decade, with the possibility of having European astronauts on board, and later to deploy a permanent infrastructure on the Moon to explore and exploit resources of our natural satellite. Russia is still very much tied to the ISS activities and wishes to continue as long as possible with the international orbital outpost. Funding, a constant hurdle for the Russian space programmes, and the lack of heavy lifting capability are challenging issues when preparing for human exploration beyond LEO. Beyond the ISS, the plans for ESA are not yet formalised: the Moon Village is still a concept, while it may materialise, the European presence on the Moon is still quite vague: since Member States have decided not to fund autonomous human rated means to reach the Moon for some decades, they can be only contributors to non Europeans strategies, meaning they should concentrate on specifics needed by the US or China (e.g. Orion service module), and trying to be on critical paths of the two major players for particular functions/missions to play a significant role involving its space agencies and industries. Yet, it remains to be seen if such a demarche is acceptable by the Member States, to what extent of engagement, and how this will be received by the United States and/or China. Budgetary burden sharing is certainly a strong argument in favour of such an approach. Japan and Canada, both contributors to the ISS, will have to find their place in the on-going re-definition of future strategies by the "Big Three". After analysing these different strategies, weighting their strengths and weaknesses, the presentation will propose some scenarios based on a more holistic approach where the different players could contribute in a more synergistic mode, reducing costs and engaging throughout an improved path for a sustainable human space exploration; including public and private funding, contributions of new actors that have not being, so far, involved in human space exploration. The outcome of the 2nd ISEF will be taken into account in building the different scenarios.

PEX.1-0021-18 INTERNATIONAL COORDINATION OF COORDINATE SYSTEMS OF SOLAR SYSTEM BODIES BY THE IAU WORKING GROUP ON CARTOGRAPHIC COORDINATES AND ROTATIONAL ELEMENTS

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L. Jorda, R. L. Kirk, S. A. Klioner, D. McCarthy, K. Meech, J. Oberst, J. Ping, P. K. Seidelmann, D. J. Tholen, P. C. Thomas, and I. P. Williams

Overview: Since 1979, the Working Group on Cartographic Coordinates and Rotational Elements (hereafter the "WG") of the International Astronomical Union (IAU) has, after most IAU General Assembly (GA) meetings, issued a report recommending coordinate systems and related parameters (body orientation and shape). This information can be used as a foundation for mapping Solar System bodies and other navigation and geophysical purposes in support of robotic and human exploration by all nations. These recommendations, which are open to further modification when indicated by community consensus, are intended to facilitate the use and comparison of multiple datasets by promoting the use of a standardized set of mapping parameters. We highlight here the WG's efforts and our just published report [1] covering 2012-2017. The WG encourages input and participation, and is available to assist users, instrument teams, and missions. See our website [2] for additional information. We also note that other IAU services exist to support space exploration, e.g. on Solar System ephemerides and planetary nomenclature.

Operation of WG: The Working Group consists currently of 18 volunteers. Volunteers may join at any time, but usually join for at least a three-year term to help with each new report following the IAU GA. The WG looks at new determinations of coordinate systems (e.g., body sizes and orientations) that preferably have been published in refereed papers, and makes recommendations as to which to use, based where possible on consensus decisions.

As a volunteer organization, the WG has no resources to verify results or conduct its own research so it relies only on published results and community input. For that reason, it is sometimes not possible to recommend one set of results over another. The WG cannot verify or "bless" any particular results. The WG has no "enforcement" powers, but tries, in reflecting the long term planetary community consensus, to make persuasive recommendations.

The WG does not deal with issues related to the formats of mapping products; such issues have largely been left to individual map

developers, archiving organizations such as the NASA Planetary Data System (PDS), or various coordination groups, such as the NASA Mapping

And Planetary Spatial Infrastructure Team (MAPSIT) [3], with whom the WG cooperates. In the past the WG has also been both a joint COSPAR and IAG working group.

General Changes: Following extensive discussion, substantial updates have been incorporated by the WG into our new report. An overview follows. First, the WG has reworded and clarified its recommendations regarding updating longitude. Second, mission and community input indicates a need for the WG to differentiate between planetary body shapes and sizes for image projection and scientific modeling vs. a reference surface for elevation and map scale. In particular, long-accepted values for the latter are documented for the Moon and (now recommended for) Titan. Third, the discussion of terminology for the poles (hemispheres) of small bodies has been modified. Fourth, updates to the orientation models of Jupiter and Saturn are not recommended at this time, as we await community consensus on a model for Jupiter and final results from the Cassini mission regarding the orientation of Saturn.

Changes for Specific Bodies: As highlights, new orientation models for Mars [4], Phobos, and Deimos are recommended for use. More precision in Martian longitude is provided by defining the position of the Viking 1 lander. Orientation models have also been updated for Neptune, Ceres, several asteroids and comets. Size information has been updated for Mercury, Ceres, Pluto, Charon, and asteroids Psyche, Europa, and Itokawa.

Other recommendations: We repeat our previous recommendations that planning and efforts be made to make controlled cartographic products. We now recommend that common formulations should be used for orientation and size and that historical summaries of the coordinate systems for given bodies should be developed. We point out that for planets and satellites planetographic systems have generally been historically preferred over planetocentric systems; and that in cases when planetographic coordinates have been widely used in the past, there is no obvious advantage to switching to the use of planetocentric coordinates.

Request for Input: The WG desires continued input from the planetary community, especially regarding the systems for specific bodies, the operation of the WG, our proposed question submitting process, and posting of updates via the WG website. We encourage volunteers to become WG members and help with our efforts. Our membership is open to all. Contact the author of this abstract for additional information.

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PEX.1-0022-18 PLANETARY SPATIAL DATA INFRASTRUCTURE: PRESENT STATE, FUTURE NEEDS, AND INTERNATIONAL COOPERATION

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Planetary spatial data are the derived products from missions to planetary bodies, including remote sensing and in-situ data. The infrastructure needed to ensure these products are accessible, searchable, and useable, varies from world to world and mission to mission. We describe how the Mapping and Planetary Spatial Infrastructure Team (MAPSIT, https://www.lpi.usra.edu/mapsit/) has been tasked by the NASA Planetary Science Subcommittee of the NASA Advisory Council to identify and prioritize the spatial data needs of the community. Given the geological breadth of planets, moons, and other solar system bodies, diversity of missions over the past 50+ years, and wide range of instruments and data acquired, it is difficult to prioritize any single need. Instead, we are focusing on highlighting existing infrastructure, identifying what still needs to be achieved, and seeking input from the community for additional priorities. We are working to create a Planetary Geospatial Strategic Plan as a roadmap toward what needs to be done. Although MAPSIT is a NASA-tasked organization, our terms of reference include cooperation and collaboration with appropriate international organizations, space agencies, and missions. We therefore seek to let the international space community be aware of our existence and work and encourage collaboration with us.

Near-term issues that MAPSIT has identified are as follows: How should the current, unprecedented influx of high-volume, planetary mission data be geodetically controlled and integrated to enable science and operation of current and future missions? How should global, regional, and local mosaics, basemaps and topographic models be created from multiple data sets? What requirements should be developed for missions to follow during the formulation and definition stages to enable the availability, searchability and usability of all acquired data? How can planetary spatial data products be used to enable and facilitate future human exploration and in-situ resource utilization?

The greatest resource from any mission is the data returned, and we seek to ensure these data are useable to all interested researchers to yield the best possible return for all global space agency stakeholders.

PEX.1-0023-18 MORE MISSIONS FOR THE SAME MONEY

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Current efforts of investigation of the Solar System are often the subject of irrational political pressures often resulting from nationalistic motives. This causes huge scientific losses, but also, contrary to appearances, political losses. The better cooperation between national space agencies could be beneficial for the space exploration and for national space programs. Fortunately, recently private companies represent a new approach. The success of Spacex is not an example of a unique genius approach. It is a result of simple application of common sense to the astronautics. Similar breakthroughs have been observed many times when a technology has become so mundane that a simple economic approach can be applied to it. The best example was the Ford's approach to car production in the beginning of XX century. The success of privates companies in the development of space rockets still seems be ignored by decision makers. The better cooperation between space agencies could be beneficial for the space exploration and for national space programs. Instead of independent attempts to develop the technology already developed by others, the decisions makers could consider buying ready products, buying licences, exchanging of technology, etc. Why do not try the barter of Rosetta for Cassini? Why do not develop a new version of Huygens lander and barter it for Curiosity rover? It hardly to calculate the second copy of the Curiosity (the Martian rover), but evidently it would be much cheaper than the RD+first copy's production cost (2.5 billion US), probablynothigherthan1billionU S. The rationalization of space expenditures would allow a significant acceleration of the planetary research. I believe that with a small increase in spending by the space agencies with a decisive increase of cooperation, it is possible to achieve several Mars rovers (of the Curiosity class) on Mars, Titan or Enceladus.

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PEX.1-0024-18 COMMUNITY EMPOWERED ROLE MODELS IN OUT REACH FOR SPACE EXPLORATIONS

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A review of the scientific Philosophical perspectives major developments during 600 BC to 2000 AD reveal incremental struggle of evolving logical strength of Space quests which are nothing but urges for space explorations. Further, sustained efforts in harnessing natural forces, Space as a tool for human evolution has been a reality. Dual use of Space Technology amongst nations has matured leading to a situation which sustains both " war and defence and space explorations" domains. While a opportunistic entrepreneur mind set gets victimised with amassing wealth for wealth. An adventurer conscience sustains space explorations. This is as evident in the 21st Century. Also, evolving entrepreneurships in societies have also empowered individual and community to try for space explorations and remain sustainable. A significant development in the evolution of human societies is emergence of United Nations. In the context of Outreach in space explorations few significant developments are worthwhile for individuals and community wellbeing. The first unique developments in empowering individual and communities is the promulgations of objectives of Environmental Education popularly cited as UNESCO/UNEP/IEEP/Tbilisi 1977. While UN charter facilitated evolution of a formal governance amongst member states for managing finite life supports on our only home the Earth, further priorities in the capabilities of individual and community for explorations is evident. These are available amongst the people science and popular community empowering movements all over the globe. In this paper best practices of space technology affecting community life style of developing nations are reported. An attempt is made to capture good space technology practices of resource management, and environmental data bases. It is inferred that Space governance mechanisms need to be evolved based on UN Sustainable Development Goals and national priorities. A specific vision agenda and time bound outreach activity plan for space explorations at community level is felt as a historical necessity. Enormous deluge of information need to be assorted and communicated in formal and informal educational opportunities.

PEX.1-0025-18 THE EUROPEAN UNION'S LEGAL COMPETENCE REGARDING SPACE ACTIVITIES

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The Treaty of Lisbon (2007) institutes a direct competence of the European Union (EU) regarding space activities. In order to promote scientific and technical progress, to implement its policies and to foster industrial competitiveness, the Union elaborates a European space policy. Among the tools it has been granted to accomplish those objectives, the EU can promote and coordinate common initiatives and support efforts in research and development. It also establishes all the useful relations with the European Space Agency (ESA). This competence of the EU makes it a new international actor in the large landscape of space cooperation. However, this competence has particular limits provided for in the treaties. This article will focus on the European Union as an international actor of space cooperation. It will address, through the study of its particular legal competence regarding space activities, the possibility and limits of its role as an international partner in international space cooperation.

PEX.1-0026-18 VENERA-D: MISSION CONCEPT FOR STUDY ATMOSPHERE,SURFACE AND PLASMA ENVIRONMENT OF VENUS

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A Joint NASA-IKI/Roscosmos Science Definition Team (JSDT) was established in 2015 with the task of defining the science and architecture of a comprehensive mission to Venus. Building on the results of the highly succesful missions Soviet and US, as well current time Venus Express and Akarsuki orbiters the overarching goals were formulated to understand why Venus and the Earth took divergent evolutionary paths. Specific areas of Venera-D investigation would address questions focused on the dynamics of the atmosphere with emphasis on atmospheric superrotation, the origin and evolution of the atmosphere, and the geological processes that have formed and modified the surface with emphasis on the mineralogical and elemental Venera-D concept included origin and evolution of the atmosphere, and the geological processes that have formed and modified the surface with emphasis on the mineralogical and elemental composition of surface materials, and the chemical processes related to the interaction of the surface and the atmosphere The Venera-D mission concept includes baseline elements (Roscosmos): orbiter (more than three years lifetime) and lander (2-3 hours on the surface) with high capable scientific paloads. Additional long lived elements (possible NASA contribution) are considered: the aerial platform for long time important measurements in atmosphere and the small long lived station

(s) on the surface (one long lived station may be included as an instrument of the lander, and will continue working after lander death) and subsatellite for plasma measurements. To aid in refinement of the Venera-D science objectives, two community modeling workshops were held in 2017: in May in Glenn Research Center and in Octoder in Space Research Institute. The Venera-D JSDT Phase 2 report will be completed by January 31, 2019. Launch of the Venera-D mission is expected from Vostochny with Angara-5 (Proton) rocket in time frame from 2026 to 2031.

PEX.2-0001-18 RUSSIAN PLANS FOR ROBOTIC INVESTIGATIONS OF MOON AND MARS

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Russia has now two coupled programs of Lunar and Martian investigations. Set of Lunar missions includes both landers Luna-25, Luna-27, Luna-28 and orbiter Luna-26. Program is aimed at investigation of previously weakly explored Lunar polar regions having the number of very unique and scientifically challenging properties. Program has very significant international contributions. Martian program starts from two EXOMARS missions accomplished jointly by Russian and European Space agencies and continues with BUMERANG project devoted to the return of Phobos samples. EXOMARS program was motivated by recent findings of surprisingly abundant methane eruptions in Martian atmosphere. First EXOMARS spacecraft -Trace Gas Orbiter -started already its observations of Martian atmosphere and its surface. Second part

-Russian landing scientific platform with ESA rover will be launched in 2020 and will start its observations of conditions at and below of Martian surface and the search of possible signatures of the past and even present primitive life. We consider also the return to Venus with longliving landing station at the end of the next decade.

PEX.2-0002-18 EARTHMOONMARS VILLAGE WORLDWIDE ACTIVITIES

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We give an update of Moon Village (MV) and MoonMars activities, with emphasis on events that took place in 2017 and 2018. The Moon Village is an open concept proposed with the goal of a sustainable human and robotic presence on the lunar surface as an ensemble where multiple users can carry out multiple activities. [1-3]. Why a Moon Village? Multiple goals of the Moon Village include planetary science, life sciences, astronomy, fundamental research, resources utilisation, human spaceflight, peaceful cooperation, economical development, inspiration, training and capacity building.

Moon Village 2017 international events:

Global Space Congress Abu Dhabi UAE 30 Jan-1 Feb

UN COPUOS Action team on Exploration 5-7 Feb 2017

UN COSPAR explo workshop Vienna 25 April, 22 May

European Lunar Symposium New Views of Moon, Muenster 2-4 May (HH, CN)

ISDC ST Louis (with ESA DG J. Woerner) 1-2 June

GLEX Global Exploration Conf Beijing 6-8 June

Concordia U Montreal MVWS 11-12 Aug (M-P B.)

Global Hands on Universe, Bowling Green 16-17 Aug

Nashville Adventure Sci Center, Eclipse 19-21 Aug (JI)

EPSC European Planetary Science Congress Riga, Moon Village Science, Explo. Technology Foresight 18-21 Sep

Adelaide Australia IAC Intl Astronautical Congress A3 exploration symposium plenaries 25-29 Sept

Hawaii International Moon Base Alliance 1-4 Oct (HR)

Columbia, LEAG Lunar Expl. Analysis Group 10-11 oct

Bremen Space Tech 24-26 Oct

ISU MVA MVWS 19-21 Nov (GR, CW, JM, AK)

ESLAB ESTEC Extreme Habitable Worlds 4-8 Dec (ESN)

MoonVillage Global Science Opera (performance over 15 countries including ESTEC event) 13 Dec (O. B.-O.)

We shall also give highlights of 2018 EarthMoonMars Village events.

Perspectives: A number of activities are planned. The EarthMoonMars Village will rely both on automatic, robotic and human-tendered structures to achieve sustainable surface operations serving multiple purposes on an open-architecture basis.

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PEX.2-0003-18 FROM THE ROBEX EXPERIENCE TOWARD THE ROBOTIC DEPLOYMENT AND MAINTENANCE OF SCIENTIFIC INFRASTRUCTURE FOR FUTURE PLANETARY EXPLORATION MISSIONS

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Abstract: During the project ROBEX (Robotic Exploration for extreme environments) the deployment of an active functional seismic network has been demonstrated during the analog field test on Mt. Etna, Italy in 2017. During this mission campaign, key functionalities of robotic operation for future mission has been demonstrated, such as autonomous long term navigation, scientific instrument detection and manipulation, deployment, precise positioning and operation. This experiment will be described in this paper as a baseline for future mission. During the ROBEX experiments modular payload carrier, interfaces and methods has been developed which allow the reuse and adaptions of such robotic technologies and methods for different scientific approaches. Various robotic operational modalities, such as tele-operation, supervised control and high autonomous functionalities will be enabling technologies for long term bases on planetary surfaces. A roadmap will be presented.

ROBEX: As key missions, a seismic network was deployed and a seismic profile measurement was conducted using only robots on the landing site. Further experiments has allowed long term autonomous navigation, exploration of craters as well as robot cooperation tasks with the aim of geological analysis and probe selection. During this one month analog campaign, a realistic mission scenario has been built up, including a control station 30km away from the remote site. The Mt. Etna site has mainly been chosen due to the high equivalence of its seismic activity to moon quakes. Earth quakes in this region have a focal depth of approximately 600 km, a value similar to what has also been considered for moon quakes. Furthermore, the region is seismically highly active, probably three to four events per day, which means that scientifically relevant data will be acquired within the one month duration of the mission. In addition, the site fulfills important criteria for an analog mission such as:

REUSE: The modularity and concepts developed from the DLR, demonstrated within the field test, allows us to proceed for the long term goal, the installation and maintenance of permanent bases on planetary surfaces, including the usage of multiple robots and agents, for various scientific experiments. In further projects the demonstration of interferometric instruments will be one use cases for cosmology. Other projects aim the autonomous cooperation between robots and the interaction with humans and astronauts.

OPERATIONS: Various operation modes for robots are currently used. Depended on the communication infrastructure and capabilities, the different modes varies from teleoperation, where the human is in direct contact to the remote robot, over shares and supervised control, where local autonomy allows the robot to operate simple sub tasks on its own, based on local perception and autonomy, up to highly complex autonomous functionalities which will allow long time autonomous operations, even in mission critically situations. In general the goal for future missions will be, to include as much autonomy on the robot site, to relive the human operator, the astronaut and reserve time for more important tasks.

All this mission and operational concepts are in line with the global exploration strategy, regarding the goal of human robot cooperation, the installation of permanent bases e.g. lunar village, and the CIS Luna habitat or the Deep Space Gateway. A robotic strategy will be presented in this paper.

PEX.2-0004-18 THE UNIVERSITY ROVER CHALLENGE: A COMPETITION HIGHLIGHTING HUMAN AND ROBOTIC PARTNERSHIPS FOR EXPLORATION

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The University Rover Challenge began in 2007 with 4 American college teams competing, now in it's 12th year there are 95 teams from 12 countries registered to compete for the top rover designed to assist humans in the exploration of Mars. The Rovers compete aided by the University teams in four tasks (3 engineering and 1 science) in the Mars analog environment of the Utah Southern Desert in the United States. In this presentation we show amazing rover designs with videos demonstrating the incredible ingenuity, skill and determination of the world's most talented college students. We describe the purpose and results of each of the tasks: Science Cache Task, Extreme Retrieval and Delivery Task, Equipment Servicing Task, and the Autonomous Traversal Task. We explain the evolution of the competition and common challenges faced by the robotic explorers. For more information see: URC. MarsSociety.Org

PEX.2-0005-18 SSERVI ACTIVITIES PREPARING FOR ROBOTIC AND HUMAN EXPLORATION OF THE MOON, NEAS AND MOONS OF MARS

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NASA's Solar System Exploration Research Virtual Institute (SSERVI) has 13 teams that focus on the intersection of science and human exploration of the Solar System. SSERVI encompasses a wide variety of scientific and technical tasks encompassing planetary science, heliophysics, astrophysics, technology development and focused human exploration studies; these tasks range from modeling and analysis of the early Solar System and formation of the Moon to studies of the early universe as enabled by the lunar farside, and from experimental studies of high-velocity impacts to studies of the effect of dust on tissues. Application of these studies to both robotic and human exploration is wide ranging; numerous payload and mission concepts have been developed through SSERVI's studies, and SSERVI Investigators have served and led numerous mission teams. This paper will describe how SSERVI addresses selected interdisciplinary, exploration-related science efforts centered around all airless bodies targeted as potential near-term human destinations, and will focus on SSERVI's activities aimed toward the next generation of robotic and human exploration, first of the Moon and then to objects beyond our nearest neighbor.

PEX.2-0006-18 HIGHLIGHTS OF SCIENCE AND EXPLORATION ACTIVITIES AT THE SSERVI ISET

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The NASA SSERVI team "Institute for the Science of Exploration Targets (ISET)" uses stateof-the art modeling, combined with interpretation of spacecraft data, to reveal what the Moon, Phobos and Deimos, and asteroids tell us about the origin and evolution of the inner Solar System. The ISET team does this over four main themes. Here we describe our progress over the last year. In Theme 1, "Formation of the Inner Solar System and the Asteroid Belt", we used new models of planet formation via pebble accretion to identify substantial problems with long held views of how planets form. We also showed a substantial fraction of asteroids were implanted into the asteroid belt from the outer solar system. In Theme 2, "Origin of the Moon and Phobos/Deimos", we showed that Phobos/Deimos could form from a debris disk produced by a Vesta-to-Ceres sized impactor striking Mars. In these models, the moons would mostly be composed of Martian debris. In Theme 3, "The History of NEAs and Lunar Bombardment", we tested models of late accretion to Earth and found the amount of material delivered may have been 2-5 times greater than previously thought, with implications for the early history of the Moon. We also found evidence that the lunar basins Imbrium and Serenitatis are actually similar in age, countering recent geological interpretations. Finally, we argued that the impact flux on the Earth and moon increased by at least a factor of 2 roughly 250 Myr ago. This result implies the apparent dearth of large terrestrial craters with ages between 250-650 Myr on stable terrains is a byproduct of a lower impact flux, not preservation bias. In Theme 4, "NEAs: Properties, Populations, New Destinations", we examined the evolution of small asteroids via YORP thermal forces that asteroids spin up and down. We found that if bodies reach a small enough size, the spin rates for disruption ensure that the body components will immediately escape, leading to a convergent series of spin-up events that rapidly disaggregate the rubble pile into its core constituents. We also led observations that looked for "minimoons", compelling nearby targets for NASA human and robotic missions.

PEX.2-0007-18 HIGHLIGHTS OF SCIENCE AND EXPLORATION ACTIVITIES AT THE SSERVI PROJECT ESPRESSO NODE

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The Project ESPRESSO SSERVI node has been in operation for one year, and has forged ahead in the pursuit of its objectives of enhancing operational safety of future human and robotic exploration; enhancing target selection, sample selection, and ISRU potential; and enhancing target characterization and analysis capabilities. Here we will present the highlights of the first year of science and exploration activities at the Project ESPRESSO node. This includes the ongoing development of the Airborne Space Environment Chamber, a key resource for enabling large-scale experiments in lunarand asteroid-like gravity and pressure environments, commissioning of laboratories for the measurement of optical constants, LIBS spectra, and Raman spectra of materials likely to be present in the regoliths of asteroids and the Moon, calibration and deployment of field LIBS and Raman instrumentation for tests of their roles in future human exploration, and prototyping and tests of new classes of miniature impact probes for recovering regolith mechanical properties. We will conclude with a discussion of our plans for the coming year and opportunities for involvement in Project ESPRESSO efforts and facilities.

PEX.2-0008-18 HIGHLIGHTS OF SCIENCE AND EXPLORATION ACTIVITIES AT THE SSERVI FINESSE NODE

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FINESSE (Field Investigations to Enable Solar System Science and Exploration) is an interdisciplinary team of scientists, technologists, and mission operations specialists focused on conducting field-based research to understand geologic processes on the Moon, asteroids, and Phobos and Deimos while simultaneously preparing for future human and robotic exploration of these destinations. FINESSE is funded by NASA's SSERVI (Solar System Exploration Research Virtual Institute) and includes team members from government, academia, and industry, including both domestic and international partners. The FINESSE Science Program is devised to improve our understanding of the effects of volcanism and impacts as dominant planetary processes on the Moon, Near Earth Asteroids (NEAs), and Phobos Deimos. The FINESSE Exploration Program is aimed at understanding which exploration concepts of operations (ConOps) and capabilities enable and enhance scientific return. We operate under the philosophy that "science enables exploration and exploration enables science." To that end,

FINESSE conducts science-driven field science investigations which simultaneously work to inform decisions and architectures for optimizing future robotic and human missions in the Solar System. FINESSE-supported fieldwork has been conducted at Craters of the Moon National Monument and Preserve in Idaho, the West Clearwater Lake Impact Structure in northern Canada, the volcanic fields of Hawaii, and newly erupted volcanic landscapes in Iceland. While in the field, new technologies and hand-held field portable instrumentation are tested in situ for both science and exploration. We compliment the fieldwork with laboratory analysis of geologic samples, analysis of remote sensing data, and have conducted laboratory experiments in unique facilities such as the Syracuse Lava Project where basalt is melted into lava and solidifies to form volcanic rock under controlled conditions. Work through FINESSE has resulted in new scientific understandings of impacts and volcanism as well as findings and recommendations regarding exploration ConOps and capabilities to optimize future exploration. FINESSE research showed that a new classification scheme for impact rocks is warranted to reflect the formation processes of impact craters throughout the Solar System. The team also demonstrated the power of impact crater age dating and showed that the East and West Clearwater Impact Structures did not form at the same time and instead are the result of two distinct impact events. Exploration of several impact age dating techniques has led to new recommendations regarding sample collection for planetary geochronology missions to accurately date planetary impact structures. We have also developed multiple new techniques for using remote sensing data (validated through ground truthing) to understand geologic formation histories of volcanic features, which is tremendously useful for lunar studies where in situ analysis is typically not possible and most science is conducted remotely. LiDAR scanning of lava tubes and volcanic features has provided new insights into the geologic formation of these features, as well as the utility of such datasets for planning and executing future missions to the Moon. In tandem, we have collected UAV data at the sub-cm scale to map and characterize rugged terrains otherwise not accessible by foot, thereby increasing our science return as well as demonstrating the use and operations of these platforms for data collection in otherwise inaccessible locations on the Moon. We have also conducted high fidelity mission simulations to assess the use and integration of handheld field portable instrumentation for planetary missions. The incorporation of new technologies into future robotic and human missions requires a detailed understanding of scientific objectives and instrument capabilities coupled with strategic and tactical integration into mission planning. Work through FINESSE has outlined optimized use cases for various instrumentation, required data and communications flows for telemetry, and best practices for optimizing scientific output during human and robotic exploration missions. This talk will focus on the new scientific knowledge collected through the FINESSE project and discuss the associated exploration implications based on the science-driven analog fieldwork.

PEX.2-0009-18 HIGHLIGHTS OF SCIENCE AND EXPLORATION ACTIVITIES AT THE SSERVI RIS4E NODE

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The Remote, In Situ, and Synchrotron Studies for Science and Exploration (RIS4E) team is one of 13 nodes of NASA's Solar System Exploration Research Virtual Institute. The RIS4E team, led by Stony Brook University, is comprised of over 60 co-investigators, collaborators, postdoctoral researchers, and students. Our work is divided into four separate, but inter-related themes designed to address the science and future human exploration of the Moon, near-Earth asteroids, and the moons of Mars:

Preparation for Exploration: Enabling Quantitative Remote Geochemical Analysis of Airless Bodies. Remote sensing enables human exploration and sample return by providing global chemical and mineral data for the targets of interest and a basis for identifying sites of maximum scientific impact for crewed exploration and sample return. The RIS4E team is conducting laboratory spectroscopic measurements in appropriate environmental conditions and pushing the state of the art in light scattering models to maximize the science return of remotely sensed infrared data.

Maximizing Exploration Opportunities: Development of Field Methods for Human Exploration. Science-motivated field work helps us evaluate the role of handheld and portable field instruments for future human exploration, enabling rapid, low-risk, comprehensive, and quantitative assessments of the local geology and regolith materials. These advances will quickly inform astronauts about where to go and which samples to select, and improve our understanding of how exploration plans based on available remote sensing data are implemented and revised in the field. Our field team has conducted several campaigns at the December 1974 lava flow at the Kilauea volcano on the Big Island of Hawaii and the Potrillo volcanic field in New Mexico to test new technologies and methodologies for crewed exploration of planetary surfaces.

Protecting our Explorers: Understanding How Planetary Surface Environments Impact Human Health. Future astronauts will be exposed to harsh environments with potentially harmful but unknown health effects. The RIS4E team is performing experiments to determine the reactivity and toxicity of lunar and analog materials to determine the potential respiratory health effects of exposure to planetary regoliths and dust.

Maximizing Science from Returned Samples: Advanced Synchrotron and STEM Analysis of Lunar and Primitive Materials. The National Synchrotron Light Source II (NSLS II) at Brookhaven National Laboratory (BNL) is a next-generation light source that provides unparalleled chemical and mineralogical analysis of precious lunar and primitive meteorite materials. Using this facility, as well as the Advanced Photon Source and a state-of-the art scanning transmission electron microscope at the Naval Research Lab, RIS4E team members are probing the oxygen fugacity and carbonaceous content of early Solar System materials and shedding new light on the process of space weathering, which occurs on every airless body in the Solar System.

This presentation will present results and discuss future directions for each of the four RIS4E science themes.

PEX.2-0010-18 HIGHLIGHTS OF SCIENCE AND EXPLORATION ACTIVITIES AT THE SSERVI CSLE NODE

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The scientific objectives of the Center for Lunar Science and Exploration are tied together by collisional and impact cratering processes and the evolution of material, especially volatiles, that are delivered by those processes. We address the earliest phases of accretional collisions using a theoretical pebble accretion model (Kretke et al., submitted) and isotopic signatures of distinct nucleosynthetic reservoirs in the solar nebula (Bermingham and Walker, 2017; Bermingham et al., submitted). Previous analyses of Apollo samples by our team and its SSERVI international partners (e.g., Barnes et al., 2016) suggested water within the Earth-Moon system was delivered by planetesimals with carbonaceous chondrite affinities. New work suggests those carbonaceous, water-bearing materials may have accreted as planetesimals in the outer Solar System beyond Jupiter and then been transported and mixed into the inner Solar System. Interestingly, we found evidence in two meteorites that complex prebiotic chemistry occurred in one of those small, water-rich worlds circa 4.5 Ga during the first few million years of Solar System evolution (Chan et al., 2018). The final stages of collisional accretion that produce larger planets reshaped the nascent Earth and created the Earth-Moon system. In our own Earth's mantle, the concentrations of the volatile elements Bi, Cd, In, and Sn appear to have been set by volatile-depleted precursors and core formation. Analyses of lunar samples suggest, however, that all four of those elements, plus Zn, have mantle concentrations lower than expected and require an additional depletion mechanism such as loss during the giant impact or subsequent magma ocean (Righter et al., 2017a). Volatiles in the lunar interior can be vented at the surface by volcanic processes. Using analyses of Apollo samples, we calculated (Needham and Kring, 2017) the amounts of CO, H2O, H2, OH, and S vented during the eruption of the Moon's mare basalts, which cover more than 17% of the surface. During peak mare emplacement 3.5 Ga, gas was being vented faster than it could escape to space, so the Moon developed a transient atmosphere that persisted for 70 million years. At its peak, the atmosphere had a pressure 1.5 times greater than that at Mars today. The mass of volatiles vented was far greater than the mass of water ice estimated to exist in permanently shadowed regions (PSRs) around the lunar poles, so the mare may be an important indigenous source of those icy deposits.

In a parallel set of exploration studies, we found: (i) In situ robotic measurements of potential ice deposits should have a mass spectrometer for determining whether the ice has an indigenous source or a meteoritic source. Those measurements will help determine the transport and depositional mechanisms for volatiles and, thus, provide a model for estimating resource potential at other lunar locations; (ii) Tele-operation of small pressurized rovers (SPRs) between human landing sites can produce major surveys of permanently shadowed regions (PSRs) for water ice needed for a sustainable exploration program; (iii) Astronaut EVA in a SPR will be more efficient, productive, and easier on crew if it is a relatively low pressure vehicle (e.g., 8 psi) with suitports rather than a relatively high pressure vehicle (i.e., 14.7 psi) with an airlock; (iv) The Deep Space Gateway (DSG) could provide a platform for monitoring the impact flux to the lunar farside and, depending on the DSG orbit, nearside locations not observable from current Earth-based monitoring stations; (v) Human-assisted lunar sample return using tele-robotically driven rovers can address multiple science and exploration objectives and produce 15 to 20 kg of samples per mission; (vi) Data rates >1 Mbps are needed for human and human-assisted robotic ops in the vicinity of the Moon.

PEX.2-0011-18 FOR A NEW ROADMAP TO THE MOON AND MARS

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With a very distant objective for planetary exploration being the permanent occupancy of Mars, the use of lava tubes should be taken as a major pathfinder.

Presentation of latest results on lunar and Martian lava tubes.

Reasons for use of lava tubes as settlement sites.

The road map would follow two branches:

Scientific objectives: discovering listing and mapping of all lava tubes on the Moon and Mars, completed by in situ characterization of the most promising - Technology objectives: developing specific machinery needed for access to lava tubes and inflated structures introduced in lava tubes for life support.

The Moon will be considered as the base used for developing equipments and learning how to subsist in such an environment.

Favored options for management of the project: association of Space Agencies, directing a structure similar to the CNES Federation, a marriage of Agencies with participative volunteer groups as fablabs, makers . of all countries, representing a new method for involving forces present in the public. The first example would be the Lunar Robotic Village, detailed explanations of the concept will be presented.

PEX.2-0012-18 SCIENCE AND EXPLORATION HIGHLIGHTS FROM THE NASA-AUSTRALIA SSERVI PARTNERSHIP

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Australia has a large and dynamic planetary science community, which includes scientists that have made fundamental contributions to our understanding of the Moon, Mars, and NEOs. In 2015 Australia and NASA came together in a formal partnership within the SSERVI program, pursuing common goals in planetary and exploration science. Since 2015 the partnership has flourished. NASA SSERVI colleagues are now collaborating with the Australian team that built the Desert Fireball Network to expand it, with new international partners, to form a Global Fireball Observatory. The result will be a global planetary facility that should observe >5 meteorite falls per month. Over 40 cameras have already been SENT to partners in the US, UK, Canada, Morocco, and Saudi Arabia. SSERVI Central is a key partner in this collaborative effort, identifying new partners and sites for cameras. Australia has a particularly high profile in geochronology, with contributions indicating a complex lunar impact history, and constraints on the geological evolution of the Moon and Mars (Norman and Nemchin). Technical advances in geochronology are continuing, with the nascent field of nanogeochronology using atom probe (Reddy, Science Advances). A very partial selection of additional recent research highlights includes: using ancient micrometeorites as a probe of the Archaen atmosphere (Tomkins, Nature); GRAIL data constraining the formation of the lunar Orientale basin (Miljkovic, Science); how giant meteorite impacts may have helped to kick-start global tectonics (O'Neill, Nature Geoscience); and how primordial planetesimals (which evolved into the asteroids that now deliver primitive meteorites) may have started life as unconsolidated mudballs (Bland, Science Advances). Regarding planetary exploration, Australia has representation on science teams for a number of current missions, including: OSIRIS-Rex [Phil Bland, Trevor Ireland]; InSight [Katarina Miljjkovic]; Mars Science Laboratory [Penny King]; Akatsuki [Frank Mills], BepiColombo [Phil Bland], ExoMars [Martin Towner], Hayabusa 2 [Trevor Ireland]. Finally, on 25 September 2017, the Australian Government announced its intention to establish an Australian space agency. This announcement was guided by input for the review of Australia's space industry capability. The agency will provide international representation, support to critical partnerships, coordination of a national strategy and activities and support for industry growth. SSERVI Australia is increasing its advocacy role in this new environment, highlighting the recognised, substantive and growing planetary science community, working with policy makers, academic and industry leaders to solidify its future capability. We are involved at every level to ensure that planetary science, space, and exploration science are key components of the future agency.

PEX.2-0013-18 HIGHLIGHTS OF THE GERMANY DLR LUNAR AND PLANETARY RESEARCH

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Germany is contributing to solar system and extrasolar research by investigating planets and dwarf planets, their moons, asteroids and comets and their significance for life by comparing the solar system to other planetary systems using the best tools of geosciences and astronomy. Therefore Germany develops instruments, data processing methods and physical models as contribution to international space missions. The activities are conducted within cooperation that are complementary to the ESA Science Program as well as worldwide cooperation with main partners in the USA, France, Sweden, Norway, Italy, United Kingdom, Japan, and Spain. German solar system exploration and research activities are related to the following missions: Mars Express, Lunar Reconnaissance Orbiter, Rosetta, Messenger, Dawn, Hayabusa2/MASCOT, ExoMars, InSight, Mars 2020, Bepicolombo, JUICE, Cheops and Plato. The contribution to SSERVI is the provision of data mainly of cameras with the focus on three-dimensional topographic information as well as geological evaluation. This presentation will give examples for topographic evaluation of the surface of Moon, Mars Vesta and Ceres as well as the upcoming landing on the NEO Ryugu in context with the Hayabusa 2 mission.

PEX.2-0014-18 12U CUBESAT DEPLOYMENT FOR UV EXPLORATION

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A 12U cubesat mission in Lunar orbit is proposed to determine the distribution of neutral gas in the Earth exosphere and its response to solar wind and magnetic activity, aiming at producing a large-scale 3D map of the Earth exosphere from outside by monitoring the Earth Lymanemission. Lunar surface observations in the UV range will be also carried out. The mission can be assembled in 2 years time from COTS elements for a very moderate cost.

A key question affecting the human race regards the possible presence of life outside of the Earth. In the last decades, more than three thousand planets have been discovered. UV observations of exoplanet atmospheres during transits allows understanding the physical processes driving the formation and evolution of planet exospheres and magnetospheres, giving access to important properties of the planets and their interaction with the parent star. Detailed calculations have been carried out to evaluate the instrumentation needed to detect bio-tracers in Earth-like planets by the transit method. Observations of the Earth as an exoplanet will obviously help in this area. This project aims at determining the distribution of neutral gas in the Earth exosphere and its response to the solar wind/activity. Solar Lyman- (Ly) photons are scattered by the Hydrogen (HI) atoms in the exosphere producing a Ly halo around the Earth that extends further than 38 Earth radii. The goal is producing the first 3D map of the Earth exosphere from outside by monitoring the Earth Ly emission. The variation of the line source function across the exosphere will be obtained allowing the detailed evaluation of the Ly flux. The spatial distribution of neutral Oxygen and Helium will also be measured. From the vantage point of a Lunar polar orbit, a cubesat with UV instrumentation on board may map the exosphere from outside measuring simultaneously the exospheric emission and the variable background obtaining the most accurate measurements of the Hydrogen distribution at large Earth radii because will allow to separate the contributions from solar radiation and other processes like excitation by high energy particles from the Sun or internal magnetospheric sources.

During is duty cycle, the satellite will also survey systematically the heliosphere in Ly, investigating the distribution of diffuse matter within the heliosphere: NEOs, cometary tails, planetary exospheres and dusty clouds. Moreover, the monitoring of the water content and the space weather in the Moon poles would be feasible.

PEX.2-0015-18 THE ISS AS A PLATFORM FOR A FULLY SIMULATED MARS VOYAGE

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The ISS is the most valuable "analogue" for deep space exploration, since it can mimic the impact of microgravity, radiation, living and psychological conditions that astronauts will face during a deep space cruise, for example to Mars.

It is therefore conceivable to use the ISS as test bed for final integrated space tests for many of the individual scientific/technological solutions needed to allow for deep space voyages. These tests would optimize synergies in such operations. As individual issues are solved these can provide more and more "complete" tests, where a larger number of solutions are integrated in a single flight simulation.

At the end this will lead to a real 'dry-run' of a deep space mission (such as a mission to Mars), as close as reasonably possible to what will be the real voyage. This Mars ISS dry run could last several hundred days, mimicking most of the challenges which will be undertaken such as length, isolation, food provision, decision making, time delays, health monitoring diagnostic and therapeutic actions and more: not a collection of "single experiments", but a complete exploration simulation were all the pieces will come together for the first in space simulated Mars voyage. These results would provide essential information to best design more advanced tests on the planned Deep Space Habitat in cis-Lunar space.

At the time of the Mars ISS dry run all the science and technological challenges will have to be mostly solved by dedicated works. These solutions will be synergistically deployed in the dry run which will simulate all the different aspects of the voyage, the trip to Mars, the permanence on the planet and the return to Earth. During the dry run i) There will be no arrivals/departure of spacecrafts; 2) Proper communications delay with ground will be simulated; 3) Decision processes will migrate from Ground to ISS; 4) Permanence on Mars will be simulated. Mars ISS dry run will use just a portion of the ISS which will be totally isolated from the rest of the ISS, leaving to the other ISS portions the task to provide the needed operational support for the ISS survival as well as the support for emergency situations.

This talk will present some important issues still open to be addressed (see for example the disciplinary reports of the THESEUS project), some example of the challenging tests that could be performed, some of the operational challenges, as well as list some of the issues not likely/possible to be simulated.

PEX.2-0016-18 RADIATION EFFECTS ON VOLATILES AND THE EXPLORATION OF ASTEROIDS AND LUNAR SURFACES

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Recent space exploration missions to a number of Solar System objects, including the Moon, Mars, Mercury, and near Earth asteroids (NEAs), have revealed a wide variety of physical conditions which give rise to a diverse assortment of environments and risks. Since many of these objects are currently under consideration by NASA as strategic destinations for future human exploration missions, a more complete description of their respective environmental conditions is desirable in order to mitigate human risk factors and determine the availability of in situ resources. Without an appreciable atmosphere, each of these potential destinations is constantly being bombarded by radiation from the solar wind, galactic cosmic rays and hypervelocity micrometeorite impacts from local (circum-planetary) or interplanetary sources. Ionizing radiation and micrometeorite impactors can deposit, transport, alter, and even produce volatiles such as water and methane in the surface materials of such bodies [1]. When one considers the possibility of human exploration of these airless bodies, ionizing radiation is known to produce DNA damage that is likely linked to cancer susceptibility, neurodegenerative disorders, developmental abnormalities, inflammatory responses, and accelerated/premature aging [2-4]. Thus, the constant radiation assault also possesses obvious, life-threatening, and program-limiting health risks for humans that must be understood, quantified, and mitigated. The Radiation Effects on Volatiles and Exploration of Asteroids and Lunar Surfaces (REVEALS) team will explore the fundamental, applied, and operational aspects correlated with radiation processing of natural regolith and man-made composite materials. The emphasis focuses upon: i) Understanding the fundamental condensed-matter physics and radiation chemistry leading to volatile formation, sequestration and emission from the Moon, Martian moons (Phobos and Deimos) and NEAs and ii) Developing and testing novel composite materials (including regolith) using 3-D printing and real-time radiation detectors based on 2-D materials. These efforts could lead to useful in situ resource utilization strategies and development of portable shielding materials, real-time radiation detection systems as well as radiation-hardened human habitats and spacesuits. Collectively, the team will help minimize risks and exposure during human exploration missions.

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PEX.2-0017-18 RATIONALE AND CONCEPTS FOR ROBOTIC AND HUMAN OUTPOSTS ON PHOBOS

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A concept of a permanent station on the martian moons is under study. Such mission can serve several purposes: (a) positioning system, (b) data relay stations for Mars surface assets or for interplanetary missions, (c) monitoring of the Mars environment, (d) scientific investigations of Mars and its moons, and (e) investigation for in-situ resources exploitation and precursory human or robotic based station. It can serve also as a Martian moon and Mars webcam. We show here a preliminary mission concept, with some applications in the study of the Mars environment

PEX.2-0018-18 SPACE RADIATION AND HUMAN EXPLORATION ON THE MOON, MARS AND NEOS - DOSIMETRY, MODELS AND CHALLENGES

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Space programs are shifting towards planetary exploration and, in particular, towards missions by human beings to the Moon and to Mars. Radiation is considered to be one of the major hazards for human long-term missions beyond Low Earth Orbit (LEO). During transit to these far away destinations and during relevant extravehicular activities (EVA) on their surface, complete shielding of the highly energetic particles is impracticable. The two sources of radiation that can impact a mission outside the Earth's magnetic field are Solar Energetic Particles (SEP) and Galactic Cosmic Rays (GCR). The main goal for exploration missions is therefore the quantification and reduction of space radiation health hazards, with the goal of maximizing the number of days that may be spent in space. The research to be carried out has to support all phases of exploration including mission planning, component design, operation and post-flight studies. Having this in mind this calls for novel and improved radiation detector assemblies as well as extended calibrations, detector intercomparisons and analysis algorithms. New measurements are a prerequisite for reliable risk assessment, a crucial input for radiation source modelling, and are also needed for real-time calibration of the detectors thereby allowing for a detailed understanding of the radiation environment the astronauts are going to live in. For exploration missions, radiation risk assessment will predominately rely on simulation models. The reliability of these models needs to be optimized through a series of tests against a wide set of measurements at sites/conditions where instruments are available or can be made available. More and more radiation details are needed to correctly assess radiation risks, and this requires detailed model outputs to be tested against proper measurements. In the last years various radiation detector systems have been send either to the Moon (circulating in Moon orbit) or are already on the surface of Mars, providing thereby a tremendously needed data set for model validation and benchmarking and input data to face the challenges ahead of us.

PEX.2-0019-18 REVIEW OF SPACE RADIATION HEALTH RISKS FOR HUMAN EXPLORATION ON THE MOON, MARS AND NEOS

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Galactic cosmic ray (GCR) and solar particle event (SPE) exposures present significant health risks for long-term space travel outside the protection of the Earth's geomagnetic field. Large uncertainties occur in projecting the risks of high linear energy transfer (LET) radiation, most notably GCR heavy ions and secondary neutrons, because no human epidemiology data for these types of radiation exists. The major health risks are fatal cancer risks and possible change to cognition and memory during a mission. Other more manageable concerns are acute radiation sickness from large SPE's and late effects such as cataracts, circulatory diseases and poorly defined central nervous effects. In this review we highlight current risk estimates for the various health risks relative to the various space agency standards. There is a great interest in mitigation approaches to space radiation risks such as shielding and biological countermeasures. The merits of radiation shielding are dependent on the model used to project risks, while biological countermeasures testing would only occur in experimental models leaving the projection to humans highly uncertain. Thus because of the need to accurately project risks in individual astronaut's, improvements in our ability to project risks from high LET radiation using data from experimental models remains the largest challenge for enabling long-term missions to the moon, Mars and near-Earth-objects (NEOS) within acceptable safety standards.

PEX.2-0020-18 TOWARDS SPACE EXPLORATION OF MOON, MARS & NEOS: RADIATION BIOLOGICAL BASIS

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Radiation has emerged as the most critical issue to be resolved for long-term missions both or- bital and interplanetary. Astronauts are constantly exposed to galactic cosmic radiation (GCR) of various energies at a low dose rate. Primarily late tissue sequels like genetic alterations, cancer and non-cancer effects, i.e. cataracts and degenerative diseases of e.g. the central nervous system or the cardiovascular system, are the potential risks. Cataracts were observed to occur earlier and more often in astronauts exposed to higher proportions of galactic ions (Cucinotta et al., 2001). Predictions of cancer risk and acceptable radiation exposure in space are subject to many uncertainties including the relative biological effectiveness (RBE) of space radiation especially heavy ions, dose-rate effects and possible interaction with microgravity and other spaceflight environmental factors. The initial cellular response to radiation exposure paves the way to late sequelae and starts with damage to the DNA which complexity depends on the linear energy transfer (LET) of the radiation. Repair of such complex DNA damage is more challenging and requires more time than the repair of simple DNA double strand breaks (DSB) which can be visualized by immunofluorescence staining of the phosphorylated histone 2AX (γH2AX) and might explain the observed prolonged cell cycle arrests induced by high-LET in comparison to low-LET irradiation. Unrepaired or mis-repaired DNA DSB are proposed to be responsible for cell death, mutations, chromosomal aberrations and oncogenic cell transforma- tion. Cell killing and mutation induction are most efficient in an LET range of 90-200 keV/µm. Also the activation of transcription factors such as Nuclear Factor κB (NF-κB) and gene expression shaping the cellular radiation response depend on the LET with a peak RBE between 90 and 300 keV/µm. Such LET-RBE relationships were observed for cataract and cancer induction by heavy ions in laboratory animals, with varying maximal efficiencies. Furthermore, there is always the added risk of acute exposure to high proton fluxes during a solar particle event (SPE), which can threaten immediate survival of the astronauts in case of insufficient shielding by eliciting the acute radiation syndrome. Its symptoms depend on absorbed total radiation dose, type of radiation, the dose distribution in the body and the individual radiation sensitivity. After the prodromal stage with nausea and vomiting and a subsequent symptom-free phase, depending on dose, the hematopoietic syndrome with suppression of the acquired immune system and thrombocytopenia (0.7-4 Sv), the gastrointestinal tract syndrome (5-12 Sv) or the central nervous system syndrome (> 20 Sv) develop and they are accompanied by exacerbated innate immune responses. Exposure to large SPE

has to be avoided by warning systems and stay inside a radiation shelter during the event. Treatment options encompass e.g. the administration of colony-stimulating factors (CSF), growth factors and blood transfusions to overcome the hematopoietic syndrome and the administration of antibiotics against secondary infections. A concerted action of ground-based studies and space experiments is required to improve the radiobiological basis of space radiation risk assessment and countermeasure development.

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PEX.2-0021-18 MELISSA AND RUSSIAN INSTITUTES, 20 YEARS OF A DISCRETE BUT PUBLISHED COLLABORATION

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Future manned missions to Moon or Mars, private or public, will be an international adventure. One of the challenges is the development of a robust closed life support system to sustain this international crew or potentially community. It is therefore crucial that system and sub-systems are developed in a collaborative mind more that with a prime to subs-contractors approach, where pieces are developed from different part of the world and only assembled at the end. This collaborative approach as the advantage to create motivation of all actors, more commitments and to technically reduced the risk with a better understanding of the distributed sub-systems. Over the 30 years of MELiSSA project, almost 20 years of them have seen collaborations with Russian institutes: - IBP Krasnoyarsk and - IBMP, Moscow. Initiated around 2000, in a difficult historical context and almost total ignorance of respective activities and culture, this collaboration has brought several successes, now published in international journals. More than a political declaration, this collaboration was more a human desire to discover, listen to existing experience and to collaborate for a common objective: the development of closed life support system. Started much before any European activity in Life Support, Russian research has accumulated a lot of experience either from Isolation manned facilities, flight hardware development and operation. At the contrary, started from almost non-European experience, the MELiSSA project benefitted of a virgin field. This collaboration mainly covered the 3 axes of MELiSSA project: - Basic D, - Flight Experiment and Isolation campaign via ground analogs (i.e. BIOS and MELiSSA Pilot Plant). The objectives of this presentation is of course to present the collaboration activities: Soil Like Substrat, Mobilisatie, Message, Nitrimel, BIOS upgrade, Higher plant activities, microbial contamination,. and the obtained results as well as to remind the historical context of this collaboration: - the general constraints, the difference and interest of the cultural and sociological approach. As a conclusion, this paper will summarize the main obstacles, which have been faced and overcome as well as the reasons why this collaboration continue.

PEX.2-0022-18 PREPARING HUMAN EXPLORATION ON MOON AND MARS: FROM SIMULATIONS TOWARDS A FUNCTIONAL BASE

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Human space flight to planetary bodies has gained new momentum over the past few years: Space agencies like ESA and NASA hope to reach the Moon within 20 years. Private companies occasionally announce more ambitious goals and timelines. Nevertheless, important technologies still have to be developed and improved before humans can face the risks and difficulties of interplanetary travel.

Meanwhile, a number of analog habitats have been built in the recent past, including habitats such as HI-SEAS or LUNARES. These habitats are built primarily for human factor studies. For example, HI-SEAS is looking into the psychology of groups in long-term isolation and confinement, among other things. Lunares takes are more physiological approach. Other habitat analogs have a more technical focus, such as the Habitat Demonstration Unit or the Inflatable Lunar/Mars Habitat (ILMH) located at the University of North Dakota. Nevertheless, all such habitats are built for the primary purpose of providing a location to conduct simulations.

With recent, impressive advances in rocket technology, it is time to advance technology for when astronauts not only lift off of Earth, but actually reach the surface of the Moon. Project MaMBA (short for Moon and Mars Base Analog) aims to apply the lessons learned from previous simulations that have been conducted at various analog bases, and combine them with the necessary technology to create a functional base that is not any more limited to terrestrial use.

Specifically, we draw lessons from (1) the longest simulation of a surface stay on Mars, conducted at HI-SEAS, (2) the first simulation with a physically disabled astronaut (ICAres-1), conducted at LUNARES, and (3) a number of two-week simulations at MDRS. All three types of simulations give insight into both errors that have been made in the respective habitat design, and features that have been received well by the respective crews.

As a result, MaMBA will consist of separate, connected modules which can be shut off independently from each other, and will adress the possibility of astronauts being (temporarily) incapacitated. Modules will be divided into work and leisure modules, and at least one of the modules will have a high ceiling to provide a 'feel' of spaciousness. The central piece of the habitat will be the laboratory module which is currently in the middle of its design phase;

construction of the first iteration of the laboratory module will commence at the end of this year. Scientists are playing an integral part in the design process for the laboratory. Moreover, as MaMBA aims to be a functioning habitat prototype, at its final stage it will have closed loops for water and air and a self-sufficient power supply. Functionality of the habitat will be verified during short and medium-duration simulations with analog astronauts starting next year.

PEX.2-0023-18 MOON DIRECT

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The recent amazing success of the Falcon Heavy launch offers America an unprecedented opportunity to break the stagnation that has afflicted its human spaceflight program for decades. In short, the Moon is now within reach.

Here's how the mission plan could work. The Falcon Heavy can lift 60 tons to Low Earth Orbit (LEO). Starting from that point, a hydrogen/oxygen rocket-propelled cargo lander could deliver 12 tons of payload to the lunar surface.

We therefore proceed by sending two such landers to our planned base location. The best place for it would be at one of the poles, because there are spots at both of the Moon's poles where sunlight is accessible all the time, as well as permanently shadowed craters nearby where water ice has accumulated. Such ice could be electrolyzed to make hydrogen-oxygen rocket propellant, to fuel both Earth-return vehicles as well as flying rocket vehicles that would provide the base's crew with exploratory access to most of the rest of the Moon.

The first cargo lander carries a load of equipment, including a solar panel array, high data rate communication geart, a microwave power beaming set up with a range of 100 km, an electrolysis/refrigeration unit, two crew vehicles, a trailer, and a group of teleoperated robotic rovers. After landing, some of the rovers are used to set up the solar array and communication system, while others are used to scout out the landing area in detail, putting down radio beacons on the precise target locations for the landings to follow.

The second cargo lander brings out a 12-ton habitation module, loaded with food, spare spacesuits, scientific equipment, tools, and other supplies. This will serve as the astronauts' house, laboratory, and workshop of the Moon. Once it has landed, the rovers hook it up to the power supply and all systems are checked out. This done, the rovers are redeployed to do detailed photographing of the base area and its surroundings. All this data is sent back to Earth, to aid mission planners and the science and engineering support teams, and ultimately forming the basis of a virtual reality program that will allow millions of members of the public to participate in the missions as well.

The base now being operational it is time to send the first crew. A Falcon Heavy is used to deliver another cargo lander to orbit, whose payload consists of a fully-fueled Lunar Excursion Vehicle (LEV). This craft consists of a 2-ton cabin like that used by the Apollo era Lunar Excursion Module mounted on a 1-ton hydrogen/oxygen propulsion system filled with 9 tons of propellant, capable of delivering it from the lunar surface to Earth orbit. A man-rated Falcon 9 rocket then lifts the crew in a Dragon capsule to LEO where they transfer to the LEV. Then the cargo lander takes the LEV, with the crew aboard, to the Moon, while the Dragon remains behind in LEO.

After landing at the Moon base, the crew completes any necessary set up operations and begins exploration. A key goal will be to travel to a permanently-shadowed crater and making use of power beamed to them from the base, use telerobots to mine water ice. Hauling this treasure back to the base in their trailer, the astronauts will feed the water into the electrolysis/refrigeration unit, which will transform it into liquid hydrogen and oxygen. These products will then be stored in the empty tanks of the cargo landers for future useprimarily as rocket propellant but also as a power supply for fuel cells and a copious source of life support consumables.

Having spent a couple of months initiating such operations and engaging in additional forms of resource prospecting and scientific exploration, the astronauts will enter the LEV, take off and return to Earth orbit. There they will be met by a Dragon - either the one that took them to orbit in the first place or another that has just been launched to lift the crew following them - which will serve as their reentry capsule for the final leg of the journey back home.

Thus, each mission that follows will require just one \$100 million Falcon Heavy and one \$60 million Falcon 9 to accomplish. Once the base is well-established, there will be little reason not to extend surface stays to 6 months. So assuming that the program hardware purchases will roughly equal its launch costs, we should be able to create and sustain a permanently occupied lunar base at an ongoing yearly cost of less than \$700 million. This is less than 4 percent of NASAs current budget – or about a quarter of what is being spent yearly on the agency ts now obsolete Space Launch System program which has been going on for over a decade without producing anything.

The astronauts will not be limited to exploring the local region around the base. Refueled with hydrogen and oxygen, the same LEV spacecraft used to travel to the Moon and back can be used to fly from the base to anywhere else on the Moon, land, provide onsite housing for an exploration sortie crew, and then return them to the base. We won't just be getting a local outpost: we'll be getting complete global access to an entire world.

Currently NASA has no such plan. Instead it is proposing the build a lunar orbiting space station dubbed the Deep Space Gateway. This boondoggle will cost several tens of billions of dollars, at the least, and serve no useful purpose whatsoever - except perhaps to provide a launch manifest for the Space Launch System. We do not need a lunar-orbiting station to go to the Moon. We do not need such a station to go to Mars. We do not need it to go to near-Earth asteroids. We do not need it to go anywhere. If we do waste our time and money building it, we won't go anywhere.

If you want to get to the Moon, you need to go to the Moon. We now have it in our power to do so. Let's seize the time.

PEX.2-0024-18 INFLUENCE OF SPACEFLIGHT ENVIRONMENT ON BIOLOGICAL SYSTEMS FOR THE MOON, MARS AND NEOS

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Human exploitation of space is a great achievement of our civilization. After the first space flights and visit the Moon a development of artificial biological environment in space systems is a second great step. First biological experiments on a board of Salyut and Mir space stations were successfully performed in 70-90th of last century. The results are: first long time cultivation of plants in space (wheat, linen, lettuce, crepis); first flowers in space (Arabidopsis); first harvesting of seeds in space (Arabidopsis); first harvesting of roots (radish); first full life cycle from seeds to seeds in space (wheat); first tissue culture experiments (Panax ginseng L, Crocus sativus L, Stevia rebaundiana B); first tree growing in space for 2 years (Limonia acidissima). The success of these missions was estimated in Guinness records. These studies are continuing in the recent experiments on a board of Shenzhou Chinese space ships with plants and tissue culture. It was found that the space environment influences on the biological systems, but the space harvest is possible. The results of the space flight experiments are discussed in the light of future space flights and long term missions on the Moon, Mars and NEOS.

PEX.2-0025-18 HELIOPHYSICS SCIENCE ENABLED BY LUNAR ORBITING PLATFORMS

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The current emphasis on returning to the Moon with a lunar orbiting platform provides an impetus and opportunity to explore newly enabled investigations that are relevant to heliophysics and to understand the coupling of the sun and its atmosphere to the magnetized space environment surrounding the Earth. To that end, a workshop focused on the science that the NASA Deep Space Gateway (DSG) platform enables was held with focused topics including heliophysics, space weather/radiation, Earth science, astrophysics, lunar and planetary, crosscutting technologies, telerobotics, human exploration support, and sample collection/return. Following this, a session at the Triennial Earth-Sun Summit (TESS) focused on the heliophysics science enabled by the DSG was convened. This talk will summarize the major heliophysics themes of those two meetings and provide context for science strategies that take advantage of lunar orbiting platforms, and for technologies required to realize the full benefit of the synergy of human and robotic exploration in the vicinity of the Moon.

PEX.2-0026-18 VARIANTS OF ROBOTIC/ HUMAN COMBINATION OF RUSSIAN LUNAR EXPLORATION PROJECTS

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Current plans of Russian participation in international projects of Moon exploration are considered. Special attention is given to the Deep Space Gateway (DSG) project where a cis-lunar platform is planned by the ISS partners. We discuss a balance of robotic and manned operations at DSG station, in particular targeted at scientific tasks. Another focus of the paper is current Russian program of robotic spacecraft as a precursor for human exploration programs. The role of crew in joint human-robotic Moon missions is specified.

PEX.2-0028-18 LUNAR VICINITY, MOON, NEO AND MARS SCIENCE ENABLED BY THE GLOBAL EXPLORATION ROADMAP: THE ISECG SCIENCE WHITE PAPER

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The 15 space agencies of the International Space Exploration Coordination Group (ISECG) are discussing an internationally coordinated approach for human and robotic space exploration, as documented in ISECG's Global Exploration Roadmap (GER), i.e. a coordinated international effort to prepare for collaborative space exploration missions beginning with the Low Earth Orbit (LEO) and continuing to the lunar vicinity, the Moon, asteroids and, eventually, Mars.

ISECG engaged the scientific community in a coordinated discussion to improve the understanding of the scientific opportunities, drivers and requirements of priority science questions that can be addressed by near-term human exploration missions to Solar System destinations as laid out in the GER. These span a deep space gateway in the lunar vicinity, the lunar surface, or a mission to asteroids. An independent Science Advisory Group (SAG) composed of scientists from a variety of nations and diverse science disciplines was set up by ISECG in 2015, with the goal of elaborating a Science White Paper (SWP) identifying the scientific opportunities in near-term exploration missions beyond LEO, the overarching science themes and their relevance to the GER mission scenarios.

Several consultation milestones were organized by the SAG, including a dedicated COSPARISECG-ESF workshop in Paris on February 2016, and making use of international events, to gather input on the SWP and incorporate feedback from the community on early versions of the white paper. These events generated input from a broad range of scientific disciplines including planetary and space sciences, astrobiology, life sciences, physical sciences, astronomy and Earth science.

The Science White Paper was published in December 2017 and is structured around the science themes "Understanding Our Place in the Universe" and "Living and Working in Space". It focusses on opportunities created by near-term mission themes in the GER, i.e. extended duration crew missions to an exploration gateway in the lunar vicinity; crewed missions to an asteroid; and crewed missions to the lunar surface.

We will present the contents of the Science White Paper, with particular emphasis on the various science opportunities enabled by the GER.

PEX.2-0029-18 LUNAR SCIENCE WITH HERACLES

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This paper provides a status of the development of the HERACLES lunar sample return mission concept.

ESA, JAXA and CSA are exploring common interests in human lunar exploration, which is one of the four cornerstones of the European Exploration Envelope Programme. It is currently a shared under-standing that the most affordable approach to the development of a human lunar exploration architecture is the flight-demonstration of key components of lunar vehicles (lander, rover and ascent vehicle) through a sub-scale demonstration mission launching in the mid-2020's timeframe. Initiated by ESA as the Human-Enabled Robotic Architecture and Capability for Lunar Exploration and Science (HERACLES), advanced studies for this mission concept are being undertaken in 2018 and 2019 in a collaborative framework with ESA in the coordination role and undertaking study of the ascent module, JAXA undertaking study of the lander, and CSA, study of the rover element.

Scientific knowledge gain is recognised by the HERACLES partner agencies as a signficiant socio-economic benefit that can be enabled by a human lunar exploration architecture. While the primary objective of HERACLES is to demonstrate key pre-cursor technologies, its initial surface operations sce-nario builds on the international science community motivation for lunar sample return [1][2] and in-volves landing at a site of high scientific interest and return of lunar samples of high scientific value be-fore conducting a long distance traverse that pro-vides further opportunities for science and exploration. Science planning for the HERACLES mission is co-led, with a multi-agency HERACLES Science Working Group responsible for developing a mission science management plan to describe science team and science payload selection processes, and data and sample policies.

The HERACLES Design Reference Mission: In the initial phase of mission planning, a HERACLES study team developed a nominal sce-nario with Schrödinger basin as the reference landing site, with a 70 day surface sample return mission, followed by a 1 year traverse encompassing one or more additional potential human exploration land-ing sites in the south pole region. The reference for returned smaple mass is 25kg, including container. A common reference set of mission science objectives was further developed by a Science Working Group in 2017, based on previous studies and agencies' consultations, and responding to the themes of the ISECG Science White Paper [3]. Cold-trapped volatiles are not included, as though these are a high scientific priority and of interest for In Situ Resource Utilisation, it was determined that a cryo-genic sample return was beyond the scope of this demonstration mission (though feasible in the architecture design). The reference science objectives have been used, with the help of a Canadian science study team, to provide a strawman science payload (imaging, elemental composition, mineralo-gy, sub-surface structure, radiation sensors, possible deployment of a small payload (<1kg) to the surface)) to assess the feasibility of payload accommodation within the current HERACLES rover concept. The capability to acquire fresh rock samples has been included in the reference, but at this time a drill capability has not.

Prioritisation of Science Investigations and Landing Site Selection: Further work is required to refine the HERACLES science scenario. The com-munity is invited to engage in the next step of trans-forming the reference scenario into prioritised inves-tigations (in-situ instrumentation and analysis of returned samples) and provide input to landing site selection. The HERACLES partner agencies are preparing a process by which the respective science communi-ties can engage and prepare their contributions. The next step is the creation of an international HERACLES Science Definition Team (HSDT) who will be tasked to generate a prioritised list of investi-gations, and make recommendations with regard to landing site selection. Sites other than Schrödinger may be considered, subject to engineering con-straints and additional exploration objectives. The HSDT report will then be used in the preparation of opportunities for science team membership and sci-ence instrument proposals, should the mission be approved for launch. Observer status in the HERACLES project is provided for agencies with common interests, with associated representation planned on the HSDT.

References: [1] National Research Council, The Scientific Context for Exploration of the Moon, 2007 [2] Lunar Exploration Analysis Group, The Lunar Exploration Roadmap: Exploring the Moon in the 21st Century: Themes, Goals, Objectives, In-vestigations, and Priorities, 2016. [3] International Science Exploration Coordination Group, Scientific opportunities enabled by human exploration beyond Low-Earth-Orbit (full) - An ISECG Science White Paper, https://www.globalspaceexploration.org/wordpress/wp-content/isecg/ISECG%20SWPF IN AL–

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PEX.2-0030-18 SPACE AGRICULTURE FOR MANNED EXPLORATION OF ASTROBIOLOGY ON MARS

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Apace agriculture is a concept of bio-regenerative life support for manned exploration of space. Mars is the best target of astrobiology missions in this century. Major focus on Mars is finding either extant or extinct life and bio-related materials. We can study on characteristic of extraterrestrial life and universal principle of biology. Any missions to Mars should be cautiously planned and conducted to avoid contamination made by any terrestrial life forms and organic materials until science community would chew it up to conclude life history on Mars. Even space agriculture is planned for the mature phase of manned mission with large (more than 20) crew size and longer (more than 10 years) operation of their outpost base, it should meet the requirements from astrobiology. Microorganisms are confined within pressurized dome. Site of settlement is physically isolated from exploration site by appropriate distance. Risk of bio-contamination would be assessed during precursor unmanned missions. Another important subject during preparatory phase is the survey of on-site resource availability for space agriculture, which aims more than 100% recycling of materials by the use of water, atmosphere and other bio-elements on Mars. The highest priority of the manned space mission is survivability of crew. Better economy of recycling materials and psychological support for crew by raising pet plants and animals are merit of space agriculture, but they are never on the first line. In order to confirm solid performance of space agriculture, it operates for providing storage for the next crew turn. Interdisciplinary discussion is quite demanding for planning phased scenario of missions to Mars, and developing space agriculture step by step.

PEX.2-0031-18 SYNERGIES AND INTERACTION BETWEEN SPACE-ARCHITECTURE, ANALOGUE HABITATS & SUSTAINABILITY

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According to ESA's Director General Johann-Dietrich Wörner, a habitable station on the Lunar surface is the next step in reaching more distant destinations in deep space. Planetary habitats have also been proposed for Mars, asteroids or even the martian satellite, Phobos. The core idea of a planetary habitats deals with people working and living together at the same place. Simultaneously, it's a metaphor for international collaboration, a global community, which brings multiple actors together in our endeavors for future space exploration. The main research question is whether it is possible to form a new three spherical model that aims to identify the three interacting components, which constitutes positive human integration in a planetary world.

This research investigates the synergies and intersection between the following three pillars:

I) Space architecture, II) Analogue habitat experimentation on Earth and III) Sustainability.

I) Space Architecture is a critical component in the development of the lunar habitat. The interdisciplinary field of Space Architecture draws from a variety of fields such as engineering, architecture, design, human factor design, space sciences, medicine, psychology and the arts. Therefore, it is simultaneously technical, humanistic, scientific and artistic. II) Analogue habitats are an important extension of the field of Space Architecture, despite taking microgravity out of the equation. These missions are designed in extreme environments on Earth, in order to simulate the physical similarities of a space environment. III) The creation of a sustainable and livable habitat on a resource-poor surface can provide the perfect case study to innovate and come up with creative solutions that will eventually make the Earth a better place.

A three spherical model is created based on the perception of interconnectivity and system thinking. The aim is to explore whether these three pillars are critical for positive human integration in the moon environment, or are too simplistic. We will present a six-month investigation into the different compartments, how they interact and how they form a synthesis.

These three components are designed in such a way that they provide feedback loops in order to positively stimulate each other. At last, new study recommendations are given for further research and framing of this discourse.

PEX.2-0032-18 EVOLVING ADVICE ON THE ROLE OF PHYSICAL PROCESSES IN EXPLORATION TECHNOLOGY DESIGN AND OPERATION

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Despite decades of engineering research and development, high costs and exacting requirements for robust systems performance continue to create high barriers to achieving humanity's goal of exploring and creating outposts beyond low Earth orbit, including Mars. Over this same time period, an appreciation grew in the physical sciences community that research on fundamental behaviors of fluids and materials in a space environment could be used to inform the design of important classes of exploration technologies and processes, with the potential for lowering costs, decreasing weight, and increasing reliability. Under the auspices of the National Academies of Sciences, Engineering, and Medicine, the community has periodically come together to examine the research questions on physical behaviors most relevant to space exploration needs, as well as related programmatic issues, such as the barriers to communications between stakeholders. This talk explores the evolution of the issues and science questions examined by these groups, and some of the most significant findings and conclusions.

PEX.2-0033-18 THE NEED FOR A RATIONAL FRAMEWORK FOR COORDINATED MANAGEMENT OF FUTURE EXPLORATION, USES AND EXPLOITATION OF OUTER SPACE ENVIRONMENTS AND RESOURCES

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Although there is an acknowledged need to manage the environments of extraterrestrial bodies like the Moon, Mars, or even asteroids, there are currently no international policies for guiding space-based activities including exploration, resource use, and exploitation that could impact planetary environments (e.g., mining, energy production, and general construction of infrastructure required for landing areas, extended human habitation, large telescopes, or facilities away from bases, etc.) There is an obvious needed to develop a clear, justifiable and implementable framework in anticipation of proposals for diverse activities and uses beyond Earth, whether by governments, non-governmental, commercial, or private entities. In recent years, a variety of suggestions have been published on how to manage space environments, based on adaptations of various Earth based analogues (e.g., industry codes of conduct and best management practices; establishment of reserves; mitigation for or control of unavoidable impacts; monitoring of claims; developing review processes similar to environmental impact assessments, etc.). Clearly, standards or approaches to avoid harmful contamination or irreversible damage to extraterrestrial environments are warranted. Yet the path forward to achieving such policies is uncertain at best. What project planners and proponents need are clear guidelines and policies that include more than vague notions of responsible activities. The development of such policies will take considerable time-as evidenced by the nearly two-decade long process for considering COSPAR's Planetary Protection policy for human missions beyond Earth orbit. Already, COSPAR's Panel on Planetary Exploration (PEX) has begun to consider issues of space environmental management beyond planetary protection concerns, but it will undoubtedly take many more years to provide necessary details. In addition, while other groups are focusing on regulatory approaches and policies for exploration and uses of beyond Earth orbit, they are a long way from dealing with the implementation details needed to guide space activities for different bodies. In the meantime, there is no cross-sector plan or standardized framework for assessing how and to what extent human or directed robotic activities might affect surface environments during either general science exploration, commercial/private activities or resource exploitation. In addition, there are no criteria on which to gauge the direct, indirect or cumulative impacts on space environments or their sustainability over time. This is particularly problematic for areas of bodies that might be affected by inadvertent transfer of Earth associated microbes and materials - which might contaminate subsurface ices or other areas considered for resource utilization (different from planetary protection concerns per se). Looking ahead, it is certain that many considerations will need research attention. How might an effective and practical process be developed to assess the extent to which human or robotic activities may affect extraterrestrial environments? Would such a process include opportunities for public review and comment? Might a uniform protocol or set of voluntary guidelines be developed to encourage project proponents to fully describe their proposals, identify how they may affect extraterrestrial environments and describe measures that will be taken to mitigate or reduce adverse effects? Just as the development of planetary protection requirements for human exploration missions have required step-wise, cross-cutting, collaborative efforts involving both science and technology communities from many countries, so too will the development of guidelines and requirements for future exploitation and use of resources-and their sustainability. This presentation will discuss the diversity of science, protection, exploitation, use, management, stakeholder and societal concerns that will need to be included in project planning, review and approval to ensure responsible exploration and use of space resources and planetary surfaces for the benefit of all humankind. Considering that international missions to the Moon, Mars and asteroids involving multiple stakeholders and objectives are possible in the coming decade, it is important to begin the stepwise consideration of framing and analyzing environmental sustainability criteria soon.

PEX.2-0034-18 PEX2 SESSION PANEL WRAP-UP

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PEX2 session panel wrap-up

The session COSPAR-18-PEX.2: "Human Exploration on the Moon, Mars and NEOs", cosponsored by Commissions B, F will include solicited and contributed talks and poster/interactive presentations. It will also be part of the 13th International Conference on Exploration and Utilisation of the Moon ICEUM13B from the ILEWG ICEUM series started in 1994. It will address various themes and COSPAR communities: Sci ences (of, on, from) the Moon enabled by humans; Research from cislunar and libration points; From robotic villages to international lunar bases; Research from Mars NEOs outposts; Humans to Phobos/Deimos, Mars and NEOs; Challenges and preparatory technologies, field research operations; Human and robotic partnerships and precursor missions; Resource utilisation, life support and sustainable exploration; Stakeholders for human exploration. One half-day session will be dedicated to a workshop format and meetings/ reports of task groups: Science, Technology, Agencies, Robotic village, Human bases, Moon Mars Villages, Society Commerce, Outreach, Young Explorers. COSPAR has provided through Commissions, Panels and Working Groups (such as ILEWG, IMEWG) an international forum for supporting and promoting the robotic and human exploration of the Moon, Mars and NEOS.

PEX.2-0036-18 ON THE METEOROID HAZARD TO THE ROBOTIC AND HUMAN EXPLORATION OF THE MOON, MARS AND NEOS

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Human and robotic space exploration in the coming decades will require the safety of this process. This task is also set in relation to exploration of the Moon, Mars and NEOs. One of the agents of danger in this case is the meteoroid environment. Here the question of constructing models of the meteoroid environment near the Earth's orbit and beyond is discussed.

PANELS (P)

NEAR-TERM EXPLORATION OF THE INTERSTELLAR MEDIUM (PIR.1)

PIR.1-0001-18 INTERSTELLAR PROBE: THE FIRST STEP OF A THOUSAND MILES

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Exploration of the heliosphere and the far reaches of our solar system by the Voyagers and New Horizons and near-Earth observations of the Kuiper Belt and exoplanetary systems have all profoundly changed how we view our own home in space. An Interstellar Probe escaping beyond the solar-system boundaries with new observational techniques would be a bold move in space exploration, enabling detailed, new understanding of the global heliosphere in the context of other astrospheres, further discoveries of unexplored Kuiper Belt Objects, and the first observations of our circumsolar dust disk. These would offer insight into the evolution of the solar system and our understanding of exoplanetary systems. With the power supplies on the Voyagers nearing their end of life, the rapid pace of discovery of exoplanets in other stellar systems, and the evolution in our own understanding brought about results from the Voyager, Cassini, and Interstellar Boundary Explorer (IBEX) spacecraft, the time is right for looking at the next steps we can make into our stellar neighborhood. Travel to near-stellar systems has been a serious topic of discussion since the speculations of Tsiolkovsky, Goddard, Oberth, and Tsien. Such discussions over the years have also helped define and illustrate how momentous a challenge such voyages are. Hence, the question facing us today is what the appropriate next step - a true first step - is in negotiating the transition from science fiction to engineering reality. The scientific imperatives associated with reaching the near interstellar medium in order to understand our origins and our own current locale in the Milky Way trace to the beginnings of the Space Age, and they have been debated and refined since that time and into the current epoch with the ongoing discoveries of the Voyager Interstellar Mission. The subjects of interstellar travel, interstellar probes, and interstellar "precursor" missions are not new but have lacked traction with policy makers and the scientific community at large because of the states of both scientific knowledge and engineering realities. With the in situ scientific revelations of the Voyager Interstellar Mission and New Horizons and the remote images in energetic neutral atoms (ENAs) from Cassini and IBEX, it is clear that that the next

scientific understanding of the grand scheme of our surroundings will come from a multifaceted partnership between NASA's planned Interstellar Mapping and Acceleration Probe (IMAP) mission, other relevant assets deployed within the orbits of the classical planets, and a vanguard interstellar mission beyond the reach of the Voyagers and New Horizons. Predicting the best path to future scientific discoveries is always problematic and subject to debate, yet it is also clear that the effective strategy is to push out the frontier with the tools at hand. The next step in reaching to the stars will require the recognition of engineering limits, scientific trades, and scientific compromises, but this is new neither in science nor exploration. Such a step would be an "Interstellar Probe." If our ultimate destiny as a species is to persevere, then that journey will be amongst the stars, and probing those regions to understand the properties of both the nearby interstellar medium and of our own stellar system will be the first, necessary, and timely, step in that "thousand-mile journey" to the stars. An "Interstellar Probe" is that step. The time for the Interstellar Probe has come.

PIR.1-0002-18 INTERSTELLAR HELIOSPHERE PROBES (IHPS)

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Supersonic solar wind streams away from the Sun in all directions, interaction with the local interstellar medium to form a giant plasma bubble, which is coined by A. J. Dessler as "heliosphere". Voyager 1 2 spacecraft have recently encountered the heliospheric boundaries of this plasma bubble, e.g. the termination shock, heliosheath and heliopause. To explore further on the dynamics on the heliospheric boundaries, even the hydrogen wall, and the local interstellar medium, an Interstellar Heliosphere Probes IHPsmission have been proposed to Chinese national space agency (two spacecraft, one towards the nose of the heliopause, one opposite). The plan is that the spacecraft is to reach 100AU when it is 100th anniversary of the PR China (2049). Thus, IHP will allow us to discover, explore, and understand fundamental astrophysical processes in the largest plasma laboratory– the heliosphere.

PIR.1-0003-18 PLANETARY SCIENCE WITH AN INTERSTELLAR PROBE

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A probe designed to exit the solar system and explore interstellar space provides a prime opportunity for planetary science. During the time period while traveling to interstellar space, flybys of planets and small bodies should be planned to maximize the science outcome of such a mission. To start, a gravity assist flyby of Jupiter is likely to be necessary. This provides a prime opportunity to study the magnetosphere and atmosphere of Jupiter as well as to image Jupiter's moons and evaluate interaction of the moons with Jupiter's magnetosphere. In particular, equipping the probe with techology best suited to search for and characterize plumes from Europa would be of extremely high value.

As many close and distant flybys of other planets as the spacecraft trajectory allows should also be planned. During distant flybys, imaging campaigns targeting surfaces and atmospheres would be of high value. Close flybys would allow in situ studies of atmospheric loss and solar wind interaction with these bodies. Finally, the New Horizons flyby of Pluto showed unexpected complexity in Pluto's surface processes, the distribution of volatiles on the surface, and atmospheric chemistry and loss. This has clearly demonstrated the importance of future flybys of objects in the Kuiper Belt (KBOs), particularly large KBOs that are known to have volatiles on the surface and may have atmospheres.

Finally, planetary science with an interstellar probe should not be limited to studies of the planets while traveling to interstellar space. Observations of planets in our solar system could also be used to advance understanding of exoplanets. Work has already begun looking at the Earth and other planets in our solar system from an exoplanet perspective to better understand how biomarkers can be detected remotely. An interstellar probe equipped with instruments that can observe transits of planets in front of our Sun from 200 AU at the spatial and spectral resolution of current and future exoplanet missions, could provide critical insights into how best to interpret observations made of exoplanet atmospheres.

PIR.1-0004-18 WHAT SHOULD AN INTERSTELLAR PROBE MEASURE?

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An Interstellar Probe is a genuine mission of exploration that sets its sight on our outer frontier, the uncharted territory beyond the boundary regions of our home, the heliosphere. It will discover and characterize, for the first time in-situ, the pristine interstellar medium that surrounds the solar system with all its constituent matter and fields, and, on its way, it will obtain a detailed radial profile of the complete boundary structures. Building on the Voyager Interstellar Mission and the Interstellar Boundary Explorer (IBEX), the probe must sample neutral atom, plasma particle, and field conditions from the outer heliosphere into the, thus far completely unexplored, pristine partially ionized interstellar plasma. Because the interstellar material presents a current sample of our galaxy in comparison with the 4.5 billion older sample of the solar system, both elemental and isotopic composition for elements at least up to Ne are key observables to address Big Bang cosmology and the evolution of galactic matter. Likewise, such a probe must sample the cosmic ray and dust distributions and composition, unaffected by modulation of the heliosphere. This mission will also present a unique opportunity to obtain the direction and strength of the interstellar magnetic field and to test locally the "great power law in the sky" of magnetic turbulence. Guided of the recent findings by IBEX and Voyager, it appears advisable to send an Interstellar Probe on a trajectory that leads through the pressure maximum (for plasma and magnetic field combined) and thus also through the likely source region of the IBEX Ribbon in the upwind direction. Such a trajectory promises the shortest distance to the key boundary structures and the pristine interstellar medium, allowing unique observations that address a number of open questions posed by Voyager and IBEX observations. An Interstellar Probe should be complemented by a global view through ENAs and UV with a mission similar to IBEX or IMAP, thus providing for a simultaneous tomographic view of the heliospheric boundary regions.

Panels (P)

Near-term Exploration of the Interstellar Medium (PIR.1)

PIR.1-0005-18 INTERSTELLAR PROBE OBSERVATIONS OF THE SOLAR SYSTEM'S DEBRIS DISKS

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Planetesimal belts and debris disks full of dust are known as the "signposts of planet formation" in exosystems. The overall brightness of a disk provides information on the amount of sourcing planetesimal material, while asymmetries in the shape of the disk can be used to search for perturbing planets.

The solar system is known to house two such belts, the Asteroid belt and the Kuiper Belt; and at least one debris cloud, the Zodiacal Cloud, sourced by planetisimal collisions and Kuiper Belt comet evaporative sublimation.

However these are poorly understood in toto because we live inside of them. E.g., while we know of the two planetesimal belt systems, it is not clear how much, if any, dust is produced from the Kuiper belt since the near-Sun comet contributions dominate near-Earth space. Understanding how much dust is produced in the Kuiper belt would give us a much better idea of the total number of bodies in the belt, especially the smallest ones, and their dynamical collisional state. Even for the close in Zodiacal cloud, questions remain concerning its overall shape and orientation with respect to the ecliptic and invariable planes of the solar system - they aren'texplainable from the perturbations caused by the known planets alone.

In this paper we explore the possibilities of using an Interstellar Explorer telescope placed at 1000 AU from the Sun to observe the brightness, shape, and extent of the solar system's debris disk(s). We should be able to measure the entire extent of the inner, near-earth zodiacal cloud; whether it connects smoothly into an outer cloud, or if there is a second outer cloud sourced by the Kuiper belt and isolated by the outer planets, as predicted by Stark Kuchner (2009, 2010) and Poppe et al. (2012, 2016). VISNIR imagery will inform about the dust cloud's density, while MIR cameras will provide thermal imaging photometry related to the cloud's dust particle size and composition. Observing at high phase angle by looking back towards the Sun from 1000 AU, we will be able to perform deep searches for the presence of rings and dust clouds around discrete sources, and thus we will be able to search for possible strong individual sources of the debris clouds - like the Haumea family collisional fragments, or the rings of the Centaur Chariklo, or dust emitted from spallation off the 6 known bodies of the Pluto system.

PIR.1-0006-18 WHAT CAN AN INTERSTELLAR PROBE TELL US ABOUT THE LISM?

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The only spacecraft which may reach the pristine interstellar medium (ISM) are the two Voyagers. They are launched in the late 70s and their instrumentation allows not to answer some questions of contemporary developments of heliophysics. Also modern spacecraft, like IBEX, give us some hints, in-situ observations are necessary to verify physical concepts. Especially, the state of the interstellar medium is required to understand the nature of the interaction between the solar wind and the ISM, e.g. the strength and direction of the magnetic field, the composition and state of the ISM are required to understand the structure of the heliosphere. Additionally of interest is the low energetic end of the cosmic ray flux which is not accessible inside the heliosphere, but is important to understand the transport on galactic scales. Another issue is to understand the composition and dynamics of interstellar dust particles, in order to get a better understanding of protostellar disks and the like.

I will address these questions, despite their accessibility by a possible interstellar mission.

PIR.1-0007-18 SCIENCE FOR AN INTERSTELLAR PROBE MISSION: WHAT WE NOW KNOW, AND WHAT WE NEED TO KNOW

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High among the scientific goals of an Interstellar Probe (ISP) mission should be a deeper quantitative understanding of the heliosheath (HS), the immense region between the heliospheric termination shock (TS) and the heliopause (HP) that marks the outward beginning of the interstellar plasma and magnetic field. For one thing, the astrospheres of stars similar to our Sun may well have similar heliosheaths. For another, the interstellar plasma and magnetic field just beyond our HP are disturbed by the activity of our Sun (Burlaga and Ness, ApJ, 2016). This doesn't mean that we can't study the IS plasma there; we just have to understand the solar disturbances. 2-3 kHz plasma waves measured on VGR1/2 (Gurnett et al., ApJ, 2015) detect electron plasma oscillations from local shock-associated electron beams and remotely sense distant shocks driven by the pressure pulses. Krimigis et al. (Science, 2009), immediately deduced from the first IBEX and Cassini/INCA energetic neutral atom (ENA) images that the pressure in the HS resides overwhelmingly in the non-thermal protons (1-13 keV) - as revealed by the surprising deficiency of thermal pressure after Voyager 2 (VGR2) crossed the TS (Richardson et al., Nature, 2008). A further inference was that the HP was shaped more like a "bubble" than a long-tailed "comet" or "magnetosphere". Since non-thermal pressure controls the configuration and dynamics of the HS, we cannot understand its effects on the local IS medium without a quantitative theoretical description. ENAs provide 2D images of a 3D object, so ambiguities in the line-of-sight (LOS) dimension must somehow be constrained. ISP will provide its own "ground truth" while it transits the HS, but after that we will have to rely upon theory/simulations to fill in the LOS-compressed 3rd dimension in our ENA images. Our present challenge, then, is to provide clear scientific information for the design for an ISP mission by combining the ENA images from IBEX, Cassini/INCA (and the upcoming IMAP)

all limited to an "inside-out" view - with all the in situ ground truth from the complete suite of operating instruments on VGR1/2 for the remainder of their lifetimes. However, in order to reliably understand plasma disturbances beyond the heliopause, we need a new quantitative theory that properly describes a heliosheath dominated by non-thermal pressure.

PIR.1-0008-18 'IT TAKES A VILLAGE.' THE CASE FOR COLLABORATIVE OUTER PLANET MISSIONS.

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A mission to one or both of our local Ice Giants (Uranus and Neptune) emerged as a high priority in the most recent Planetary Science Decadal Survey [1] and was also specifically mentioned supportively in the Heliophysics Decadal Survey [2]. In 2016, NASA convened a science definition team to study ice giant mission concepts in more detail [3]. Uranus and Neptune represent the last remaining planetary type in our Solar System to have a dedicated orbiting mission. The case for a Uranus mission has been made eloquently in the Decadal Surveys. Here we summarize some of the major drivers that lead to enthusiastic support for an Ice Giant mission in general, and use the example of a Uranus Mission concept to illustrate opportunities such a mission might provide for cross-division collaboration and cost-sharing. The Cassini spacecraft has been able to make unprecedented observations of the heliosheath during its tour of the Saturnian system, due to a fortuitous combination of the capabilities of its instrumentation and the vision of a small group of plasma physics experts who recognized the opportunity post launch [4]. Future missions might not include such a comprehensive instrument suite without deliberate prior planning. A mission to the outer solar system pro-vides numerous opportunities for cross-disciplinary science and collaboration, including, but not limited to: 1) Heliophysics. Studies of the heliosphere via inclusion of energetic neutral atom (ENA) imaging technology could be performed during cruise and, like Cassini, make observations of both planetary and heliospheric ENA emission during an orbital tour. 2) Exoplanets. Exoplanetary studies would certainly benefit from in situ study of Uranus and Neptune since the majority of exoplanets that have been discovered are also Ice Giants [e.g., 5]. Measurements at infrared to millimeter wavelengths of dust in the inner solar system, looking inward from the outer solar system, could also be compared with what is seen when looking at proto-planetary and planetary disks around other stars to help put observations of distant solar systems in context.

3) Interstellar Probe. It is conceivable to combine an Ice Giants mission with the long desired follow up to the two Voyager spacecraft in the form of an "Interstellar Probe" to investigate the structure of the furthest reaches of our solar system and its interaction with the interstellar medium [6]. In this scenario, Ice Giant or-biter(s) and probe(s) could be dropped off en route

to the interstellar medium. 4) Astrophysics. Instrumentation could be specifically designed to make useful long-wavelength radio observations of the cosmic microwave background during interplanetary cruise to an Ice Giant planet and then to perform deep sounding of the atmosphere and satellites of the Ice Giant itself. 5) Interagency collaboration. Other agencies (e.g., ESA, JAXA) are pursuing many of the same overarching goals [e.g., 7] and there is much that a combination of agencies could achieve that a single agency alone cannot. However, different timelines and mission development processes can hamper coordination. As an example of one strategy to foster collaboration, NASA missions of opportunity have helped US participation in missions being developed by other agencies. The 'directed good fortune' represented by NASA MoOs is an excellent model which we suggest can be more broadly applied. These examples highlight how cooperation across NASA Divisions and between space agencies furthers the specific goals the Planetary Science Division has identified for this workshop. Most strongly, the "Origins" theme is addressed, using observations of solar system planets and the Sun's magnetosphere to connect our mature solar system to young and forming exoplanetary systems. (Cosmological studies would also address "Origins" in the most inclusive sense.) And interagency collaborations can enhance or enable investigations in all the Workshop's themes, by either expanding the scientific payload possible compare to a NASA-only mission, or in the extreme by enabling a mission that would not be feasible for budgetary or other programmatic reasons. Future missions, including a long anticipated voyage to Uranus and Neptune should consider not just the directed mission, but also ways to make the most of other logistical and scientific opportunites along the way. In this presentation we will pro-vide examples of what has been achieved through both fortuitous and directed collaboration and suggest strategies to enable cross-division collaboration and cost-sharing to improve collaboration over the upcoming decades. References:
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PIR.1-0009-18 CODEX: DISCOVERING THE ORIGINS OF THE SOLAR SYSTEM

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CODEX will explore the interstellar space surrounding our solar system and investigate it dynamic interaction with the heliosphere. A steady wind of interstellar atoms and dust grains penetrates to within several AU of the Sun *the inner edge of the interstellar medium* where CODEX's instruments, several hundred times more sensitive than any previously flown, will analyze the composition of this unique sample of matter in detail. These observations will reveal the physical properties and nucleosynthetic status of the present-day galaxy, answering questions about the origin of our solar system, the stars, our galaxy, and the universe. The instruments on CODEX can also reveal the properties of other sources of pickup ions in the solar wind, and may be able to make detailed observations of the composition of comets. CODEX is a mission to the inner edge of the interstellar medium and is an indispensable precursor to humankind's inevitable exploration of interstellar space.

PIR.1-0010-18 AN OPPORTUNITY FOR ASTROPHYSICS FROM THE OUTER SOLAR SYSTEM

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The outer solar system is a unique, quiet vantage point from which to observe the universe around us. Astrophysical measurements from beyond 5 AU can enable several niche astrophysical science cases that are too difficult to perform from platforms near Earth, including building a detailed understanding of the cosmic extragalactic background throughout the electromagnetic spectrum, measurements of the properties of dust and ice in the outer solar system, searches for moons and other small, faint structures around exoplanets, determinations of the mass of planets far from their parent stars using gravitational microlensing, rapid follow-up of gravitational wave transient events, and fundamental physics. A future mission to the ISM offers a unique opportunity to impact all of these science cases in a profound way not available from platforms closer to Earth. Further, performing astrophysical measurements during a cruise phase of such a mission offers an opportunity to provide both high-impact science during the long quiescent periods en route to the ISM, as well as to maintain technical expertise over generations of scientists and engineers. In this talk, I will outline some of the science impacts such a mission could have, and discuss some options for realizing instruments and measurements that would be of interest in the next decade and beyond.

PIR.1-0011-18 WHAT THE VOYAGERS AND ENA HAVE TAUGHT US ABOUT THE NEARLOCAL INTERSTELLAR MEDIUM (LISM)

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In situ measurements by the two Voyagers over the past 14 years have revealed the presence of the long-predicted termination shock (TS) and heliopause (HP), albeit not where theory had placed them. Further, the advent of energetic neutral atom (ENA) imaging by Cassini/INCA since 2003 and IBEX since 2009 have provided images of the global heliosphere that have challenged our long-held views of its shape and the processes that are dominant in its formation (Krimigis et al, and McComas et al, 2009; Dialynas et al, 2017). In addition, continuing measurements from Voyager 1 beyond the HP, currently at 141.2 AU (1 AU=1.5x108 km, the Sun-Earth distance), have shown that the influence of solar activity extends well beyond the HP (at 121.6 AU), 20 AU into the LISM. This influence is manifested through the frequent appearance of anisotropies in the galactic cosmic rays (GCR) where none were predicted, that last as long as a year and are accompanied by electron plasma oscillations in the vicinity of the spacecraft. Further, Voyager 2 traversing the region south of the ecliptic, currently at 116.7 AU is still within the HS. Thus, an ISP mission with a fast (20 AU per year compared to Voyager's 3.62 AU/year) trajectory would traverse a dynamic region near and beyond the TS and HP, and enable imaging the shape of an apparently asymmetric (HS width 27 AU at V1, but > 33 AU at V2) heliosphere from beyond its boundaries through ENA. Further, it would monitor the influence of solar activity in the LISM and determine both, its shape and variability. In situ measurements should include the ISM magnetic field (ISMF), plasma density and distribution function, plasma waves, and neutral atom density and composition, as a minimum. All of these measurements would be new information with modern instrumentation that would place the very limited Voyager measurements into the proper context.

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PIR.1-0012-18 THE COMPELLING SCIENCE DISCOVERIES ENABLED BY THE INTERSTELLAR PROBE, PERFORMANCE REQUIREMENTS AND CRITICAL RESOURCE CONSTRAINTS

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Venturing on to an escape trajectory beyond the solar system offers science discoveries of different proportions that will naturally bridge planetary, helioand astrophysical disciplines by putting our solar system and heliosphere in the context of the increasing number of other exoplanetary systems and astrospheres detected. Science discoveries enabled by an Interstellar Probe include new understanding of the global structure of our heliosphere and its interaction with the Local Interstellar Medium (LISM), observations of the circum-solar dust disk providing insights in to planetary formation processes, discoveries of unexplored Kuiper Belt Objects such as Quaoar, transit observations of solar-system planetary atmospheres to provide standard candles to aide in the interpretation of exoplanetary observations, and possibly the first flyby observations of the hypothetical Planet Nine.

The first explicit Interstellar Probe will target up to 1000 AU distance from the Sun, which requires asymptotic speeds in excess of 10 AU/year. Two mission scenarios are studied enabled by the SLS Block 1B, assuming a New Horizons-like spacecraft: Direct inject to Jupiter followed by a passive Jupiter Gravity Assist (JGA), or a reverse JGA followed by an Oberth Maneuver close to the Sun requiring a heat shield, building on the flight experience of the Parker Solar Probe heat shield. Assuming a flown payload-to-spacecraft-mass fractions, the allowable payload mass is about 50 kg (including 30% reserve). Similarly, power supplied by a generalpurpose Radioisotope Thermoelectric Generator leaves about 50 W for a science payload. This illuminates the criticality of light-weight, low-power, compact instruments and innovative, yet reliable payload solutions.

A historical overview of the payload mass and power of past and current missions is given to guide further trade-off studies in resources and science return. Updates are presented on the compelling science targets of an Interstellar Probe, and on current mission trade-off studies that drive the high-level science requirements and define the choice of science payload. Resource requirements are summarized and anticipated characteristics of the science targets coupled with the mission performance are used to derive basic performance requirements.

PIR.1-0013-18 SIMULATIONS OF THE GLOBAL HELIOSPHERE IN PREPARATION OF AN INTERSTELLAR PROBE

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Current state of art in the modeling of the global heliosphere will be reviewed. The structure of the global heliosphre is determined by the interaction of the solar wind (SW) with local interstellar medium (LISM). The interaction models take into account multi-component nature of both LISM and SW, heliospheric and interstellar magnetic fields, time and latitudinal variations of the solar wind, etc. We will explore outstanding open questions that could be solved by Interstellar Probe in the light of recent spectacular results obtained by Voyager and IBEX spacecraft.

PIR.1-0014-18 PLANET NINE FROM OUTER SPACE

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At the outskirts of the solar system, beyond the orbit of Neptune, lies an expansive field of icy debris known as the Kuiper belt. The orbits of the individual asteroid-like bodies within the Kuiper belt trace out highly elongated elliptical paths, and require hundreds to thousands of years to complete a single revolution around the Sun. Although the majority of the Kuiper belt's dynamical structure can be understood within the framework of the known eight-planet solar system, bodies with orbital periods longer than about 4,000 years exhibit a peculiar orbital alignment that eludes explanation. What sculpts this alignment and how is it preserved? In this talk, I will argue that the observed clustering of Kuiper belt orbits can be maintained by a distant, eccentric, Neptune-like planet, whose orbit lies in approximately the same plane as those of the distant Kuiper belt objects, but is anti-aligned with respect to those of the small bodies. In addition to accounting for the observed grouping of orbits, the existence of such a planet naturally explains other, seemingly unrelated dynamical features of the solar system.

PIR.1-0015-18 SHOCK WAVES IN THE VERY LOCAL INTERSTELLAR MEDIUM

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Voyager 1 has made in situ measurements of the very local interstellar medium (VLISM) since August 2012 and its magnetometer has detected several shock waves in the VLISM. Interplanetary shocks propagate through the supersonic solar wind and then through the inner heliosheath after colliding with the heliospheric termination shock (HTS). Interplanetary shock waves can be transmitted through the inner heliosheath and then across the heliopause (HP) into the VLISM. The first in situ VLISM shock observed by Voyager 1 was remarkably broad and had properties different than shocks inside the heliosphere (Burlaga et al. (2013)). We present a model of the 2012 VLISM shock, which was observed to be a weak, quasi-perpendicular, low magnetosonic Mach number, low beta, and subcritical shock. Although the heliosphere is a collisionless environment, we use the Chandrasekhar function and show that the VLISM is collisional with respect to the thermal plasma since the electron and proton collisional mean free paths are relatively small. The thermal collisions introduce dissipation terms such as heat conduction and viscosity into the system. We show that the VLISM shock is determined by thermal proton-proton collisions, which is the dominant thermal collisional term. VLISM pickup ions (PUIs) that are generated by secondary charge exchange do not introduce a significant pressure nor dissipation through the shock transition meaning the VLISM shock is not mediated by PUIs but by the magnetic field and thermal gas only. Weak VLISM shocks are not controlled by wave-particle interactions and therefore are controlled by thermal particle collisions. As a result, we find that the weak VLISM shock is very broad with a thickness of about 0.12 AU, corresponding to the characteristic thermal heat conduction scale length.

PIR.1-0016-18 THE ASTROSPHERE AND MASS-LOSS RATIO OF PROXIMA CENTAURI

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Our understanding about the heliosphere dramatically evolved from the results from Voyager, Cassini and Interstellar Boundary Explorer (IBEX). With the rapid discovery of exoplanets in other stellar systems it is important to understand how this new acquired knowledge affects the astrospheres around other stars. In particular, recently the shape of the Heliosphere is being challenged by theoretical and observation work (Opher et al. 2015; Diyalinas et al. 2017). The nearest star to the Sun, Proxima Centauri, is particularly interesting as it was recently discovered to host an Earth-size planet in its "habitable zone", Proxima b. Here we investigate the astrosphere around Proxima Centauri. As the star moves through the surrounding partially-ionized medium, neutral hydrogen atoms penetrate the astrospheres and through charge-exchange with the supersonic stellar wind creating a population of hot pick-up ions (PUIs). We present global magnetohydrodynamic simulations that treats the PUIs as a separate fluid. Most global models treat the PUI and thermal component as a single fluid. Planetary atmospheres are affected by particle fluxes from their host stars. The only means by which coronal winds of Sun-like stars have ever been probed is by the circumstellar H Lyman-alpha absorption fin the interaction region between the wind and the interstellar medium, namely the "astrospheres". The Lyman-alpha constrains on the stellar wind based on Hubble Space Telescope measurements rely on prior hydrodynamical models. Here we revisit the constraints on the mass-loss of Proxima Centauri (Wood et al. 2011) with improved theoretical predictions and discuss the implications for Space Weather effects on Proxima b.

PIR.1-0017-18 JOHNSON THERMO-ELECTROCHEMICAL CONVERTER (JTEC), AN INNOVATIVE POWER SOURCE FOR FUTURE SPACE MISSIONS

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Long-duration missions deep into the interstellar medium face a unique challenge when it comes to energy storage and power generation. Unfortunately, over the past five decades, the thermoelectric converter technology used in existing Radioisotope Thermoelectric Generators convert heat into electricity has only achieved a net efficiency of less than 10%. More critically, the performance degradation over time of systems such as the MMRTG may limit operations in the long decades after such a mission has left the solar system. Furthermore, alternative mechanical power conversion techniques, though higher in conversion efficiency, may be difficult to qualify for reliable operations for a 50-year mission. The Johnson Thermo-Electrochemical Converter (JTEC) is an emerging technology that may address both lifetime and efficiency issues.

The JTEC is a high efficiency, solid state, direct heat to electric converter that is projected to achieve over 40% conversion efficiency. It represents a game changing approach to platform energy conversion and system thermal management. This is a versatile technology that can operate in reverse as a heat pump for refrigeration or as a fully distributed electrical and thermal energy management system. It can be integrated into complex host spacecraft configured as distributed nodes that effectively supply and remove heat to and from various subsystems while converting excess heat into electrical power.

The JTEC operates on the Ericsson Thermodynamic cycle. In contrast to less efficient Brayton and Rankine thermodynamic cycles, the ideal Ericsson cycle is Carnot equivalent in conversion efficiency. The JTEC uses hydrogen as a working fluid and electrochemical Membrane Electrode Assembly (MEA) cells to perform the required heat engine gas compression and expansion processes.

PIR.1-0018-18 A COMPACT ION AND NEUTRAL GAS MASS SPECTROMETER FOR THE FUTURE INTERSTELLAR PROBE MISSION

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A future interstellar mission provides an excellent opportunity for the in-situ measurement of the local interstellar medium, undisturbed by the Sun's gravity and radiation. This presentation models first the expected signal for assumed local interstellar medium properties of: 26km/sec bulk flow speed, 7000K temperature and 0.01 /cm3density, andthenoiseexpectedf romtheU V blacksky, the

PIR.1-0019-18 MISSION CONCEPT FOR DIRECT MULTIPIXEL IMAGING AND SPECTROSCOPY OF EXOPLANETS USING THE SOLAR GRAVITY LENS

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Delivering a moderately sized optical telescope to the Solar Gravity Lens (550 AU from the Sun) enables direct, multipixel (megapixel) imaging and high-resolution spectroscopy of a habitable Earth-like exoplanet situated up to 100 light years. It is possible to achieve an amazing, kilometer-scale resolution on its surface, enough resolve surface features and signs of habitability. While exciting, this opportunity presents immense engineering challenges both from an instrument development and mission, spacecraft design perspective.

In this paper we deal with the later issue and propose a mission, spacecraft concept, relying on near-term technologies, capable of delivering a moderately sized optical instrument to the SGL in less than 50 years from launch. Building upon various previous studies (from JPL, APL, KISS, NASA Innovative Advanced Concepts), the mission design relies on a Solar-Thermal Propulsion (STP) based kick stage, used deep in the gravity well of the Sun, allowing the SGL probe to achieve escape velocities in excess of 20 AU/Yr. In comparison the escape velocity of Voyager 1 is approximately 3.7 AU/Yr. To achieve large Delta-Vs at the perihelion, the STP engine concept utilizes heat from proximity to the Sun to heat up the Hydrogen (at 3400k) and expel it at high velocity, delivering an ISP of 1200-1350s. The probe, as designed with help JPL's Team-X, is a RTG based probe with 50 kg of Instruments (mainly the Optical Telescope), totaling to a wet mass of 600 kg. The optical telescope is also used as optical communications terminal for downlinking data to Earth from the SGL.

Given the early nature of this study, sensitivity analysis are performed, showing escape velocity contours vs. spacecraft mass, time of flight, launch year and launch vehicle types. Mission trajectories using other more advanced propulsion technologies like Nuclear Electric Propulsion (NEP) are also evaluated and compared to the above STP based baseline. Finally, impact of various space and time constraints from specific SGL exoplanet target, on mission design and mission concept of operations, are also discussed.

PIR.1-0020-18 THERMAL PLASMA MEASUREMENT REQUIREMENTS FOR INTERSTELLAR PROBE.

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An Interstellar Probe mission represents a natural, and long awaited, follow up to the Voyagers. In situ measurements from the Voyager spacecraft have provided vital information on our solar system plasma and beyond, while remote measurements, such as by IBEX and Cassini-INCA, provide maps of the edge of our solar system providing a tantalizing glimpse of the complex plasma environment in the interstellar medium. We will discuss what these observations tell us about the plasma environment and the implications of this to the plasma instrumentation required for such a mission. Relatively few missions have probed the distant Solar System, much less exceeded it. The earliest measurements of solar wind variation were made by the Mariner 10 spacecraft from 1973-1975. Mariner 10 pioneered the gravity assist manoeuvre to facilitate flybys of Mercury and Venus and en-route made measurements of solar wind plasma between 0.45 and 0.85 AU (one astronomical unit, AU, is 1.5x108 km). Results showed a decrease in the solar wind core (thermal) electron temperature (Te) with radial distance from the Sun as Te R-0.3 ± 0.08 [Ogilvie and Scudder, 1978]. A similar radial relationship, with Te R-0.34

± 0.16, was found by Sittler et al. [1981] reporting on solar wind data collected by Voyager 2 between 1.36 and 2.25 AU. By combining the Mariner 10 and Voyager 2 plasma analyser data sets from 0.45 to 4.76 AU, Sittler and Scudder [1980] found a similar polytropic relationship with Te R-0.37. One of the first studies to differentiate between 'types' of solar wind was by Feldman et al. [1979]. They found a relatively steep decrease in electron temperature in high-speed solar wind streams between 0.47 with 0.62 AU with a power law dependence of Te R-1.14. In the same study Feldman et al. found, perhaps surprisingly, that the high-speed solar wind actually gets hotter between 0.62 and 1.00 AU, with core electron temperature increasing as R+0.28. One of the studies covering the most vast distances was made by Richardson et al. [1995]. Using IMP 8 and Voyager 2 data, at 1 and 40 AU respectively, they report Te decreasing as R-0.49 ± 0.01. McComas et al. [1992] showed that the best fit power law for the core temperature, derived from Ulysses data from 1.15 to 3.76 AU, is R-0.7 and that the core electron density drops with increasing radial distance as R-2 as expected for constant velocity spherical expansion. This was also reported to be the case by Bougeret et al. [1992] for proton density between 0.3 and 1 AU based on Helios 1 and 2 data between 0.3 and 1 AU. Gazis and Lazarus [1982] reported that Te obeyed the same power law of R-0.7, this result was found using Voyager 1 and 2 data between 1 and 10 AU. Pillip et al. [1990] reported observations just prior to solar minimum with Helios 1 and (primarily) Helios 2, covering the distance range 0.3 to 1 AU, indicated varying power laws with values between R-0.3 and R-1.4. The Pillip et al. study separated observations 'roughly between four types of solar wind structure'. Previous work had not differentiated between low speed streams/sector boundaries or compression regions. The Pillip et al. result for high-speed streams, with the solar wind temperature increasing with distance, is almost the same as that found between 0.62 and 1.00 AU by Feldman et al. [1978b]. Despite four decades of study, theoretical models do not quantitatively describe the observed radial profile of solar wind electron temperature. As part of a one-fluid model of the solar wind Parker [1963] described a steady state expansion of thermally driven electron-proton plasma flowing out of the hot solar corona with Te R-0.28. Two-fluid models have also been used to take into account the different electron and ion temperatures and bulk velocities observed at 1 AU in the solar wind [Sturrock Hartle, 1966; Hartle Sturrock, 1968; Cuperman Harten, 1970, 1971; Hartle Barnes, 1970; Wolff et al., 1971]. In general these models find similar results, with a temperature fall off with distance between R-0.2 and R-0.3, depending on proton thermal conductivity and energy exchange rate. For adiabatic cooling we expect a reduction of Te as R-1.3. While if we expect the solar wind to behave as an isothermal gas the temperature would show no dependence on R, which Hoang et al. [1992] show to be the case from 1 to 4 AU based on observations by the Ulysses unified radio and plasma receiver (URAP). Any missions to the outer planets or beyond will provide invaluable additions to our current state of knowledge, providing the measurements are sufficiently comprehensive.

PIR.1-0021-18 THE PREDICTION OF PARTICLE BOMBARDMENT INTERACTION PHYSICS DUE TO IONS, ELECTRONS AND DUST IN THE INTERSTELLAR MEDIUM ON A GRAM-SCALE INTERSTELLAR PROBE

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The Breakthrough Starshot initiative proposes to send a Gram-scale laser driven spacecraft to the Alpha Centauri system in a 20 year mission travelling at v 0.2c. One of the challenges of this mission as the spacecraft moves through the interstellar medium is the presence of dust and gas (mostly hydrogen). The dust has a typical matter-density of 2.57×1027gcm−3 with typical particle mass being 3×10−13g although some of the largest particles may be 5×10−9g in mass. These dust particle will deposit 1012-1016 MeV onto the spacecraft with an energy flux of order 0.3Js−1m−2. We consider the erosion of the spacecraft frontal area due to dust and also heating effects as well as charged particle penetration due to ions and electrons for which at the Project Starshot cruise speeds charged particle collisions can result in a collision energy as high as 75 MeV for the non-metals (hydrogen and helium) and as high as 300 MeV for the metals (Carbon and Oxygen). In this paper, we attempt to characterize the likely environment for the starshot mission and estimate the particle bombardment shielding requirements in terms of mass and thickness of material. We also examine the penetration effects and stopping power of the various bombarding particles and consider the implications for the success of the starshot mission. Current analysis estimates that the likely erosion rates are of order 10−10-10−11gs−1 and that the frontal area temperatures are in the range 200-400

K depending on the ratio of frontal area to radiating area in the range Ao/A 1-100. For an assumed shielding material with atomic number range 3- 13 (Lithium to Aluminium), this would suggest a shielding thickness of 1-3 mm, with a mass in the range 0.01-0.2; depending on the material choice. The aim of this work is to keep the shielding mass down to less than 5% of the total Gram-scale vehicle mass. The work presented highlights the close coupling in the Project Starshot spacecraft design between the chosen vehicle geometry and the particle bombardment requirements.

PIR.1-0022-18 ENABLING A SOLAR SYSTEM ESCAPE MISSION VIA THE NASA SPACE LAUNCH SYSTEM

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Extending the reach of mankind well beyond our local solar system has been a very appealing dream and goal, to realized only by the significant advancements of technology, that was well beyond our capabilities until now. The act of sending a deep space probe beyond our local solar system has been explored and studied for decades. Unfortunately, to explore and reap the scientific benefits by the generation that launched the deep space probe, the extremely long flight times would thus, leave these scientific rewards, to our children or their children. To date, every solution proposed required significant, multi-decade, sustained investments in advancing technology that defied logical applications of the terrestrial societies financial and scientific and engineering resources, until now. The development of the heavy lift capacity Space Launch System and the critically important and efficient, exploration upper stage enables exploration of space well outside our local solar system with more realistically appealing flight times that would allow the mission scientists, to reap the rewards of exploration. This paper will demonstrate that, coupling the capabilities of SLS to current existing rocket propulsion stage systems, one can leverage the New Horizons and Solar Probe Plus engineering and integration experiences, where a small capable science probe, coupled with a clever mission design trajectory, can achieve launch energies (C3) on the order of 200-350 km^2/sec^2 can then reduce flight times to a goal of 200 Au in 23-30 years. The SLS system overview and capabilities will be presented. Several vehicle configuration engineering and orbit performance capability studies performed will be presented along with the candidate Spacecraft payload as the results of these studies performed will be provided. Additionally, a conceptual system development timeline will be presented that will close the case being made that exploration outside of our current solar system is achievable today when coupled to the capabilities currently under development by the SLS system.

PIR.1-0023-18 DIRECT MULTIPIXEL IMAGING OF AN EXO-EARTH WITH A MISSION TO THE SOLAR GRAVITATIONAL LENS

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We discuss our recent study of a mission to the regions outside our solar system, with the objective of conducting direct high-resolution imaging and spectroscopy of a habitable exoplanet by exploiting optical properties of the solar gravitational lens (SGL). A mission to the focal area of the SGL (which lies beyond 548.7 astronomical unites (AU) on the line connecting the center of the exoplanet and that of our Sun, called the focal line of the SGL) carrying a modest telescope and coronagraph could deliver direct megapixel imaging and high-resolution spectroscopy of a habitable Earth-like exoplanet orbiting a host star at a distance of up to 30 parsec.

The remarkable optical properties of the SGL include major brightness amplification (1e11 at a wavelength of 1 um) and extreme angular resolution (1e10 arcsec) in a narrow field of view. The entire image of such an exo-Earth is compressed by the SGL into an instantaneous cylinder with a diameter of 1.3 km in the vicinity of the focal line. Moving outwards while staying within the image, the telescope will take photometric data of the Einstein ring around the Sun formed by the light from the exoplanet and will process the data to reconstruct the image of the exoplanet with a few km-scale resolution of its surface, enough to see its surface features and signs of habitability.

Recently, we evaluated the feasibility of the SGL-based technique for direct imaging and spectroscopy of an exoplanet and, while several practical constraints have been identified, we have not identified any fundamental limitations. We determined that the foundational technology already exists and has high TRL in space missions and applications. Furthermore, the measurements required to demonstrate the feasibility of remote sensing with the SGL are complementary to rotational tomography measurements and ongoing microlensing investigations, so our effort would provide high-value scientific information to other active astrophysics programs.

PIR.1-0024-18 HELIOPAUSE ELECTROSTATIC RAPID TRANSIT SYSTEM (HERTS)

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The Electrostatic Sail (E-Sail) is a new propulsion technology that uses the solar wind to produce thrust without the use of propellant, enabling low-cost, rapid trip times (10 years) to the edge of the solar system previously considered impossible. The E-Sail uses the momentum of solar wind ions for spacecraft propulsion with the help of long, positively charged wire(s). The system produces a thrust vector radially outward from the Sun, but which can be turned at will up to 30° angle and whose magnitude can be easily adjusted.

The E-Sail design is a novel approach to solar propulsion. The thrust produced by an E-sail declines at a rate of 1/r (where r is the solar distance) and can provide useful thrust out to distances of 30 Astronomical Units (AU). Unlike other propellantless concepts such as solar photon sails, the electric sail does not rely on a fixed area to produce thrust. In fact, as the electric sail moves away from the sun, the Debye sheath dynamically changes, allowing the positive electric field to grow, increasing the apparent area of the virtual sail as the solar wind plasma density decreases.

Studies performed at the NASA George C. Marshall Space Flight Center show that an E-Sail mission to the heliopause can be accomplished in less than 10 years, a feat Voyager 2 took 35 years to accomplish. E-Sail propulsion exceeds the 2012 Heliophysics Decadal Survey speed goal of 3.8 AU per year. Put in more human terms, the E-Sail technology will bring the time frame of heliopause (and beyond) missions to well within a person's career. Most of the subsystem technologies required to field an Electric Sail are at Technology Readiness Levels (TRL) greater than 4, with several having been previously space-qualified.

PIR.1-0025-18 DIRECTED ENERGY PROPULSION FOR RAPID INTERPLANETARY MISSIONS

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All propulsion systems that leave the Earth are based on chemical reactions. Chemical reactions, at best, have an efficiency compared to rest mass of 10^{-10} (or about 1eV per bond). All the mass in the universe converted to chemical reactions would not propel even a single proton to relativistic speeds. While chemistry will get us to Mars it will not allow extremely rapid interplanetary mission nor ever allow interstellar capability in any reasonable mission time. However, recent advances in photonics and directed energy systems now allow us to realize extremely high speed missions using either direct photon propulsion or beamed power to ultra high Isp ion engines. The choice of the two modes depends on the specific mission requirement. It is the only known technology, besides matter-antimatter annihilation propulsion that is capable of relativistic flight. Photonics, like electronics, and unlike chemical and nuclear propulsion is an exponential technology with a current double time of about 20 months. The cost of such a system is amortized over the essentially unlimited number of launches and applications. In addition, the same photon driver can be used for many other purposes including planetary defense, space debris mitigation, standoff molecular composition analysis, solar system LIDAR, long range power beaming among others. This program has also spun off three additional NIAC programs using this core technology. This technology would be a profound change in human capability with enormous implications from very small to large spacecraft. Known as NASA Starlight, we are now in the third year of funding including a current NASA Phase II program. In addition to NASA and congressional support we have private sector support including the Breakthrough Foundation with a pledged 100M\$ Research and Development program to explore the fundamental technology involved (Starshot). The FY 2017 congressional appropriations request directs NASA to study the feasibility of an interstellar mission to coincide with the 100th anniversary of the moon landing quoting our NASA program as an option. We will discuss the many technical challenges ahead, our current laboratory prototypes and recent data on kilometer baseline arrays as well as the transformative implications of this program.

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For technical information on this program and 50 technical papers see our website: http://www.deepspace.u http://arxiv.org/abs/1604.01356

PIR.1-0026-18 PROTON SPECTRAL RADIATION ENVIRONMENT OF THE OUTER HELIOSPHERE AND LOCAL INTERSTELLAR MEDIUM

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Proton flux measurements at plasma to cosmic ray energies from the Voyager 1-2, Interstellar Background Explorer (IBEX), and Cassini spacecraft each provide partial basis for development of time-averaged flux models with applications to dynamics of particle acceleration, pressure balance at the heliopause and space weathering of extreme Kuiper Belt, Oort Cloud, and interstellar (e.g., 1I'Oumuamua) objects. Each spacecraft presently covers a unique range of space and energy with Voyager 1 reported to be in the local interstellar medium, Voyager 2 still in the heliosheath, and with IBEX and Cassini (through Sept. 2017 end of mission) remotely measuring energetic neutral atoms (ENAs) from some combination of heliosheath and local interstellar sources. Voyager 2 provides the only in-situ measurements of plasma, suprathermal, and higher energy proton distributions in the heliosheath, while IBEX and Cassini indirectly provide measurements of the suprathermal proton flux spectra from models for the ENA sources. Voyager 1 provides the only direct measurements of proton and heavier ion fluxes beyond the heliopause at few MeV and higher energies, while lower energy fluxes are respectively precluded at plasma and suprathermal energies by an inoperative sensor and penetrating cosmic ray background. The so-called secondary-ENA IBEX source beyond the heliopause in the very local interstellar medium could include a mixture of ENAs from charge-exchange interactions of heliospheric and interstellar suprathermal ions, although solar cycle dependence suggests a dominance of the heliospheric source. It has been suggested that remote observations of interstellar molecular cloud ionization rates limit the suprathermal flux spectrum, but sub-MeV ions would not penetrate into such clouds and would more likely arise internally as pickup ions in stellar wind flows within the clouds. Current limits on pressure balance at the heliopause do not preclude a substantial suprathermal component from the local interstellar environment. Future Voyager-2 measurements beyond the heliopause will directly sample the plasma environment but suprathermal fluxes would still be hidden beneath penetrating background and could only be measured by a future interstellar probe. We use moment and flux distribution data from the spacecraft sources, as available from the NASA Space Physics Data Facility (SPDF), the

NASA Virtual Energetic Particle Observatory (VEPO), and instrument team publications, to compile time-averaged data models for the proton flux spectra in the heliosheath and in the local interstellar medium. These models are then applied to sample calculations of total proton pressures, re balance at the heliopause, and of space weathering parameters for radiolysis and sputtering on more distant icy bodies of the Kuiper Belt and Oort Cloud.

PIR.1-0027-18 LOOKING BACK AT OUR HELIOSPHERE IN ENA

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Energetic Neutral Atoms (ENAs) have been used over the past several decades to image space plasmas in planetary magnetospheres as well as the structure of the heliosheath. ENA measurements of the heliosphere have (obviously) all been taken from vantage points in the inner heliosphere which is a useful perspective. ENAs created in the inner heliosphere from the solar wind generally have an outward velocity, and thus do not reach sensors closer to the sun. Thus, solar wind plasma is only 'visible' in ENAs to an inner heliosphere observer after it reaches the termination shock, where it's outward motion is slowed and it is heated. This allows us to study the outer heliosphere with ENAs with limited background signal from the inner heliosphere. This perspective from the inside looking out is convenient to study the outer boundary of the heliophere, but contains no direct information about the plasma and processes occurring in the inner heliosphere. Further, since these are integrated line of sight measurements, the overall shape of the heliosphere is difficult to untangle from intensity variations/acceleration processes. ENA sensors placed outside the heliosphere, conversely, would allow us to remotely sense both the inner and outer heliosphere, allowing us full access to the evolution of the solar wind as it travels from the sun outward. Further, such a perspective would allow us to more directly measure the boundaries of the heliosphere with the LISM without the obscuration of the inner heliosheath. In this paper, we present modeled views of ENA images from the outside looking in, at a distances of 250 AU, highlighting both the added information about inner heliospheric processes and the boundary interactions with the LISM. From the images presented at different energies, we see that varios aspects of the heliosphere can be studied, including the overall shape, accelleration processes and pick up ion proceses in the inner heliosphere.

PIR.1-0028-18 THE COMPACT DUAL ION COMPOSITION EXPERIMENT (CODICE) FOR THE INTERSTELLAR PROBE MISSION

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We have developed a new, versatile, fully integrated Compact Dual Ion Composition Experiment - CoDICE - that simultaneously provides high quality solar wind plasma, pickup, and energetic ion composition measurements over six decades in ion energy in a wide variety of space plasma environments, including the solar wind, inner and outer heliosheaths, as well as the local interstellar medium. CoDICE measures three critical ion populations namely: Elemental, isotopic, and charge state composition, and 3D velocity distributions of 10 eV/q-80 keV/q (1) plasma and (2) pickup ions, and Elemental and isotopic composition, and energy spectra and angular distributions of 30 keV-10 MeV/nucleon (3) energetic ions. CoDICE uses a common time-of-flight subsystem that requires significantly less mass and volume compared with two or three separate instruments, provides directionally-validated double and triple coincidence measurements and therefore excellent signal-to-noise ratios, and simplifies spacecraft interfaces and accommodation requirements for the Interstellar Probe Mission. This paper describes the design principles, ray tracing simulations, laboratory prototype testing, and proof-of-concept validation of the CoDICE concept, as adapted for measuring the solar wind plasma, pickup, and energetic ion populations expected to be present in the heliosphere en route to the termination shock and in the interstellar medium.

PIR.1-0029-18 MECHANICAL CONSIDERATIONS FOR INTERSTELLAR PROBE

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Mechanical considerations for Interstellar Probe Interstellar Probe, a mission to the 200-1000 AU region, could be made possible by leveraging APL's experience with several enabling technologies. Those technologies are heat shield technology similar to that employed by Parker Solar Probe (PSP), RTG technology like that employed on New Horizons and miniaturization of space vehicles similar to MBD. Implementing heat shield technology will be key to mission implementation. Accelerating the space vehicle using a gravity assist from the sun is necessary to achieve the speeds to reach the desired region of space in a reasonable amount of time. To achieve those speeds the vehicle will need to pass much closer to the sun than PSP. We will look at innovative ways to implement the PSP shield technology. Combinations of shield thickness, spacing and configuration should be examined. Shielding material should be reexamined to see if more advanced materials are available than those used on PSP. The material used on PSP, while effective for blocking heat, is lacking in mechanical strength. If a suitable, stronger material were available is would make shield stacks easier to implement. A cylindrical shield will also be examined to determine whether or not a spin stabilized vehicle could be used. Since solar arrays are not practical in the desired region an RTG or similar RPS will be required. During the design, integration and test of New Horizons a lot was learned. We will leverage what we learned so any design suggested can handle the heat of an RPS. Since an RPS can't be installed until late in IT, typically on the pad, lessons learned on New Horizons will help here as well. Any design will be scrutinized for late access for RPS installation. Access for personnel, integration fixtures, etc. will be considered. In any design suggested the minimization of the space craft size and mass it crucial. The smaller the space craft the smaller the shield required for the close approach to the sun. Less mass would also mean more energy delivered by the launch vehicle, reducing travel time. While a cube satellite like MBD is insufficient to perform the science mission the technology could be used to reduce size and mass. MBD was essentially a flying electronics box. Similar technologies should be looked at for interstellar probe. Reducing box to box harness, reducing box walls where possible, combining box functions are all ways to reduce size and weight. Flexible printed wiring assemblies should be considered for use as another method of reducing size and mass. Smaller payloads require smaller sun shield for close approach so the advantages of cube sat similar technologies are obvious. Mechanical considerations for Interstellar Probe Interstellar Probe, a mission to the 200-1000 AU region, could be made possible by leveraging APL's experience with several enabling technologies. Those technologies are heat shield technology similar to that employed by Parker Solar Probe (PSP), RTG technology like that employed on New Horizons and miniaturization of space vehicles similar to MBD. Implementing heat shield technology will be key to mission implementation. Accelerating the space vehicle using a gravity assist from the sun is necessary to achieve the speeds to reach the desired region of space in a reasonable amount of time. To achieve those speeds the vehicle will need to pass much closer to the sun than PSP. We will look at innovative ways to implement the PSP shield technology. Combinations of shield thickness, spacing and configuration should be examined. Shielding material should be reexamined to see if more advanced materials are available than those used on PSP. The material used on PSP, while effective for blocking heat, is lacking in mechanical strength. If a suitable, stronger material were available is would make shield stacks easier to implement. 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PIR.1-0030-18 ENERGETIC NEUTRAL ATOM (ENA) AND ENERGETIC PARTICLE OBSERVATIONS FROM AN INTERSTELLAR PROBE

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Recent observations from the Interstellar Boundary Explorer (IBEX) and Cassini have revealed the interaction of our heliosphere with the very local interstellar medium (VLISM). This complex interaction has several features that appear unique to the specific configuration of the heliosphere with respect to the VLISM such as the narrow "ribbon" of enhanced ENAs below about 6 keV and the wider "belt" of ENA emissions above 6 keV. In-situ observations from the Voyager Interstellar Mission (VIM) have also shown a region of space where the pressure is dominated by pickup ions. These observations call for further investigation to understand the interaction of our Sun with the VLISM using the next generation of measurements. Here we describe the scientific contributions gained from a combination energetic neutral atom (ENA) imager and energetic particle spectrometer on an in-situ platform destined for several hundred AU. Specifically we detail remote and in-situ measurements that will advance our understanding of pickup ions and the interaction of the Sun with the VLISM inside of the termination shock, during transit of the heliosheath, and finally from a perspective outside of our heliosphere.

PIR.1-0031-18 AN ENERGETIC AND SUPRATHERMAL PARTICLE INSTRUMENT FOR AN INTERSTELLAR MISSION

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Understanding the physical processes in both the solar system interplanetary environment and the interstellar medium will be one of the major objectives for an eventual Interstellar Probe (ISP) mission. As shown by the Voyager measurements, the non-thermal ions have key roles in mediating dynamical processes at the termination shock and in the heliosheath, the interface between the solar system and Very Local Interstellar Medium (VLISM). In the 1999 NASA Interstellar Probe Science and Technology Definition Team (IPSTDT) report, a capable energetic particle spectrometer is required to measure the non-thermal ions and electrons to characterize the influence of the interstellar medium on pickup ions, anomalous cosmic ray, and galactic cosmic ray particles. In particular such instrument should able to make energy, composition, directional measurements from above the solar wind plasma energy to several MeV/nucleon. These are the minimum measurement requirements to properly characterize the source and acceleration mechanism of the particle population. In the past, this type of in- situ particle observation has been obtained on platforms that could provide ample instrument resources such as mass, power, and telemetry. However, for a mission to the interstellar space, a new class of miniaturized instrumentation is required. The Johns Hopkins University Applied Physics Laboratory (APL) has been designing and flying field and particle instruments for both heliophysics and planetary missions to the outer solar system, such as Voyager and New Horizons. On both of these missions, the APL particle instruments have made breakthrough science discoveries in both planetary and the outer heliospheric environment. Specifically, the energetic particle instrument on New Horizons that was launched in January 2006 has mass and power that are less than 1.5kg and 2.5W respectively. Since then APL has been leveraging dramatic advances in modern electronics and senor technologies to develop new class of miniaturized instruments that can be accommodated on spacecraft such as ISP and other small satellites.

PIR.1-0032-18 PHYSICS-BASED ASSESSMENT AND ANALYSIS OF CRITICAL SUBSYSTEM FUNCTIONS AND ISSUES FOR AN INTERSTELLAR MISSION

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The goal of a realistic interstellar mission to the nearest star recently announced by NASA as a new space exploration objective targeted for circa 2069, presents a daunting but exciting prospect for creating a pragmatic but visionary mission design. In light of such a long-range mission goal, potential technological developments that might be mission enablers are difficult to foresee with sufficient realism, but the basic physical principles underlying subsystem conceptual design for meeting the mission scientific objectives are well within our grasp. Consequently, an ongoing academically-inspired study at Johns Hopkins University will report on progress in analyzing and evaluating several critical subsystem issues. Contributions from students enrolled in the Applied Physics and Space System curricula will be summarized. These include but are not necessarily limited to the following: acquiring a quality mix of relevant compressed scientific data, optimizing trajectories during transit and destination arrival in the targeted system, insuring a survivable spacecraft bus in an ill-defined but harsh environment, providing an accurate navigation capability at sub-relativistic speeds, insuring a robust communication system over extraordinary distances, and maintaining a survivable but effective command and data handling subsystem. Given the options for a mission trajectory, maintaining spacecraft integrity in close-encounter gravity-assist maneuvers and through long-duration interstellar media at near relativistic speeds will be assessed and analyzed. Maintaining accurate navigation and guidance and control on the cusp of an ever-present "lost in space" condition and the need for exquisite pointing, tracking and stabilization will also be investigated. Finally, the acquisition, storage, and compression of scientific data and its transmission to earth are particularly important regardless of overall mission goals, and will likely require autonomous and intelligent in situ measurements and critical feature extraction. Wherever possible tradeoffs will be exercised and highlighted over the scope of possible missions and will be constrained with respect to system performance and spacecraft size, weight and power (SWaP) requirements. These trades will be made over a range of potential mission scales spanning an interstellar precursor mission (1000 AU) up to a Proxima Centauri scale mission to identify where and how much technology innovation is needed for a closeable design.

PIR.1-0033-18 IN-SITU INVESTIGATION OF THE INTERSTELLAR MEDIUM

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After the exciting in-situ observations of the termination shock and the entry of the Voyager 1 spacecraft into the inner and possibly outer heliosheath, there is a growing awareness of the significance of the physics of the outer heliosphere. Its understanding helps to clarify the structure of our immediate interstellar neighborhood, contributes to the clarification of fundamental astrophysical processes like the acceleration of charged particles at a stellar wind termination shock and beyond, and also sheds light on the question to what extent interstellar-terrestrial relations are important for the environment of and on the Earth and of exoplanets. In order to explore the boundary region of the heliosphere, it is necessary to send a spacecraft to perform advanced in-situ measurements particularly in the heliosheath, i.e. the region between the solar wind termination shock, and the heliopause, as well as in the (very) local interstellar medium. Solar activity is decreasing to 'normal values' below those of the Grand Solar Maximum which was typical of the space age so far. This is likely to reduce the size of the heliosphere and allows us to study a 'normal' heliosphere by launching an Interstellar Probe (IP) which will also provide within a shorter time than previously believed the first comprehensive measurements of key parameters of the local interstellar environment such as its composition, state, and magnetic field. Together with an accurate determination of the state of the heliospheric plasma across the heliosphere, these quantities are crucial to our understanding of how the heliosphere, and, much more generally, astrospheres, are formed and how they react to varying interstellar environments.

PIR.1-0034-18 APPROACH TO ADDRESSING RELIABILITY AND UNCERTAINTIES FOR A 50 YEAR MISSION

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NASA is currently studying a possible Interstellar Probe mission concept that would venture in to the unknown space between our star and other potentially habitable planetary systems. This mission could approach 20 AU/year asymptotic speed; target operations out to 1000 AU, meaning the spacecraft would need to operate for 50 years or more. In designing such a mission, the reliability of the spacecraft and instruments is critically important. This paper addresses the general approach to assess the reliability concerns for such an undertaking. The approach needs to integrate the understanding of failure mechanisms over time and environmental interactions with a robust fault management system, functionally redundant systems, and a resilient architecture. Included in this approach is the application of probabilistic methods to discern where uncertainties and risk drivers exist and inform a testing campaign to reduce them to an acceptable level of risk.

PIR.1-0035-18 PRAGMATIC MAXIMIZATION OF ASYMPTOTIC FLYOUT SPEED FOR NEARTERM EXPLORATION OF THE INTERSTELLAR MEDIUM

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Near-term exploration of the interstellar medium in the region of 200-1000 AU is possible with existing technology, but remains programmatically challenging due to the long travel times, long periods of mission inactivity, and overall mission costs. We consider multiple trajectories that will provide a range of possible science returns, including the in situ measurements so needed from the interstellar medium itself. Flybys of the gasor icegiant planets, observations of our solar system disk and zodiacal light, a second reconnaissance of Pluto, flybys of newly discovered Kuiper Belt Objects, or a close-up of the putative super-earth, “Planet Nine,” all present compelling opportunities but require different departure trajectories, or aim-points. Furthermore, an Interstellar Probe Mission departing the solar system at up to 20 AU/year will fly by objects in our solar system at many 10s of kilometers per second, several times faster than New Horizons’ flyby of Pluto. We will present trajectories that address these different objectives, possible overlapping solutions, challenges to achieving different families of solutions, and ultimate asymptotic fly-out speeds.

PPP.1-0001-18 RECENT CHANGES IN THE NASA OFFICE OF PLANETARY PROTECTION

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NASA has been active in the implementation of planetary quarantine/protection practices and policies since the 1950's when both COSPAR and NASA were founded. In 2017, NASA moved primary responsibility for planetary protection from the Science Mission Directorate to the Office of Safety and Mission Assurance. Reorganization within NASA allows for closer coordination between the Planetary Protection Office and the expanding technical needs of robotic and human spaceflight missions to comply with planetary protection requirements. In addition to supporting numerous missions, the Planetary Protection Office is NASA's focal point for interactions with COSPAR and other international agencies on matters related to terrestrial biological contamination during exploration of other planetary bodies and to extraterrestrial contamination of Earth during sample return. Research on scientific knowledge for planetary protection and development of advanced methods for life detection will be collaboratively managed by the science mission directorates and the Planetary Protection Office.

PPP.1-0002-18 PLANETARY PROTECTION ORGANIZATION ESTABLISHED IN JAXA

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Japan Aerospace Exploration Agency (JAXA) has been contributing space exploration for several decades. During the period, JAXA space missions have been implemented and been evaluated to accord with planetary protection policy of COSPAR. However, there have been no JAXA organization specifically responsible for the management of planetary protection policy. We have established the planetary protection organization in JAXA, recently. Though we are still on the way of establishing organizations and preparing domestic code to accord with COSPAR planetary protection policy, we will report the current status of the JAXA planetary protection organization.

PPP.1-0003-18 PLANETARY PROTECTION AND THE LAW: LEGAL CONSEQUENCES OF OUTER SPACE CONTAMINATION

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Planetary Protection is (also) a legal principle. The prevention of “harmful contamination” is subject to an entire article of the Outer space treaty, the major international law instrument that governs space activities, in force in 105 countries. The legal nature of Planetary Protection may have legal consequences. This article will address the concrete mechanisms and possible solutions to be find in law in the hypothesis of outer space contamination. The diversification of space activities and the growing number of actors involved in it raise new issues regarding the general application of international space law. Among them, the recognized principle of Planetary Protection shall be addressed and its legal implications shall be studied. The question shall then be asked of what can be done, on a legal basis, regarding a planned activity which may lead in a “harmful contamination”. Which legal process may apply to prevent such a situation? What are the concrete tools that law provides to deal with this situation? Finally, the issues regarding the legal consequences of harmful contamination caused by a passed operation in outer space shall also be addressed. Answering those interrogation will involve to focus on the international law mechanisms that may apply and to determine the actors, such as States or international organizations, which could initiate a legal procedure. Studying Planetary Protection through its legal nature allows to consider its concrete implications and to reinforce the effectiveness of its recommendations.

PPP.1-0004-18 LACUNA IN THE UPDATED PLANETARY PROTECTION POLICY AND INTERNATIONAL LAW

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The Planetary Protection Policy (PPP) has proclaimed the lofty ideal "All the planets, all the time." Originally formulated as Planetary Quarantine Requirements (PQR), the policy imposed strict decontamination standards for spacecraft during the initial period of interplanetary exploration. The policy properly has been seen as a work in progress, continuously open to consideration of new data, and subject to periodic re-examination and question with a view toward improvement to better meet the goals of science. This process has led to several revisions of the PPP to improve, simplify and clarify the standards.

In keeping with past practice, the policy was recently revised in light of new data and experience, and the current update is pending before the COSPAR Bureau and Council for review and approval. Specific changes to the PPP add Enceladus to the group of target bodies within the solar system subject to heightened protective measures, and modify the provisions regarding the establishment of special regions on Mars.

These new updates mark another important development in the evolution of the PPP. The PQR and the PPP were based on the precept that outbound spacecraft to celestial bodies should not contaminate natural celestial environments with Earth organisms. Therefore, the policy generally requires that certain missions, particularly to target bodies that could harbor evidence of past or current alien life, take active measures to decontaminate the spacecraft. Nevertheless, recent and proposed missions demonstrate that significant gaps remain in the policy. Instead of enhancing decontamination the policy actually promotes purposely and intentionally enlarging the number of potentially contaminating Earth organisms carried by a spacecraft that could reach celestial bodies, including those bodies which are subject to active decontamination requirements. Thus, even with the new updates, the PPP may not be fully consistent with the international obligations of the Outer Space Treaty, and the continued existence of the entire PPP policy could be in jeopardy.

This article discusses the flight characteristics of two specific missions, one launched and one in development, which are consistent with the PPP but nonetheless pose a substantial risk of biological contamination of celestial bodies. The manner in which the risks can be reduced is identified, and suggestions are made to close some of the gaps that remain in the PPP to comply with international law.

PPP.1-0005-18 IMPLEMENTING PLANETARY PROTECTION MEASURES FOR COMMERCIAL SPACE MISSIONS: INTERNATIONAL STANDARDS AND NATIONAL LEGISLATION

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When international discussions about protecting against biological and organic contamination began in the late 1950s, the subject was known as "spacecraft sterilization" or "planetary quarantine," and the discussants naturally assumed that space missions that might spread contamination would be state-sponsored. In fact, it was largely the United States that insisted that the 1967 United Nations Outer Space Treaty (OST) contain the possibility for private space flight to be allowable and subject to the OST, itself. Thus, Article VI of the treaty allows for activities in outer space to be carried out by non-governmental entities, but to "require authorization and continuing supervision by the appropriate State Party to the Treaty." Along with Article VI, a key set of provisions in the OST are to be found in Article IX, which requires States Parties to the Treaty to "pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, [to] adopt appropriate measures for this purpose." Also stated is the obligation that "If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space. . would cause potentially harmful interference with activities of other States Parties. . it shall undertake appropriate international consultations before proceeding with any such activity or experiment." These basic treaty commitments bind any national government that is signatory to the OST to move carefully and thoughtfully when implementing national regulations that provide for authorization and continuing supervision of space activities conducted by private, commercial entities. Given that the COSPAR Planetary Protection Policy has been recognized by the UN Committee on the Peaceful Uses of Outer Space (COPUOS) "as a reference standard for spacefaring nations and in guiding compliance with Article IX of the Outer Space Treaty" it might be considered that adherence to the COSPAR policy, at least in broad outlines, should be a fundamental building block of national regulations implementing the OST, and of any further elaboration of international law regarding space exploration and use. Such an addition was recently included as a building block by The Hague International Space Resources Governance Working Group (their Draft Building Block 9), and is consistent with both recent regulations from Luxembourg and the intention (if not the specific wording) of recent space commerce legislation being considered in the United States. COSPAR has recently (March 2017) taken steps to ensure a broadened representation on the Panel of Planetary Protection to assist with the general understanding of the purpose and consequences of its planetary protection policy, and the Panel terms of reference document now contains the explicit provision that the policy "should be based upon the principle that COSPAR planetary protection policies should enable the exploration of the solar system, not prohibit it." COSPAR policies do not exist to prohibit space resource and other commercial use of outer space, but rather to inform that use and ensure that a full understanding of the costs and the benefits of space missions to other worlds is accessible and can be part of the decision process to approve such a mission.

PPP.1-0006-18 NEXT STEPS IN PLANETARY PROTECTION FOR HUMAN SPACEFLIGHT

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Planetary protection is defined as: a) the prevention of contamination of extraterrestrial bodies by terrestrial microorganisms, and b) biohazard containment of returned samples from bodies in the Solar System that could harbor life.1 While the majority of interplanetary missions to date have involved robotic exploration, future missions will include human explorers. Current planetary protection requirements do not address the unique challenges associated with human exploration. The purpose of this abstract is to review planetary protection efforts for crewed missions and provide a forward plan for implementing them at the systems level.

Article IX of the UN Outer Space Treaty of 1967 provides the definition of planetary protection, outlined above.1 COSPAR holds the international standard in line with this treaty2, while NASA's Planetary Protection Policy (NPD 8020.7G) outlines the U.S. implementation of the COSPAR standard.3,4 NPI 8020.7 groups future human spaceflight planetary protection studies as follows: 1) microbial monitoring, 2) contamination mitigation and control, and 3) environmental effects. Additionally, a NPI 8020.7 outlines a five-step plan for forward work: 1) a literature review, 2) community inputs, 3) completion of recommended studies, 4) developing a draft NPR, and 5) implementation with NASA teams. The literature review was published in 2016.5 Inputs from the community were gathered at the Planetary Protection Knowledge Gaps for Human Extraterrestrial Missions, held in 2015.6 Johnson and Race (2016) outlined notional requirements and prioritized studies needed before final requirements can be produced. This prior work sets the stage for completing the necessary studies and finalizing planetary protection requirements for human spaceflight.

We propose a continuation of the systems engineering approach adopted thus far. The challenges associated with the implementation of notional requirements will be quantified in detailed discussions with internal stakeholders. The status and results of high-priority studies that have been completed since 2016 or are ongoing will be incorporated into discussions with stakeholders. In this way, we plan to bridge the gap between the science behind planetary protection and the engineering development that will implement it, allowing finalized planetary protection requirements to be developed for future human space missions.

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PPP.1-0007-18 STRATEGIC ADVICE ON PLANETARY PROTECTION FOR THE OUTER SOLAR SYSTEM BODIES

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The PPOSS project is an initiative supported by the European Commission under the H2020 programme (2016-2018) that provides an international platform and forum where science, industry and policy actors meet to nurture discussions and exchange knowledge on planetary protection of the outer solar system. This project is structured around three basic pillars that encompass the description of the state of the art and good practices to implement planetary protection requirements, the identification of scientific challenges and knowledge gaps in relation to the outer solar system and the development of an engineering roadmap for the European industry sector.

In the context of the findings and outcome from these activities, as well as targeted consultation with stakeholders, an overall integration is being made towards providing strategic advice and recommendations for planetary protection of outer solar system bodies.

A high level international integration committee, including representatives from space agencies and the scientific community, among others, will meet at two occasions during 2018 and as result, a policy briefing document substantiating the recommendations will be put forward to COSPAR Panel on Planetary Protection.

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PPP.1-0008-18 FORWARD CONTAMINATION PLANETARY PROTECTION FOR OCEANWORLD EXPLORATION: A STAKEHOLDER CONVERSATION

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Robotic exploration of our solar system's ocean worlds - especially icy moons of Jupiter and Saturn with vast interior oceans - is imminent. Within decades, our probes could conceivably encounter alien microbial life. In Earth's analogues - seafloor hydrothermal vents and cryosphere - life abounds. This makes the risk of "forward con-tamination" real. How ready are we? What are humanity's obligations? Today's governing requirement is a single value: limiting to 10e-4 the probability of a viable Earth organism entering a liquid water reservoir. By international treaty, this forward-contamination requirement constrains NASA, JAXA, ESA, and private companies. It strongly drives concepts, procedures, technologies, and costs. But where did this value come from? Is it appropriate? Is protection of future science the only consideration that matters? The 10e-4 requirement has not changed since its origin. It may still be appropriate for the mission concepts we are now designing, but without a refreshed, explicit conversation among an international cross-section of stakeholders, mission plans may be at risk. Our technical community may learn that other viewpoints matter. Many changes could justify revisiting the requirement rationale: 1) improved technology for bio-assays; 2) expanded definition of self-replicating organisms; 3) recognition that diverse environments can be habitable; 4) understanding of multi-cellular community behavior; 5) expanded astrobiology target list; and 6) evolved sociological and international context for setting technology policy. We briefly describe the requirement's origin, and summarize progress in biology of extremophiles, scenarios for the origin of life, self-replication of non-life macromolecules, evolution in changing environments, and how microbial communities sustain habitability. All these factors affect how we might quantify the probability of survival and replication in a given alien environment. We summarize how policies are developed for low-probability, high-consequence risks, including compensation of cognitive limitations about probabilities and how perceptions of risk are acculturated. We consider the application of the risk of contaminating another world: an irreversible event affecting subsequent generations, albeit with-out physical hazard. We assess how decision responsibility might be distributed, and the ethical dimension that could affect our community's definition of forward-contamination requirements. We compare this case

to other cases where society has dealt with technical risks full of unknowns, and describe how a stable stakeholder consensus could be developed to underpin governing policy.

PPP.1-0009-18 REVIEW OF PLANETARY PROTECTION POLICY DEVELOPMENT PROCESS

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In response to a request from NASA, the National Academies of Sciences, Engineering, and Medicine has conducted a study to review the current state of the planetary protection pol- icy development process. The study addresses two key questions. First, is the U.S. and international policy-making process responsive to the present state of science, technology, and engineering? Second, can the current policy-development process be extended to encompass the commercial and exploration interests of state and non-state actors? The paper will present a summary of the study's main conclusions and recommendations on how to ensure that the planetary protection policy process is supportive of future scientific and societal interests, including traditional robotic spacecraft missions, human exploration activities, and burgeoning private sector endeavours.

PPP.1-0010-18 PLANETARY PROTECTION CHARACTERIZATION OF SAMPLE-RETURN MISSIONS FROM THE MARTIAN MOONS

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The Committee on Planetary Protection Requirements for Sample-Return Missions from the Martian Moons

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COSPAR's planetary protection policy does not currently specify the status of sample-return missions from Phobos or Deimos, the moons of Mars. Although the moons themselves are not considered potential habitats for life or of direct relevance to prebiotic chemical evolution, recent studies indicate that a significant amount of material ejected from Mars in the recent past could be present on the surface of Phobos and, to a lesser extent, Deimos. Such interplanetary ejecta might mediate the transfer of viable organisms from Mars to its moons. JAXA, in cooperation with NASA and ESA, is developing the Martian Moons Exploration (MMX) mission to return samples from Phobos or Deimos to Earth in the late 2020s. The detailed design of MMX will depend on whether or not the samples collected are designated as restricted or unrestricted Earth return. The former designation, per NASA, ESA, JAXA and COSPAR policy, would require that MMX "break the chain of contact" between the sampled object and Earth. In addition, the samples will need to be maintained in high containment and undergo a biohazard test protocol after return to Earth. To lessen the scientific uncertainties concerning the planetary protection status of the martian moons, NASA and ESA commissioned research to assess the extent to which material from Mars might be deposited on its moons and to assess if the post-ejection environmental conditions might inactivate potential martian life transported to Phobos and Deimos. The tests included hypervelocity impact inactivation of relevant Earth organisms, as well as ionizing radiation and heat. To provide an independent assessment of the results of the aforementioned research activities and to recommend whether or not samples return from the martian moons be classified as restricted or unrestricted Earth return, NASA and ESA issued parallel request to the National Academies of Sciences, Engineering and Medicine and the European Science Foundation (ESF), respectively. The paper will briefly summarize the activities of the joint committee established by the National Academies and ESF to undertake the requested assessment.

PPP.1-0011-18 REPORT ON THE JOINT WORKSHOP ON INDUCED SPECIAL REGIONS

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The Joint Workshop on Induced Special Regions convened scientists and planetary protection experts to assess the potential of inducing special regions through lander or rover activity. A Special Region is defined as a place where water activity and temperature are sufficiently high and persist for long enough to plausibly harbor life. The Workshop, sponsored by both the former Planetary Protection Subcommittee and the Planetary Science Subcommittee, was anticipated to be the first of a series spanning the intersection of planetary protection and science.

Recognizing that the participants were approaching the concept of induced special regions from very different perspectives, the conveners provided a set of questions in advance of the workshop, to be answered by the intended participants. The intention was to develop: a common understanding of several disciplines needed to discuss Mars exploration potentially involving Special Regions, foundational knowledge for constructive workshop discussion, and input to help construct the agenda of talks and discussion groups for the workshop.

The Workshop was hosted by USRA at their headquarters facilities in Columbia, MD, November 29 - December 1, 2017. In the first part of the workshop, the conveners and participants reviewed the goals of the workshop and definitions of terms in order to establish a common base for discussion, including a review of the answers to the questions distributed before the workshop. Conveners then introduced three new, more specific questions addressing items that could directly affect mission operations and design. This was followed by introductory presentations by participants with pertinent expertise on four major subjects at play concerning those questions.

The questions presented were: 1. What is a safe stand-off distance, or formula to derive a safe distance, to a purported special region? a. What is viability/distance for micro-organism transport? b. Is there a residence time for a lander on Mars by when a rover/lander will be "safe"? 2. Questions about RTGs, other heat sources, and their ability to induce special regions:

a. Can a rover RTG on the surface induce a special region? Under what specific conditions? b. Can a buried RTG induce a special region? Does it pose a long-term contamination "threat?"

Is it possible to have an infected area on Mars that does not contaminate the rest of Mars?

What would be a proper buffer zone?

The participants were then divided into three subgroups, each possessing a balance of different expertise and personalities. All three subgroups addressed each question separately, and presented their answers in plenary sessions. Through this process, workshop conveners hoped to create an environment where everyone in the subgroups would have a voice, and each of the subgroups would have the opportunity to develop unique answers, in order to highlight areas of consensus and divergence. The resulting presentations from each group provided the opportunity for in-depth discussion in areas of disagreement with all expertise represented. On the final day, the participants were S. remixed into three new groups, and each group synthesized the responses to one of the workshop questions from material developed over the previous two days, with the goal of deriving the consensus view. In the final plenary session, the answers to the questions were reviewed, discussed, and consensus achieved.

The workshop participants reached a general consensus addressing the posed questions, details of which will be presented at the session. 1. While a spacecraft on the surface of Mars may not be able to explore a special region during the prime mission, the safe stand-off distance would decrease with time because the sterilizing environment that is the martian surface would progressively clean the exposed surfaces. However, the analysis supporting such an exploration should ensure that the risk to exposing interior portions of the spacecraft (i.e., essentially unsterilized) to the martian surface is minimized. 2. An RTG at the surface of Mars would not create a Special Region but the result depends on kinetics of melting, freezing, deliquescence, and desiccation. While a buried RTG could induce a Special Region, it would not pose a longterm contamination threat to Mars, with the possible exception of a migrating RTG in an icy deposit. 3. Induced Special Regions can allow microbial replication to occur (by definition), but such replication at the surface is unlikely to globally contaminate Mars. An induced subsurface Special Region would be isolated and microbial transport away from subsurface site is highly improbable.

PPP.1-0012-18 REPORT ON THE 2018 COSPAR PANEL ON PLANETARY PROTECTION COLLOQUIUM

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In consultation with the COSPAR Scientific Commissions B (Space Studies of the Earth-Moon System, Planets, and Small Bodies of the Solar System) and F (Life Sciences as Related to Space), the COSPAR Panel on Planetary Protection is organising a colloquium to cover all aspects related to update the COSPAR Planetary Protection Policy, mainly:

Phobos/Deimos sample return planetary protection category and requirements 2. Icy moon planetary protection requirements 3. Mars Special Regions planetary protection requirements

These three topics are addressed in dedicated meetings and reviews and are reported during this session. Results and recommendations described in these report and consequences for the COSPAR Planetary Protection Policy are discussed during the colloquium. A consolidated update of the COSPAR Planetary Protection Policy, including editorial updates, is prepared during the colloquium for discussion during the 2018 COSPAR Scientific Assembly.

PPP.1-0013-18 REORGANISATION OF THE COSPAR PANEL ON PLANETARY PROTECTION

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The COSPAR Panel on Planetary Protection is mandated to promulgate, and maintain with new scientific and technological advances taken into account, a planetary protection policy for the reference of spacefaring nations, both as an international standard on procedures to avoid organic-constituent and biological contamination in space exploration, and to provide accepted guidelines in this area to guide compliance with the wording of the UN Outer Space Treaty of 1967 and other international agreements. The Panel on Planetary Protection is cited in the COSPAR Strategy Statement, adopted March 2015, as a principle vehicle by which COSPAR fulfills one of its Missions: Support of Developed Space Programs. Henceforth, it is proposed that the COSPAR Panel on Planetary Protection Terms of Reference be updated so that the it can continue to fulfill its mandate of supporting spacefaring nations involved in planetary protection.

PPP.1-0014-18 CONSIDERING PLANETARY PROTECTION OF OUTER SOLAR SYSTEM BODIES - THE EUROPEAN PPOSS PROJECT

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With the increasing evidences of the presence of liquid water in the outer solar system, the number of potential habitable environment increases, as a consequence, the issue of contaminating these environments is more and more important and relevant. There are currently six ongoing missions to the outer solar system and small bodies and the main space agencies are currently planning several exploration missions to the outer solar system (in particular asteroids and the Jovian system).

Space exploration missions are international endeavours and planetary protection is by nature an issue of global relevance. While planetary protection policy is discussed and defined at the international level, it is important to reach a common understanding of planetary protection issues, in particular in the context of future collaborative exploration missions.

The PPOSS project is an initiative supported by the European Commission under the H2020 programme that provides an international platform and forum where science, industry and policy actors meet to nurture and catalyse discussions, exchange of knowledge and produce policy recommendations on the matter of planetary protection. It will look at case studies, lessons learnt and good practices in order to pave the way for an improved and more informed policy for planetary protection of outer solar system bodies, in particular icy moons. Looking forward, PPOSS will identify scientific challenges and knowledge gaps as well as define scientific requirement for outer Solar system bodies planetary protection. PPOSS will also involve interactions with the European industry and will develop as set of European industry roadmaps. Eventually PPOSS will integrate the information and knowledge generated through the project to provide science and policy recommendations for the definition, improvement, and implementation of an adequate planetary protection policy for outer solar system bodies.

PPOSS will be active for three years (2016-2018) and is structure around a well-defined and coherent work plan that includes five lines of actions:

1) International Planetary Protection Handbook: describe the state of the art and good practice for implementing planetary protection requirements, and identify good practices and lessons to be learnt. 2) Research White Book: identify scientific challenges, scientific requirements and knowledge gaps related to planetary protection of outer solar systems bodies, including small solar system bodies. 3) European Planetary Protection Industry Roadmap: develop an European engineering roadmap for the industry sector. 4) Strategic advice and recommendations: review of the international outer solar system planetary protection regulation structure and categorisation, suggest improvements. 5) Transfer of knowledge: facilitate the dissemination of knowledge related to planetary protection.

The PPOSS project Coordination and Support Action has received funding from the European Comission’s H2020 Programme (2016-2018) under grant agreement 687373.

PPP.1-0015-18 FROM APOLLO TO THE FUTURE, THE NASA CURATION MODEL FOR ENGAGING THE SAMPLE SCIENCE COMMUNITY MAXIMIZES SCIENCE ON EXTRATERRESTRIAL SAMPLES

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The Astromaterials Acquisition and Curation Office at Johnson Space Center (JSC) has enjoyed a long-term partnership (50 years!) with a broad community of planetary sample scientists. This partnership has enabled the curators of planetary samples to plan for and enact evolving requirements for preservation of sample scientific integrity and for handling and long-term storage. The basis for this relationship is a standing peer review advisory committee composed of leading scientists who are recognized for achievements in sample analysis. The committee and its descendants have brought familiarity with the most relevant scientific investigations and the associated analytical and contamination challenges.

Beginning with Apollo, the review committee was charged with oversight of curatorial operations and with ensuring fair access to samples. As additional samples from other planetary bodies were acquired, the committee evolved, taking on new responsibilities, reflected in committee name changes. However, oversight of curatorial operations and fair allocation of samples remain basic responsibilities. Committee recommendations are sent to the NASA Headquarters Discipline Scientist for approval. To minimize conflict of interest and maximize fair access, the rules governing the make-up of the committee is structured. Systematic rotation of leadership and staggered terms of membership allow the committee to retain expertise while bringing in fresh ideas.

The first peer review committee was called the Lunar Sample Analysis and Planning Team (LSAPT) and was formalized in early 1968 with about 15 members. Their function was to review a) the equipment and procedures used in the new Lunar Receiving Laboratory (LRL);

b) the proficiency and capability of the LRL staff; c) the sequence of sample analysis and allocation after quarantine release; and d) the findings of the Preliminary Examination Team (PET) [1]. According to the LSAPT member Gerald Wasserburg, one of the first issues they faced was deciding whether to have most of the sample analyses performed in house at the LRL or to distribute samples to members of the scientific community [2]. LSAPT concluded that the major scientific investigations should be carried out externally to the LRL by scientists chosen for their expertise in specific disciplines. Further they recommended that the PET's basic characterization of samples be circulated to the broad scientific community. LSAPT set its own agenda, paid attention to facility details, closely monitored the move of samples from the LRL to the interim curatorial facility in 1973, and was active in inspecting curation facilities. Between 1975 and 1979, a Facility Subcommittee of LSAPT oversaw the design and construction of a permanent facility for preservation of lunar samples. The result was an outstanding facility still in use today.

In 1977, a separate peer review committee, the Meteorite Working Group (MWG), was formed to evaluate requests for new meteorites then being collected in Antarctica under what would in 1980 become a 3-agency agreement (National Science Foundation, NASA, Smithsonian Institution) [3]. By 1979, after lunar samples were moved into the new permanent facility, the vacated gloveboxes and laboratory were prepared for meteorite curation. Recognizing that LSAPT had been helpful in setting up the JSC curatorial facility for Antarctic meteorites, JSC recommended the review committee be given expanded duties, including advice on curation and analysis of materials from other planetary bodies and the name be changed to Lunar and Planetary Sample Team (LAPST) [4]. In 1993, LAPST was renamed the Curation and Analysis Planning Team for Extraterrestrial Materials (CAPTEM) to reflect additional functions. CAPTEM is chartered to be (1) a community-based, interdisciplinary forum for discussion and analysis of matters concerning the collection and curation of extraterrestrial samples, including planning future sample return missions and (2) a standing review panel, charged with evaluating proposals requesting allocation of all extraterrestrial samples contained in NASA collections [5].

Efficiency and flexibility are gained through use of subcommittees, both ad hoc and standing. Transition of the MWG to a subcommittee of CAPTEM was completed in 2017. Today subcommittees review allocation requests for lunar samples, Antarctic meteorites, cosmic dust, Stardust cometary samples, Genesis solar wind samples, and samples returned from asteroids. Other subcommittees address facilities, informatics, and micro-cratered substrates. Planetary samples have been sent to research teams in over 30 countries world-wide. The expertise in the care and fair distribution of astromaterials by NASA using this model spans generations of planetary sample scientists and is a valuable resource to be tapped for future sample returns - OSIRIS-REx, Hayabusa 2, and Mars 2020.

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PPP.1-0016-18 THE IMPORTANCE OF SAMPLE RETURN, CURATION, AND PLANETARY PROTECTION FOR NASA'S EXPLORATION OF OUR SOLAR SYSTEM

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Sample return is an essential component of solar system exploration that enhances the understanding of our solar system acquired with fly-by, orbital, or surface missions, by providing a unique data set critical for understanding the formation and evolution of our solar system — material from another planetary body available for study in laboratories on Earth. The ability to perform analysis in well-equipped terrestrial laboratories enables scientific progress not possible with analyses performed in situ during a mission. These include, but are not limited to, much higher precision, replication of results, investigations at very small scales (down to picometers), sample manipulation capability and processing, and the ability to modify analytical experiments as logic and technology evolves. Analysis of returned samples contributes fundamental chronological and geochemical ground truth of planetary materials that enhances the value of both remotely sensed and surface observations beyond their stand-alone importance. Further, sample return is a critical component of the human exploration program for human health and safety issues as well as resource detection and characterization. [1]

As we visit other worlds, both robotically and with humans, we have a responsibility to comply with planetary protection provisions in support of U.S. obligations under the 1967 Outer Space Treaty. It is NASA's policy that the conduct of scientific investigations of possible extraterrestrial life forms, precursors, and remnants must not be jeopardized. In addition, the Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from another planet or other extraterrestrial sources. Therefore, for certain space-mission/target-planet combinations, controls on organic and biological contamination carried by spacecraft shall be imposed in accordance with directives implementing this policy. [2] NASA requirements for planetary protection addresses: (a) the control of terrestrial microbial contamination associated with robotic space vehicles intended to land, orbit, flyby, or otherwise encounter extraterrestrial solar system bodies, and (b) the control of contamination of the Earth and the Moon by extraterrestrial material collected and returned by robotic missions. [3]

Because much of the research done on returned extraterrestrial samples involves high resolution analyses, small amounts of contaminants, whether obtained during system development/ fabrication, collection, or subsequent handling and storage on Earth, can degrade and impair scientific measurements and hence the value of the samples. Among the primary purposes of astromaterials curation are to (a) safeguard the scientific integrity of extraterrestrial materials and (b) make them available for scientific study. [4] As a result curation has a major role in sample collection and return mission planning especially in the areas of contamination knowledge and control. Early mission involvement provides a means to advise on decisions that affect long-term scientific integrity of collected extraterrestrial materials [5] and collect the information and spacecraft coupons necessary to archive direct evidence of the as-flown collection approach and condition to be able to resolve future potential analytical questions. A key benefit of terrestrial laboratory analysis of returned samples is the ability to replicate results. Important, unexpected, or ambiguous analyses can be verified by independent experimental techniques and independent laboratories but may also require access to pre-flight contamination knowledge or as-flown material coupons. [6] This is becoming increasingly important for new mission concepts associated with icy bodies, organically interesting destinations, and investigating indicators for extraterrestrial life.

Although the purpose and objectives of planetary protection and curation are very different, there is overlap in some of the activities and data needs—especially in the areas of contamination control and contamination knowledge which are of vital importance to both.

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PPP.1-0017-18 INCREMENTAL PROGRESS TOWARDS DEVELOPING PLANETARY PROTECTION REQUIREMENTS FOR HUMAN MISSIONS: OVERVIEW OF RECENT WORKSHOPS, FINDINGS AND PLANS

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The Committee on Space Research (COSPAR) maintains a planetary protection policy with associated requirements as an international reference standard for spacefaring nations to guide compliance with Article IX of the UN Outer Space Treaty. Updating the COSPAR Plane- tary Protection Policy is an iterative process based on new discoveries, new understanding of scientific observations, and/or a response to needs identified to prepare future space missions. The current COSPAR policy for human missions to other celestial bodies is built around a set of qualitative principles and guidelines adopted in 2009, which address the rationale, but not the specific requirements for implementation of planetary protection on crewed missions. With plans underway for future human exploration beyond LEO, planetary protection measures must be re-considered and incorporated into the design, development and operations of diverse systems, including space suits, habitat modules, rovers, in-situ resource utilization (ISRU) equipment, waste disposal systems, containment hardware, and more.

Because of insufficient scientific and technological knowledge for establishing quantitative requirements, NASA initiated a stepwise path aimed at translating COSPAR Principles and Guidelines into detailed requirements. What followed from the initial NASA effort has been a multi-year, international and interdisciplinary process that has focused on three specific areas of importance to planetary protection and human missions: 1) Microbial and human health monitoring; 2) Technology and operations for contamination control; and 3) Natural transport of contamination on Mars. This presentation will provide a summary overview on recent stepwise progress towards the eventual goal of developing quantitative PP requirements for human missions.

As the first step in the process, NASA convened a workshop, Planetary Protection Knowledge Gaps for Human Extraterrestrial Missions (2015), to capture the current state of knowledge in the aforementioned three areas and to identify research needed to inform development of planetary protection requirements for the future human exploration. The workshop participants identified 25 separate knowledge gaps across the three study areas, and highlighted the crosscutting, collaborative research and technology-development work applicable to diverse mission phases-from pre-launch and in-route flight, to activities and infrastructure on the Martian surface, and during Earth-return and post-landing operations. Details of the 2015 NASA workshop are available online.

Subsequently, COSPAR (The Committee on Space Research), together with NASA and ESA, organized a follow-on interdisciplinary workshop in 2016 to consider next steps in the review and formulation of Planetary Protection Policy for future human missions beyond Earth Orbit. This presentation (in PPP1) will provide detailed information on the deliberations and summary findings of the COSPAR 2016 workshop, which was organized around the same themes as the 2015 NASA workshop– Microbial and human health monitoring; Technology and operations for contamination control; and natural transport of contamination on mars. In addition to analyzing potential microbial contamination, mitigation options, and dispersal concerns for human missions, this international workshop also discussed current gaps in COSPAR PP policy for future human missions to places other than Mars-particularly to asteroids and other bodies where biological contamination may not be of such significant concern.

In brief, the 2016 COSPAR Workshop on Refining Planetary Protection Requirements for Human Missions began by reviewing the findings of the 2015 NASA workshop and considered recent efforts, activities and the state of the art in the context of current COSPAR Planetary Protection Policy. As the three work groups deliberated about their suggested research and technology development needs, they also prioritized the research needs based on mission criticality and time priorities, and assessed the prospect of using different locations and mission opportunities to gather useful data. The COSPAR 2016 workshop was deliberately designed to collect inputs from both public and private space exploration organizations, thus providing a forum for international and interdisciplinary coordination and communication about future needs and efforts. The workshop report concluded by synthesizing the combined priority gaps of the three groups, and suggesting high priority actions to close the gaps though flight opportunities on robotic missions to Mars, on the ISS, or other missions, or Earth based research that could enable the needed measurements to fill the gaps in coming years.

This presentation will also provide cursory information on yet another recent workshop in this series: The 2nd COSPAR Workshop on Refining Planetary Protection Requirements for Human Missions, which was held in May 2018. This workshop aimed to align the previously identified knowledge gaps in planetary protection with mission opportunities in the timeframe between now and the first crewed flight to the Martian surface. Information from the 2018 workshop will feed forward into subsequent working meetings and will produce another COSPAR report (anticipated publication by end of 2018) to summarize and assess potential opportunities for addressing knowledge gaps in the 3 key areas flowing from all the workshops.

PPP.1-0018-18 BEYOND PLANETARY PROTECTION? PLANETARY SUSTAINABILITY AND THE RESPONSIBILITY OF SPACE SCIENCE

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The current COSPAR planetary protection guidelines address scientific space exploration only and they are primarily concerned with the issue of contamination (either contaminating celestial bodies with terrestrial micro-organisms or back-contamination of Earth). Other impacts of human space exploration that may be detrimental to space exploration itself are not covered. The best known example is the anthropogenic space debris orbiting Earth, but similar problems will occur in other places due to scientific and commercial space exploration in the near future. These problems share many similarities with environmental problems on Earth (tragedy of the commons etc.)

One possible approach to discuss and mitigate the impact of space exploration on the environment is to add the space environment as an additional goal to the 17 Sustainable Development Goals set by the United Nations. The resulting "Planetary Sustainability" and its ethical, scientific, economic, and legal ramifications were discussed during a workshop sponsored by the International Space Science Institute in March 2018. Here, we will first summarize the results of this workshop. Then we will discuss how this approach of Planetary Sustainability could help to plan future space missions. Finally, we will put a few propositions to debate what the role of space science in general could be, assuming space science is to support a sustainable development and is to avoid irreversible damage to the very thing it wants to study.

PPP.1-0019-18 PLANETARY PROTECTION IN EXTRASOLAR MISSION PROFILES

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Current Planetary Protection regulations cover solar system bodies only as we are currently restricted to the confines of our solar system. There is no current regulation outside of our solar system as this has not been within our technological capability. With advanced mis- sion concepts like the NASA Starlight program, whose goal is to enable the first relativistic interstellar missions. This program is capable of sending life far outside our solar system in the future. It is important to consider the implications of such a program. The collaborative Extrasolar Travelers project (ET) at UC Santa Barbara is exploring the viability of sending small animals in stasis on interstellar missions. This is an interesting case study to further Planetary Protection (PP) policy for future mission profiles and challenges. This paper will address the standing of the ET project within the scope of current PP regulations concerning the chance of contamination of solar system bodies as well as extrasolar bodies. The Starlight missions be propelled by directed energy and accelerated to relativistic speeds allowing interstellar missions to nearby stellar and exo-planet systems. While direct physical interaction with exo-planets is not planned it is important to consider the possibility of accidently impacts. With the extremely large kinetic energy per mass of the spacecraft a direct impact or exoplanet atmospheric interaction would result in the spacecraft being vaporized and thus likely biologically sterilized. However, it is important to ensure responsible PP procedures. Specific scenarios for the brief time the craft will spend in the solar system and fall under current PP regulations need to be discussed as well as the field of extrasolar or interstellar contamination events. The concept of backward contamination does not play a role in these mission profiles. While it is perfectly feasible to apply existing regulations for forward contamination to the abovementioned missions while they traverse the solar system, a discussion of possible PP regulation policy for extrasolar space needs to take into account several additional factors. The primary rationale for planetary protection regulations in the solar system is the protection of future science by avoiding contamination of a potential habitat with Earth organisms. As we do not have any data on life beyond the confines of our planet, adhering to such rationale makes sense in the immediate vicinity of Earth. It is likely that life that has developed around the same star under comparable (or at least not vastly different) conditions could be similar to Earth life. Thus protection of scientific missions that may be challenged by contamination with comparable life-forms of a related biology and chemistry makes sense. The idea of panspermia is one of the main reasons for this argument. If the idea of panspermia can be upheld for interstellar distances will be discussed in the paper and the ramifications for PP considerations for interstellar missions discussed in this light. Also the implications of the massive change in order of magnitude when mission time and distance are concerned need to be considered for PP regulations outside of our solar system. Last not least human agency in the proliferation of life in a Universe in which we know of only one instance of existing life needs to be discussed.

PPP.2-0001-18 ESA MISSIONS PLANETARY PROTECTION STATUS

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This presentation will report the planetary protection status of ESA flight projects with planetary protection requirements. It will cover Rosetta, Mars Express, ExoMars 2016, ExoMars 2020, JUICE, Solar Orbiter, and Bepi Colombo.

PPP.2-0002-18 OVERVIEW AND STATUS OF NASA'S PLANETARY PROTECTION MISSION PORTFOLIO

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NASA planetary science and exploration are pursued through a wide range of planetary science missions and instruments. This presentation focuses on the exciting range of missions and hardware that the Office of Planetary Protection has in its portfolio and provides an overview of mission-specific presentations that will be given on planetary protection activities at this COSPAR meeting. The currently growing portfolio contains over 30 missions and 15 cubesats, including international instrument contributions as well as commercial partners and spanning the full range of planetary protection categories from Category I through Category V as well as restricted and unrestricted Earth return. The Office of Planetary Protection, located at NASA Headquarters in the Office of Safety and Mission Assurance, is responsible for assuring that NASA missions and NASA contributions to missions with external partners are compliant with NASA requirements for planetary protection and consistent with COSPAR guidelines.

PPP.2-0003-18 PLANETARY PROTECTION PROGRESS OF HAYABUSA2 AND ITS PIGGYBACK PROCYON: LAUNCH, EARTH SWING-BY, OUTBOUND CRUISING AND ARRIVAL TO THE ASTEROID

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Hayabusa-2 is Japan's second asteroid sample return mission which was successfully launched into the planned Earth departure trajectory with the H-IIA rocket on December 3rd, 2014, together with a group of its interplanetary piggyback microspacecraft, including the PROCYON(Proximate Object Close flYby with Optical Navigation)spacecraft, the world's first 50 kg-class deep space micro-spacecraft developed by the University of Tokyo and the Japan Aerospace Exploration Agency.

The Hayabusa-2 spacecraft will go to Ryugu, a C-type NEO, and attempt surface investigations with daughter rovers (MINERVA-II series and MASCOT), artificial impact cratering experiment (SCI) and both surface and sub-surface sampling (Sampler) in 2018-2019 and plans to return to the Earth in December 2020.

The PROCYON mission objective was to demonstrate a micro-spacecraft bus technology for deep space exploration and proximity flyby to asteroids performing optical measurements.

Both of the above missions were fully evaluated by the COSPAR Planetary Protection Panel at the dedicated COSPAR colloquium

and scientific assembly in 2014 and the COSPAR PPP has endorsed the Category-2 for their outbound trajectories and the non-restricted Earth return for the inbound trajectory of Hayabusa-2.

As a part of the fulfillments of the Category-2 classification, both spacecraft must be compliant with the COSPAR PPP requirements of non-impact probability to Mars since they would have enough energy to reach and beyond the orbit of Mars, due to the Earth swing-by and ion engine operations for their outbound cruising.

As for the Hayabusa-2 spacecraft, it successfully performed its Earth gravity assist in December 2015, resulting on accurate orbit determination for the post-swing-by orbit to be ready to restart the ion engine operation. Thus the non-impact probability to Mars did not change from the estimate given by Chujo, et al. (2015). In the smmer of 2018, the spacecraft will arrive at teh asteroid Ryugu and start its rendezvous operation.

As for the PROCYON spacecraft after the completion of the bus system demonstration, it started deep space maneuver using the ion engines but the enginen failure prevented the spacecraft from insertion to the asteroid 2000 DP107 flyby trajectory via the Earth swing-by in 2015. Thus it now can be said that the spacecraft will never impact on Mars.

In this paper, we summarize the mission status of the both projects in terms of the COSPAR PPP perspectives.

PPP.2-0004-18 A ROVER OPERATIONS PROTOCOL FOR MAINTAINING COMPLIANCE WITH PLANETARY PROTECTION REQUIREMENTS

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The Mars Science Laboratory (MSL) mission, with its Curiosity rover, arrived at Gale Crater in August 2012 with the scientific objective of assessing the past and present habitability of the landing site area. It is not a life detection mission, but one that uses geological, geochemical, and environmental measurements to understand whether past and present conditions could have supported life. The MSL mission is designated Planetary Protection Category IVa, with specific restrictions on the landing site and surface operations. In particular, the mission is prohibited from introducing any hardware into a Mars Special Region, as defined by COSPAR policy and in NASA document NPR 8020.12D. Fluid-formed features such as recurring slope lineae are included in this prohibition. Finally, any evidence suggesting the presence of Special Regions or flowing liquid at the actual MSL landing site shall be communicated to the NASA Planetary Protection Officer immediately, and physical contact by the rover with such features shall be entirely avoided.

In January 2016, the MSL Project began using a daily rover operations protocol to ensure ongoing compliance with its planetary protection categorization. A particular challenge comes from the fact that the characteristics of potential Special Regions may not be obvious in the rover downlink data (e.g., landscape images, chemical measurements, or meteorology), or easily distinguishable from characteristics of other processes that do not imply Special Regions. For this reason, the first step in the process is for the lead scientist on that day of operations (a role that rotates through senior scientists on the mission) to scrutinize all the targets that may receive interaction by rover hardware, such as targets for arm contact, or paths for wheel contact. Based on the expertise of the lead scientist, and definitions of Mars Special Regions, if any features of concern are identified, other scientists on duty that day would be brought into a discussion. Typically the tactical team has a mix of experts in geology, astrobiology, geological materials, geochemistry, and meteorology. If this team cannot rule out the concern of introducing rover hardware into a potential Special Region, arm and wheel usage would be prohibited in that day's planning.

This halt in tactical operations would allow a separate Special Regions Team to re-consider the data more deliberately, but still on timeline that would allow rover operations to resume as quickly as possible. This team is chosen in advance to have a broad range of expertise that can weigh the evidence for a potential Special Region, including representatives from the institutional planetary protection organization and involvement of the MSL Project Manager. If this team cannot rule out the concern, rover operations continue to hold while the NASA Planetary Protection Office is engaged to determine the best course of action for the mission.

It is worth noting that evidence of modern, fluid-formed features at Gale Crater is not expected and would represent a major scientific discovery for the mission and Mars Exploration Program. However, this low-likelihood outcome still requires vigilance to ensure compliance with planetary protection requirements.

PPP.2-0005-18 PLANETARY PROTECTION IMPLEMENTATION ON EXOMARS MISSION 2016

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The ExoMars Mission 2016 was an ESA lead mission launched on March 2016 by a Roscosmos supplied Proton-M/Breeze-M rocket. The system consisted of an ExoMars Orbiter which accommodate scientific instruments and an Entry, Descent and Landing Demonstrator Module (EDM) to be landed in a non-special region on Mars. The project has been categorized by ESA as COSPAR Planetary Protection Category III for the Orbiter and Planetary Protection Category IVa for the EDM. Thales Alenia Space Italy (TAS-I) was the ExoMars Industrial Prime Contractor and was responsible for the Planetary Protection Implementation to ESA. Because microbial contamination could impact future science missions and compliance with international treaty was required, Planetary Protection measures were implemented on ExoMars 2016 hardware to verify bioburden levels complied with COSPAR regulation. The implementation of the Planetary Protection requirements for ExoMars Mission 2016 comprised restrictions on impact probabilities for flight hardware not intended to directly contact Mars and biological contamination control for the parts of the spacecraft to be in contact with Mars surface. This presentation reports the Planetary Protection implementation for ExoMars Mission 2016. It covers all the aspects of the mission: design, manufacturing, integration, tests, launch campaign at Baikonur Cosmodrome in Kazakhstan and the orbital transfer phase from Earth to Mars. Techniques and procedures applied to spacecraft, instruments and support equipment in order to meet planetary protection requirements as strategies used for spacecraft integration to achieve the bioburden level constraints required by planetary protection policy are described. The obtained results of Probability of Impact analysis as the final Bioburden budget results are also provided.

PPP.2-0006-18 PLANETARY PROTECTION STABILITY ASSESSMENT OF DAWN'S ENDOF-LIFE ORBIT AT CERES

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Dawn is a Discovery mission that launched in 2007. The purpose of the mission is to learn more about the epoch of planet formation and the evolution of the solar system by studying from orbit the protoplanet Vesta and dwarf planet Ceres. These are the two largest objects in the main asteroid belt. Dawn successfully completed its prime mission at Vesta and Ceres as well as an extended mission at Ceres. The lowest altitude at Ceres occurred in the originally planned end-of-life orbit, a circular orbit at 385 km. During the extended mission, the team raised the altitude to pursue new science objectives. Now the Dawn team is preparing for the second extended mission, in which the spacecraft will use its uniquely capable ion propulsion system to transfer into a highly elliptical orbit (orbital eccentricity = 0.8) with a periapsis altitude of 35 km for a new science campaign. The new end-of-life orbit has prompted the Dawn team to revisit the planetary protection (PP) requirements to ensure they can be satisfied. Dawn is categorized as a PP Category III Flyby mission due to the Mars gravity assist during the interplanetary transfer to Vesta. Vesta and Ceres are Category II bodies. According to the PP plan, the project must demonstrate the spacecraft will remain in Ceres orbit for greater than 20 years. In this work, we describe the final extended mission and planned destination orbit. We also summarize the results of our Monte Carlo study and in-depth orbit stability analysis, demonstrating that all PP requirements will be satisfied for the end-of-life orbit.

PPP.2-0007-18 INSIGHT PLANETARY PROTECTION STATUS

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The InSight Project is a Discovery mission that consists of a single spacecraft with an overarching mission goal of illuminating the fundamentals of formation and evolution of terrestrial planets by investigating the interior structure and processes of Mars. The

flight system is comprised of a 2008 Phoenix mission heritage cruise stage, aeroshell (heatshield and backshell), and lander. The lander payload contains cameras, a seismometer, a mole to penetrate the regolith (5 meters) to measure the geothermal gradient of Mars, and an auxiliary payload sensor suite to measure wind, temperature, and pressure. As a Mars lander mission without life detection instruments, the InSight mission has been designated PP Category IVa. Therefore, planetary protection bioburden requirements are applicable to this mission and require microbial reduction procedures and biological burden reports. InSight will launch in May/June of 2018 and has completed an approved Planetary Protection Plan, Subsidiary PP Plans, PP Implementation Documentation, and has conducted 90% of the biological verification assays. The flight system is in the process of being assembled and being readied for launch. The status of the PP activities will be reported.

PPP.2-0008-18 EMM: PLANETARY PROTECTION IMPLEMENTATION PLAN

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Emirates Mars Mission: Planetary Protection Implementation Plan

The United Arab Emirates is planning to launch a spacecraft to Mars in 2020 as part of the Emirates Mars Mission (EMM). The EMM spacecraft, Amal, will arrive in early 2021 and enter orbit about Mars. Through a sequence of subsequent maneuvers, the spacecraft will enter a large science orbit and remain there throughout the primary mission. This paper describes the planetary protection implementation plan for the EMM mission.

The EMM science orbit, where Amal will conduct the majority of its operations, is very large compared to other Mars orbiters. The nominal orbit has a periapse altitude of 20,000 km, an apoapse altitude of 43,000 km, and an inclination of 25 degrees. From this vantage point, Amal will conduct a series of atmospheric investigations.

Since Amal's orbit is very large, the plan is to demonstrate a very low probability that the spacecraft will ever encounter Mars' surface or lower atmosphere during the mission. The EMM team has prepared methods to demonstrate as follows:

A. the launch vehicle targets support a 0.01% probability of impacting Mars, or less, within 50 years B. the spacecraft has a 1% probability or less of impacting Mars during 20 years; and C. the spacecraft has a 5% probability or less of impacting Mars during 50 years.

The EMM approach to planetary protection is to bias the trajectory away from Mars so that the resulting probability of impact with Mars meets the probability requirements. The approach assumes failure of the Space Segment and avoids the need for a probability of failure analysis. The project views this as a conservative approach and more defensible than leveraging a reliability analysis. The significance of this approach is that the launch vehicle must place the upper stage and observatory on trajectories that satisfy planetary protection, and the project recognizes the cost of additional fuel to maintain the trajectory bias. This approach is satisfied by trajectory and navigation. The description of the Space Segment is included for information only.

The purpose of the Planetary Protection Implementation Plan (PPIP) is to provide all relevant information about the detailed implementation (e.g. analysis, procedures, and activities) of the planetary protection requirements in line with the planetary protection plan.

The EMM mission design resembles the mission design of many previous Mars missions, differing only in the specific parameters and final destination. The mission involves a direct launch toward Mars, a 7-month Type I cruise to Mars, a standard Mars Orbit Insertion (MOI), a transition from the capture orbit to the science orbit, and a scientific investigation in a high orbit about Mars. Special care is given to each phase to ensure that planetary protection guidelines are followed.

PPP.2-0009-18 MARS 2020 PLANETARY PROTECTION STATUS

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The Mars 2020 (M2020) flight system consists of a cruise stage; an entry, descent and landing system (EDL); and a Radioisotope Thermoelectric Generator (RTG) powered roving science vehicle that will land on the surface of Mars. The M2020 Mission is designed to investigate key question related to the ancient habitability of Mars and will conduct assessments that set the stage for future human exploration of Mars. The project will also acquire and cache samples of rock and regolith for possible return to Earth by a subsequent mission. NASA has assigned the M2020 Mission as a Category V Restricted Earth Return due to the possible future return of collected samples. As indicated in NPR8020.12D, Section 5.3.3.2, the outbound leg of a Category V mission that could potentially return samples to Earth, Mars 2020 would be expected to meet the requirements of a Category IVb mission. The entire flight system is subject to microbial reduction requirements, with additional specific emphasis on the sample acquisition and caching subsystem. A bioburden accounting tool is being used to track the microbial population on the surfaces to ensure that the biological cleanliness requirements are met. Initial bioburden estimates based on MSL heritage allows M2020 to choose more precisely how the bioburden is allocated to each hardware element. Mars 2020 has already started to implement its Planetary Protection Plan and Planetary Implementation Plan. Planetary protection sampling activities commenced with the start of flight system fabrication and assembly. The status of the Planetary Protection activities will be reported.

PPP.2-0010-18 PROGRAM OF ACTIONS UNDERTAKEN TO MEET THE PLANETARY PROTECTION REQUIREMENTS IN THE EXOMARS-2020 MISSION

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The major goal of the planetary protection program in the international mission ExoMars-2020 is to preclude the possibility of Mars contamination by terrestrial microorganisms. For this mission the Russia side designs a descent module (DM) the key elements of each are a probe (ESA) and a landing platform with service and research systems, and equipment. Since one of the prime mission objectives is search for life forms using the probe tools, according to the COSPAR classification ExoMars-2020 generally falls into category IVb. DM (without the probe) must comply with the bioburden limits imposed to landers in the category IV missions that visit a target body with no intention to search for life. Within the ExoMars-2020 project the Russian side answers for the planetary protection on specific stages of spacecraft (SC) development including the DM manufacturing and integration with the transit module and rover, in-process testing, and pre-launch preparations on cosmodrome Baikonur. The procedures applied are aimed at: - bioburden reduction on the stage of DM elements and equipment preparations for assembly using the heat, radiation and ultraviolet methods compatible with the structural materials of elements, units and equipment with consideration for their individual bioburdens; microbiological control of the DM elements and assembly room cleanness according to the ISO class 8; - microbiological control of the SC bioburden during DM integration with the transit module and rover in the clean tent and cleanness of the latter according to the ISO class 7, SC in-process testing and pre-launch preparations. These procedures will ensure implementation of the planetary protection requirements in the ExoMars-2020 mission.

PPP.2-0011-18 OVERVIEW OF MMX MISSION AND ITS PLANETARY PROTECTION PLAN

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Martian Moons eXploration (MMX) is a mission proposed by ISAS/ JAXA, that is currently under Phase-A study. The goal of MMX is to investigate the origin of the Martian moons, and then to make a progress in our understanding of planetary system formation and of primordial material transport around the border between the innerand the outer-part of the early solar system.

MMX mission is designed to retrieve samples from Martian Moons to Earth. The spacecraft is planned to be launched in 2020s by an H3 rocket and transferred to Mars. After Mars orbit insertion, it will be located on the quasi-satellite orbit (QSO) of one of the Martian Moons. During the proximity operation phase, the spacecraft will perform remote-sensing observation of Martian Moons and Mars from the QSO, descent and land on a Martian Moon, collect samples, and then ascent back to the QSO. Flyby observation of another Martian moon is also planned. After 3-year stay in the Martian system, the spacecraft will be inserted into the escape orbit from Mars and go back to the Earth. The capsule including samples will be separated and re-enter the Earth atmosphere.

The mission must be compliant with the COSPAR PPP requirements. The MMX pre-project team has carried on preparations for establishment of the planetary protection plan with support by JAXA Planetary Protection Working Group. In this presentation, the overview of the MMX mission and its planetary protection plan are shown.

PPP.2-0012-18 EUROPA CLIPPER PLANETARY PROTECTION STATUS

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The Europa Clipper mission will explore Europa and investigate its habitability utilizing a set of five remote sensing instruments that cover the spectrum from thermal emission through the ultraviolet, four in-situ fields and particles instruments, a two-channel radar, and a gravity science investigation. Key mission objectives will be to produce high-resolution images of Europa's surface, determine its composition, look for signs of recent or ongoing activity, measure the thickness of the icy shell, search for subsurface lakes, and determine the depth and salinity of Europa's ocean. Roughly 40 flybys of Europa-with closest-approach altitudes varying from several thousand kilometers miles to as low as 25 kilometers-will be executed over an approximately 3.5 year Prime Mission.

As an orbiter mission to a Jovian moon with a subsurface ocean, the Europa Clipper mission has been designated a Planetary Protection Category 3 mission that must meet the following requirement:

Reducing the probability of inadvertent contamination of an ocean or other liquid water body to less than 1 x 10-4 per mission

To implement this requirement, a multi-pronged approach of trajectory biasing, impact avoidance, biological probabilistic modeling and hardware biological allocation sampling will be employed. The baseline implementation approach for hardware cleanliness includes microbial reduction, spacecraft assembly in

an ISO 7 or better cleanroom environment, and recontamination control. The current status of the Europa Clipper PP approach will be presented.

PPP.2-0013-18 A SYSTEMS-LEVEL APPROACH TO PLANETARY PROTECTION AT EUROPA

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We are on the precipice of one or more missions to explore Europa and other ocean worlds. However, there are unique challenges in responsibly exploring worlds that are potentially rich in endogenous ecosystems and habitable niches. In order to protect Europa from forward contamination, and to achieve science goals that include assessing its habitability and searching for life, a more sophisticated approach to planetary protection is required than is reflected in current planetary protection paradigms. Significant progress has been made in the past decade to bound the nature and formation of Europa's surface features, its ice shell and ocean processes, and surface environment that should form the foundation for placing statistical bounds on the timescales over which contamination might occur.

We seek to provide the basis for revising COSPAR's planetary protection policies for Europa in short order, so as to enable ethically and scientifically responsible exploration in the near future. At present, planetary protection for Europa does not include consideration of its geological processes, whereas for Mars, geological timescales are integrated into COSPAR policies. The categorization of special regions on Mars has enabled progress in exploring its surface and subsurface, and thus provides a case study for how policies for Europa might be developed. For Europa, current requirements place restrictions on all missions that exceed those for Mars surface missions. A well-justified risk posture for future spacecraft exploration of Europa should include full consideration of how the ice shell works. Here we review accomplishments in understanding Europa's geophysical processes and surface environments, including all published models, and explore the impact of these discoveries on planetary protection, including considering the viability of potential contaminating organisms. We recommend strategies for calculating potential forward contamination, and for the establishment of Europan special regions.

PPP.2-0014-18 PLANETARY PROTECTION FOR HUMAN MISSIONS TO MARS: A FORWARD LOOK

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Robotic explorers currently sent to the red planet have stringent planetary protection requirements imposed. The COSPAR international consensus planetary protection policy obliges nations sending these missions to comply with specific biological cleanliness levels for hardware that may end up on the surface. This preserves the ability of future missions to do science at Mars unhindered by the contamination left behind by preceding missions. Yet this paradigm is not readily compatible with crewed missions sent to the martian surface: A decision to allow humans and their life support systems on the surface implies a level of biological con-tamination orders of magnitude more than that permitted for robotic missions. Still, the same two-fold intent of planetary protection remains: ensuring that the conduct of scientific investigations of possible extraterrestrial life forms, precursors, and remnants is not jeopardized, and; protecting the Earth from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from an interplanetary mission (forwardand back-contamination, respectively). Other presentations at this Assembly are addressing the future path to planetary protection requirements for crewed missions, but this presentation takes a forward look at the impact of planetary protection implementation on the hardware and systems needed for crewed exploration at the martian surface, based on recent expert reports and NASA mission architecture studies. In conclusion, planetary protection implementation will be a feature of future exploration efforts for Mars, including crewed missions. Determining how planetary protection should be implemented for crewed missions is contingent on improved knowledge of the Mars environment. It will likely result in broad impacts to engineering design and surface operations, that need to be integrated in planning from the earliest stages.

PPP.2-0015-18 OVERVIEW ON THE SMALL LUNAR LANDER SLIM AND ITS PLANETARY PROTECTION PLAN

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"SLIM" is a project in ISAS/JAXA to demonstrate a "pin-point" landing on the lunar surface with small spacecraft. The spacecraft is designed to achieve 100 meter-order landing error ellipse in order to satisfy such needs for future surface explorations on a celestial body with gravity. Since the conventional ground-based navigation is not accurate enough to achieve this level of landing error ellipse, image-based onboard navigation system and autonomous landing will be demonstrated by the SLIM mission along with several other new technologies. Some of these new technologies aim to realize a light-weight spacecraft for future interplanetary missions. The SLIM spacecraft itself weighs 600 700 kg wet mass and 200kg-class dry mass, both of which are much lighter than any previous lunar landers. Its main engine consists of 500N-class bipropellant thruster with N2H4 and MON3. Although the SLIM's main mission is technology and operation demonstration described above, additional small scientific payloads will also be employed. SLIM project status is in phase-B at this moment, and will be launched with Japanese rocket in 2020 or

2021. Based on the mission scope and mission design mentioned above, the SLIM team categorizes the Luna lander into Category II of the COSPAR planetary protection policy, which mainly requires a planetary protection plan and other documentations, including the spacecraft organic inventory. In this talk, the overview of the SLIM mission and its planetary protection plan will be presented and discussed for requesting the COSPAR-PPP to support the Category II proposal in a timely manner.

PPP.2-0016-18 A MATHEMATICAL MODEL FOR ASSESSING THE EUROPA CLIPPER PROBABILITY OF CONTAMINATION REQUIREMENT

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The planned Europa Clipper mission must comply with the NASA Planetary Protection requirement in NPR 8020.12D, which states: “The probability of inadvertent contamination of an ocean or other liquid water body must be less than 1×10-4 per mission”. Mathematical approaches designed to assess compliance with this requirement have been offered in the past, but no accepted methodology is in-place to trace the end-to-end probability of contamination. As a result, hardware can presumably be either overor under-treated. Over-specified microbial reduction protocols can greatly add to the cost (and schedule) of a project. On the other hand, if microbes on hardware are not sufficiently eliminated, there is increased risk of potentially contaminating another body with terrestrial organisms, adversely affecting scientific exploration and possibly conflicting with international treaty.

A mathematical model was developed by the Europa Clipper Project to demonstrate compliance with the NPR requirement stated above. Given an initial bioburden launched with the Clipper flight system, as specified in the Planetary Protection Equipment List (PPEL), the model calculates the probability of contaminating the Icy Bodies of Europa, Ganymede and Callisto. This calculation relies on two primary probabilistic calculations:

1) The probability that Clipper fails to perform a planned maneuver and impacts Europa, and 2) The conditional probability at least one viable microorganism survives the impact and reaches the Europa ocean.

Microorganism survival probabilities are calculated along each potential impact trajectory by quantifying organism mortality when exposed to the known lethality factors of space such as radiation, temperature and vacuum. The concept of a bio-region is introduced, a critical notion to this modeling which enables an understanding of how organism lethality depends on the flight system design and configuration.

Should an impact with Europa occur, impact heating and its effect on an organism's chance for survival is calculated. Modeling of this event considers the impact shock pressures and plastic deformation that are experienced by the Clipper flight system under potential impact velocities, angles, orientations, and ice composition conditions. Radiation exposure once on the Europa surface and timescales to a potential ocean contamination event are also folded into the survival calculation.

This objective mathematical framework enables Europa Clipper to ensure its Planetary Protection obligations are met, while minimizing impact to the Project.

PPP.2-0017-18 BIOBURDEN CONTROL ELEMENTS OF PLANETARY PROTECTION FOR THE EUROPA LANDER MISSION CONCEPT

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The Europa Lander mission concept would search for biosignatures, evaluate overall habitability and investigate geophysical properties and dynamics from the surface of Europa. The baseline instrument package would include provisions for imagery, organic and inorganic chemistry, microscopy, and geophysical activity monitoring. These instruments would characterize Europa's geophysical properties and dynamic processes while directly analyzing surface ice samples to identify microscopic features and quantify both inorganic and organic compounds.

The Europa Lander Mission would represent a novel challenge for Planetary Protection. COSPAR policy states that Europa missions must demonstrate less than a 1 in 10,000 probability of contamination, where contamination is defined as the introduction of one viable Earth organism into a liquid water body. The Europa Lander mission flight system concept, consisting of four distinct vehicles, magnifies and diversifies the challenge of preventing forward contamination of Europa by Earth organisms.

To meet the applicable requirements, the initial Planetary Protection architecture for the Europa Lander mission concept includes a diverse set of bioburden control elements: stringent microbial reduction, cleanroom assembly, a large biobarrier and a terminal sterilization system (TSS). Depending on sensitivity to microbial reduction processes, components and subsystems would be subjected to 6-log microbial reduction, full sterilization treatment, or situated in select locations for end-of-mission incineration by the TSS.

Once assembled and integrated into a four-vehicle stack, the upper three vehicles, all of which are planned to contact Europa, would be protected from recontamination by a biobarrier. To further reduce bioburden, vapor hydrogen peroxide would be applied behind the biobarrier after last access. After arrival at Europa, forward contamination from less-stringently treated components would be prevented by activating the TSS either prior to a non-nominal impact or at the end of the approximate 20-day surface sampling mission.

In combination, these elements would provide high levels of bioburden control for the Europa Lander mission concept; the current status of this approach and progress towards meeting the contamination probability limit will be presented.

Note: This abstract contains predecisional information, for planning and discussion only

PPP.2-0018-18 PLANETARY PROTECTION STRATEGY AND IMPLEMENTATION FOR MARCO, THE FIRST INTERPLANETARY CUBESAT MISSION

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The MarCO technology demonstration spacecraft are launching as a secondary payload on the InSight mission's launch vehicle. The primary MarCO mission objective is to relay entry, descent, and landing telemetry from the InSight lander to Earth. To accomplish this objective, the two identical CubeSats will perform a Mars flyby and pioneer a number of small spacecraft technologies for interplanetary use.

MarCO is also pioneering meeting Planetary Protection requirements within the framework of a CubeSat mission. Classified as a Planetary Protection Category III flyby mission, the project is required to address both impact constraints for launch vehicle elements and the potential for contaminating InSight. Meeting these requirements by adopting the contamination analysis and control architecture typically applied to Mars missions would limit the benefits of the low-cost, highly-adaptable CubeSat paradigm. Instead, a strategy comprising bioassays of specific hardware,

conservative bioburden estimation, and worst-case vehicle breakup and burnup analyses was employed to ensure Planetary Protection compliance.

InSight contamination risk was addressed through bioassays and worst-case assessment of particle delivery to the InSight cruise stage from the MarCO thruster plumes. Plume contamination potential was determined using bioburden specification values, and the resulting propellant bioburden estimate was combined with worst-case assumptions on plume shape, direction and distance to InSight. These calculations indicated bioburden transfer of less than one spore for the entire mission. In parallel, internal bioassays of the propulsion units and the propellant demonstrated far less contamination risk than the plume calculation alone.

The Mars impact risk was addressed by estimating the fraction of spores surviving entry through Mars' atmosphere and comparing that against the requirement that launch vehicle hardware impact the planet with fewer than 500,000 spores. First, a spore burden estimate was developed for each flight module using spore density specification values. Then, entry heating for eighteen MarCO flight system elements was determined across a range of entry cases. Finally, a conservative estimate of bioburden reduction was calculated using appropriate heat microbial reduction parameters with the entry case that developed the least amount of entry heating.

Through these efforts, the project both demonstrated that the MarCO mission is in compliance with Planetary Protection requirements and developed a framework for small spacecraft bioburden analyses that can be used, and refined, for future CubeSat missions.

PPP.2-0019-18 BACKWARD PLANETARY PROTECTION FOR POTENTIAL MARS SAMPLE RETURN

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Any concepts that propose to return samples from Mars would have to assure a very low probability of inadvertent release of Mars material into the Earth's biosphere in order to provide protection against the extremely unlikely possibility of biological hazards in the returned material. Backward planetary protection (aka containment assurance) requires breaking the chain of contact with Mars: any Mars material reaching Earth would have to be inside a robustly sealed sample container. And the integrity of the sample container would have to be maintained (with an unprecedented degree of confidence) until delivered to a secure receiving facility on Earth. NASA's Mars 2020 mission has identified, as one of that its principal objectives, caching of carefully selected samples on the Mars surface for possible delivery to Earth by a future mission (or set of missions). While no decision has been made as to if or when the future mission(s) might take place, the NASA Mars Exploration Program has initiated a preliminary investigation of options for implementation. This presentation describes the status of the ongoing effort to investigate architecture options for Mars sample return that could follow the collection of a cache by the 2020 rover and focuses on sample containment assurance aspects of the options. Potential planetary protection requirements and potential challenges to containment assurance are discussed, plans to assess and mitigate these challenges are outlined, and corresponding technology development is described.

PPP.2-0020-18 THE BASIC PLANETARY PROTECTION PROVISIONS OF THE

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The main purposes of "Expeditsia-M" interplanetary mission is landing "Boomerang" spacecraft (S/C) onto the Phobos surface, Phobos soil sampling and their delivery on the Earth inside a sealed indestructible container for physical and chemical study as well as a remote sensing of Mars and Deimos. According to COSPAR classification the stage of the Earth-Mars transit and the spacecraft flight in the near-Martian space are related to category III, while the mission stage on delivery of Phobos soil samples to the Earth falls into category V. Thus, in this mission, it is necessary to protect Mars from terrestrial microorganisms and the Earth from a potential threat when delivering soil from the Mars satellite. The first objective can be achieved by limiting the probability of S/C destruction (failure) and its fall on Mars, which is confirmed by calculation of S/C reliability at different mission stages and ballistic analysis of the flight trajectory. Taking into account the fact that the soil is returned from the Mars satellite and, thus, being aware of the responsibility for Earth's safety Lavochkin Association and IBMP RAS will provide measures to fulfill the requirements of the Earth's planetary protection in the delivery of Phobos soil that will include: 1) ensuring the tightness of the container with Phobosian soil at all stages of the mission, until landing on Earth. 2) analysis of non-sterile Phobos soil samples delivered to the Earth in conditions of rigid isolation in a specialized laboratory certified to carry out works with especially dangerous microorganisms. Detection of any sign of extraterrestrial life will result in isolation of the samples with subsequent sterilization prior to physical and chemical analyses. 3) "the break of the contact chain" between Earth and the equipment returned from Phobos.

PPP.3-0001-18 SCIENTIFIC CHALLENGES TO PREVENT THE BIOLOGICAL CONTAMINATION OF OUTER SOLAR SYSTEM BODIES - WHAT DO WE NEED TO KNOW FOR PLANETARY PROTECTION?

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With increasing evidence of the presence of liquid water in the outer Solar System, the number of potentialy habitable environments has increased and, in consequence, the issue of contaminating other solar system bodies has become more important and relevant. Within the current Planetary Protection framework, the challenges to prevent the unwanted biological contamination of Outer Solar System bodies of astrobiological interest, here especially Europa and Enceladus, are tightly linked to the potential of Earth organisms to arrive at and survive and replicate in an environment in the Outer Solar system that would be habitable for them ("problematic species"). The identification of these relevant groups of organisms was addressed through background research, a dedicated international workshop and the consultation of additional experts in geology, geophysics, space radiation dosimetry, radiation biology, planetology, and microbiology. Problematic species for icy moons were identified as those that are able to survive long periods of desiccation and exposure to radiation and thereafter can replicate at low temperatures under oligotrophic anaerobic conditions in the presence of salts. There is a need for long-term microbiological research to characterise the cleanroom microbial community with respect to the presence of problematic species. The unknowns about the environment, especially the radiative environment, but also the extent of exchange processes between the moon's surface and the subsurface ocean, its composition and the temperature gradient in the ice shell also need to be explored in respect to their effects on microorganisms.

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PPP.3-0002-18 THE PPOSS PROJECT - RESEARCH WHITEBOOK CHAPTER ON ORGANIC CONTAMINATION CONTROL

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The Organic Contamination Control (OCC) aspect of the Planetary Protection of the Outer Solar System (PPOSS) project is aimed at preventing contamination between Earth and other bodies, in particular the icy moons, in the context of life detection missions. Organic contamination may be considered as any terrestrial organic material that could be mistaken for (false positive result), or whose signal could overwhelm and mask (false negative result), an extra-terrestrial organic signature. So far, the search for life beyond the Earth has focused on Mars and so current thinking towards avoiding forward contamination of potentially habitable environments is based upon our knowledge of the Martian environment. As there is now increasing evidence for the potential of life to exist on the icy moons of the outer solar system, it is necessary to think about the unique challenges for planetary protection and contamination control these environments hold. The OCC chapter of the PPOSS Whitebook discusses our current state of knowledge and best practices in OCC, identifies knowledge gaps, and works toward a goal of adapting and improving current policy for the Icy Moon environments. Due to the non-self-replicating nature of organic contaminants (unlike biological contaminants) OCC is primarily concerned with affecting the reliability of the current mission rather than damaging the future scientific prospects of the body, although this must still be considered. While organic compounds are highly scarce on Mars and the challenge is purely

to detect them, organics are likely to be plentiful on the icy moons. The complex radiation environment, which we are yet to fully understand, will create polymers and macromolecules leading to a complex and varied suite of organics. This means that the background level of indigenous abiotic organic compounds will be high and the challenge will be to distinguish between the sources of the observed organics. Specific contamination requirements will depend on the instrument(s) being flown and the science objectives of the mission. Because of this, instead of this project defining quantitative requirements for OCC (as there are for Biological Contamination), instead, it is suggested that a peer-reviewable framework should be developed which each mission must use to produce their own mission-specific level of acceptable contamination at the design phase. Planetary Protection and contamination control policy will need to be adaptable as our knowledge about the target bodies increases through future successful missions. The PPOSS project Coordination and Support Action has received funding from the European Comission's H2020 Programme (2016-2018) under grant agreement 687373.

PPP.3-0003-18 QUANTITATIVE PLANETARY PROTECTION FOR SAMPLE RETURN FROM OCEAN WORLDS

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Volcanism on ocean worlds [1-3] facilitates sample return missions, enabling flexible, sensitive, and specific analyses on Earth to study how far chemistry has evolved in these oceans. Such mission concepts have yet to quantitatively address planetary protection (PP) [4,5]. They fall in Cat. V-Restricted Earth Return [6], as icy world oceans contain chemical energy [7] and organics [8], are shielded from exogenic radiation by ice, and ocean material has likely not been naturally exchanged with Earth [9].

Quantifiable forward PP: The probability of introducing a single viable terrestrial microbe into a liquid-water environment must be < 104, an arbitrary but manageable value [10]. Current policy [9,11] requires that this probability be estimated from bioburden at launch (F1), organism survival to radiation during the cruise (F2) and near the target (F3), the probabilities of encountering the target (F4) and surviving landing/impact (F5), and subsurface transport mechanisms, timescales (F6), and survival (F7). The compliance and cost of specific designs could be assessed from measurements of molecular contaminants as robust proxies for microbial particulates [12] (F1); known microbial radiation tolerance [13] and planetary radiation budgets [14] (F2-F3); trajectory design (F4); projected impact velocities [15] (F5); ice transport timescales [16] (F6), and growth rates in ice [17] (F7).

As an alternative to the difficult quantification of these factors, a binary decision tree has been proposed [10]: Do current data indicate that the target body lacks (1) liquid water? (2) bioessential elements? (3) physical conditions in the range of extreme conditions for Earth life?

(4) chemical energy? (5) complex organic nutrients? (6) Is the likelihood of contact with the habitable environment less than 10−4? (7) Can treatment at 60°C for 5 h eliminate physiological groups that can propagate on the target body? If one or more of these decision points is evaluated negatively, the spacecraft must be heated above 110°C for 30 h for sterilization.

In contrast, current back PP requirements are only qualitative: Current policy [9,11] prohibits destructive impact upon return, and in the absence of sample sterilization, requires fail-safe sealing of the sample container with a method to verify its operation before Earth return (B1); containment until transfer to a receiving facility (B2); "breaking the chain of contact" with the target (B3); no return to Earth of uncontained hardware that contacted the target (B4); reviews and approval of mission continuation prior to launch from Earth, leaving the target for return, and commitment to Earth reentry (B5); and life detection and biohazard testing prior to any sample distribution (B6).

These provisions and their means of evaluation could be quantified. A maximum leakage rate could be specified for particles above 10 nm (the size of prions, the smallest known pathogens [18]) (B1-B2), even for impact at terminal velocity, accidental or intended (bypassing the risk of failure of the reentry system, but requiring monitoring of sample integrity). For leak detection, He is commonly used [23], but its van-der-Waals radius of 0.14 nm could place too stringent a constraint for containment of pathogens over 70 times larger. To meet (B3)-(B4), uncontained parts in contact with ocean world material could be jettisoned prior to reentry with maximum allowed probabilities of Earth/Moon impact, or of microbial survival upon reentry. (B6) could require life detection prior to or after opening the sealed container [19].

Next steps to set policy: An ongoing European effort, Planetary Protection of Outer Solar System, is seeking to make recommendations for the definition, improvement, and implementation of PP policy [20], and could help quantify provisions (B1)-(B6).

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PPP.3-0004-18 MICROBIAL DIVERSITY ANALYSES OF AIRBORNE DUST COLLECTED FROM KIBO'S PRESSURIZED MODULE AT THE INTERNATIONAL SPACE STATION

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We have been monitoring environmental microbes of the Japanese Experiment Module KIBO's pressurize module of the International Space Station (ISS) from the beginning of operation and detecting a wide variety of microorganisms. It has long been known that the crew is a major source of microorganisms in manned spacecraft, such as the ISS. Thus far, we have been collecting environmental samples on board from the pressurized module using small swabs or tapes and analyzing microbiota on the ground. The method is suitable to quantitatively monitor population dynamics of microorganisms, however, it is not feasible to detect minor microorganisms with low numbers because of the quantity of each sample. Therefore, we considered the Inter-Module Ventilation (IMV) system on the ISS, giving that huge amount of dust often trap in the mesh and astronauts must clean it occasionally. Dust specimen from the IMV system in KIBO module was collected on board and, subsequently, it was subjected to DNA-based next generation sequencing on the earth in order to comprehensively analyze fungal microbiota. Our results showed that major fungal microbes in the dust of KIBO's IMV were not of commonly isolated environmental fungi such as Aspergillus or Penicillium, but human commensal species, such as Candida and Malassezia, which are known as opportunistic pathogens.

PPP.3-0005-18 CURATING NASA'S FUTURE EXTRATERRESTRIAL SAMPLE COLLECTIONS: THE ROLE OF ADVANCED CURATION

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Introduction: The Astromaterials Acquisition and Curation Office at NASA Johnson Space Center (JSC) (henceforth referred to herein as NASA Curation Office) is responsible for curating all of NASA's extraterrestrial samples. Under the governing document, NASA Policy Directive (NPD) 7100.10F "Curation of Extraterrestrial Materials," JSC is charged with "The curation of all extraterrestrial material under NASA control, including future NASA missions." The Directive goes on to define Curation as including ". documentation, preservation, preparation, and distribution of samples for research, education, and public outreach." Here we describe some of the ongoing efforts to ensure that the future activities of the NASA Curation Office are working towards a state of maximum proficiency.

Founding Principle: Curatorial activities began at JSC (Manned Spacecraft Center before 1973) as soon as design and construction planning for the Lunar Receiving Laboratory (LRL) began in 1964 [1], not with the return of the Apollo samples in 1969, nor with the completion of the LRL in 1967. This practice has since proven that curation begins as soon as a sample return mission is conceived, and this founding principle continues to return dividends today [e.g., 2].

Advanced Curation: Part of the curation process is planning for the future, and we refer to these planning efforts as "advanced curation" [3]. Advanced Curation at NASA is founded as a cross-

disciplinary field of advanced research and development under the auspices of the NASA Curation Office. Advanced Curation conducts research, explores and invents new innovative technologies and techniques for collection, handling, characterization, analysis, and curation of astromaterials that could be used for both next-generation human and robotic space exploration missions and current collections. Advanced Curation has a primary goal of expanding the sample processing and storage capabilities of NASA's astromaterials curation facilities, preparing the Curation Office for future sample return missions as well as maximizing the science returns of our existing sample collections. In addition, the program integrates, tests, and evaluates new technologies and operational procedures for future sample return missions through human and robotic analog studies. These goals are aimed at improving our core curation functions of protecting the scientific integrity of NASA's astromaterials collections and serving as responsible distributors of astromaterials to the global community of sample scientists and educators in a fair, timely, and professional manner. The Advanced Curation initiatives described will allow for the reduction of contamination to astromaterials and the unprecedented preservation of the scientific integrity of all samples from mission inception through ATLO, sample collection, preliminary examination on Earth, curation, and secure delivery of the samples to Earth-based laboratories for in-depth scientific analyses.

Looking Forward: We are fully committed to pushing the boundaries of curation protocol as humans continue to push the boundaries of space exploration and sample return through both human and robotic exploration efforts. However, to improve our ability to curate astromaterials collections of the future and to provide maximum protection to any returned samples, it is imperative that curation involvement commences at the time of mission inception. Specifically, when curation involvement is at the ground floor of mission planning, it provides a mechanism by which the samples can be protected against project-level decisions that could undermine the scientific value of the returned samples.

Concluding Remarks: The return of every extraterrestrial sample is a scientific investment. The curation facilities and personnel are the primary managers of that investment, and the scientific community, at large, is the beneficiary. The NASA Curation Office has the primary goal of maintaining the integrity of all of NASA's astromaterials and ensuring that the samples are distributed for scientific study in a fair, timely, and responsible manner. It is only through this openness and global collaboration in the study of astromaterials that the return on our scientific investments can be maximized. For information on requesting samples and becoming part of the global study of astromaterials, please visit curator.jsc.nasa.gov

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PPP.3-0006-18 NATURAL TRANSPORT OF CONTAMINATION ON MARS IN THE CONTEXT OF HUMAN EXPLORATION

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In the context of the human exploration of Mars, the issue of transport of viable microorganisms and organic contaminants from regions of exploration by human missions to Mars and eventual probabilities of reaching possible Special Regions needs to be considered. Natural transport consists of movement by aeolian processes, including abrasion/deflation, suspension and deposition of small particles (i.e. dust, microorganisms and organic molecules), as well as long-distance transport of larger particulates by intermittent saltation events.

Relative to other needs of atmospheric science to understand the present martian climate in terms of global circulation, including extrapolations backwards and forward in time, the concerns for planetary protection also require greater depth of knowledge of meteorological processes at or near the surface of Mars. Adequately understanding the efficiencies, frequencies, and durations of entrainment processes requires measurements at actual exploration zones to set limits on acceptable contamination by subsequent human missions.

Here we present the findings from a specialist study group investigation to identify the key priorities in the context of natural transport of contaminants arising from human exploration on Mars.

PPP.3-0007-18 DECONTAMINATION OF SPACE EQUIPMENT USING COLD ATMOSPHERIC PLASMAS

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A new apparatus for the decontamination of sensitive material like space equipment using cold atmospheric plasmas (CAP) is developed, built and tested. CAPs are partly ionized gases, socalled plasmas, that can be produced in air providing a chemical reactive cocktail of molecules, atoms and charged species. These reactive nitrogen and oxygen species are responsible for the sterilizing nature of CAP. CAPs are used in medicine and hygiene and due to these interesting applications the field is one of the fastest growing fields in plasma physics over the last years. In a first project we investigated the use of afterglow plasma produced in a CAP for the decontamination of space equipment [1]. The afterglow plasma contains only the long-living species like ozone, NO2, etc. which allows the treatment of very sensitive materials at room temperature. In a follow-on project the apparatus was completely redesigned to gain efficacy, stability and reproducibility. Measurements of the decontamination efficacy combined with physical measurements of the produced reactive components and their effect on treated materials allow a better understanding of the involved processes. We will give an overview on the status of the plasma decontamination project funded by the Bavarian Ministry of Economics.

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PPP.3-0008-18 ADVANCEMENT OF VAPOR HYDROGEN PEROXIDE (VHP) APPLICATIONS FOR PLANETARY PROTECTION IMPLEMENTATION

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Planetary Protection ensures that spacecraft meet stringent cleanliness requirements to prevent forward contamination (microbial contamination of the solar system by Earth-launched spacecraft that could pose a hindrance to a mission's science objectives). Spacecraft assemblies with large surface areas, and those that are difficult to clean or possess limited access, often undergo Heat Microbial Reduction (HMR). This approach significantly reduces the bioburden as per ECSS-Q-ST-70-57C (dry heat bioburden reduction for flight hardware). Unfortunately, many thermally-sensitive materials cannot be exposed to such high temperatures and require different modes of microbial reduction. VHP, which is a low-temperature process capable of destroying microbes, has a protocol approved by NASA's Planetary Protection Office as an alternative sterilization modality. Although surface sterilization specification has been established, sterilization procedures for complex geometries (e.g., vented boxes and electronic chassis inside the warm electronics box of a rover) require the use of biological and chemical indicators to demonstrate efficacy of the process. Unfortunately, removal of the biological and chemical indicators exposes the sterilized surfaces to recontamination. Thus, this study aims to propose a standard protocol for a bounding set of different configurations and geometries that would not require biological and chemical indicators. In our testing campaign we modified various operational parameters of our VHP generator to develop a sterilization cycle capable of processing complex spacecraft hardware. This study also describes the development of a scalable modular enclosure that can be used in-situ (e.g., at the site of hardware integration in a cleanroom or on the launch pad). The development of aseptic assembly and in-situ sterilization techniques can provide an alternative sterilization method to HMR (especially following rework of hardware), as well as reduce the time for mission assembly, test, and launch operations.

PPP.3-0009-18 INVESTIGATION OF GAMMA IRRADIATION FOR PLANETARY PROTECTION PURPOSES

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The planetary protection requirements for Mars and icy-moon missions must be met prior to launch. These requirements protect future scientific investigations by preserving the target environment from unwanted Earth biological contamination. The current spacecraft bioburden reduction process relies primarily on Heat Microbial Reduction (HMR) and the occasional use of Vapor Hydrogen Peroxide (VHP) to reduce bioburden on spacecraft. However, many modern spacecraft materials cannot be exposed to such high temperatures and time durations. VHP, although a low-temperature process, is only a surface sterilization technique. Therefore, to provide additional options for spacecraft hardware sterilization, the planetary protection discipline is developing a gamma irradiation microbial reduction technique capable of penetrating bulk materials. Gamma irradiation is advantageous due to its ability to reduce the bioburden of complex geometry instruments, such as deployable antennas, reaction wheel lubricants, and composite structures such as aeroshells, which cannot be sterilized otherwise, or cannot be adequately sterilized by heat. Gamma irradiation is also an ambient temperature technique that can be used on many heat-sensitive subsystems, such as batteries. In this study, organisms that possessed varying resistance capabilities, such as resistance to heat, dry conditions, and radiation, were analyzed. The goal of this study is to provide the planetary protection discipline with a standardized test protocol to begin the validation of gamma irradiation as a standard sterilization technique for flight hardware.

PPP.3-0010-18 THERMAL INACTIVATION OF BACTERIAL SPORES USING A PRECISION TEMPERATURE CONTROL SYSTEM

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Additional information about the thermal inactivation of bacterial spores is needed in the context of Mars sample return missions and icy moon exploration. Engineering areas that could benefit from this information include applications of brazing, sealing, impact heating and atmospheric entry heating. Most published information on spore inactivation does not include temperatures above 200 ºC. To address this information gap, an apparatus was built to heat microorganisms rapidly using a precision temperature control system and this apparatus was employed to study microbial spore inactivation, targeting temperatures from 125 to 500ºC. This apparatus consisted of a clear acrylic chamber, an aluminum stand securing tungstenhalogen lamps (the heat source), and a platform to support test silicon wafers that served as substrates for the spores. 1 cm square silicon wafers, 100 µm thick were chosen because silicon wafers have high absorptivity in the visible portion of the spectrum but low emissivity in the mid-infrared (enabling rapid heating), are available in very thin wafers (minimizing thermal response time), have very high thermal conductivity (which minimizes temperature differences across the sample) and are biologically inert. Temperatures were monitored by thermocouples attached to blank silicon wafers. Thermocouple voltages are recorded by a National Instruments data acquisition board and read by a laptop computer running LabView data acquisition and control software. Wafer heating employed a 'bang-bang' control program based on the temperatures read from the thermocouples. When the measured temperature was below a prescribed temperature-vs.-time profile, power was applied to the halogen lamps via a solid-state relay whereas when the measured temperature was at or above the profile value, power was removed. The control system could be programmed to execute any specified custom heating profile. Two bacterial spore types were studied: (1) Bacillus atrophaeus ATCC 9372, which are used in industry as a biological indicator for dry heat reduction processes and (2) the very heat resistant spore produced by

Bacillus sp. ATCC 29669. Samples were prepared by inoculating the silicon wafers with bacterial spores then dried under vacuum. The samples were exposed to a prescribed heating profile (ambient to target temperature in 60s with a linear heating ramp, followed by immediate cooling) under ambient atmospheric conditions. Spore survival was assessed by suspending, sonicating, diluting and pour plating in tryptic soy agar. After incubation, colony-forming units were counted. Test results for viability indicate that under these test conditions, B. atrophaeus did not survive above 200 ºC and the heat resistant spore ATCC 29669 was inactivated at temperatures of 225 ºC.

PPP.3-0011-18 A SUMMARY ON CUTTING EDGE ADVANCEMENTS IN STERILIZATION AND CLEANING TECHNOLOGIES IN MEDICAL, FOOD, AND DRUG INDUSTRIES, AND ITS APPLICABILITY TO SPACECRAFT HARDWARE

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JPL SI R&TD Cleaning/Sterlization

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Issued primarily by COSPAR (the Committee On SPAce Research), international planetary protection policies mandate that all spacecraft hardware in contact with extraterrestrial environments "of chemical evolution and/or origin of life interest and for which scientific opinion provides a significant chance of contamination which could compromise future investigations"

be sterilized. These policies seek to limit the (forward) biological contamination of the target body by terrestrial microorganisms on the spacecraft, so that future missions to the target body will provide accurate and reliable scientific results. Also these policies seek to prevent the (backward) biological contamination of the Earth by a sample returned from the target body. Bioburden reduction is an integral part of current space missions and its importance will magnify as sterilization requirements become more stringent in the future. Since life detection and sample return procedures require a sterile in situ environment (to protect scientific results), subsystems and instruments which will be in contact with extraterrestrial matter must be sterilized. Since the first Viking mission, Heat Microbial Reduction (HMR) has served as a well-understood common practice for sterilization. More recently, NASA and ESA have approved a standard protocol for Vapor Hydrogen Peroxide (VHP) sterilization to address some of the drawbacks of HMR by lowering operating costs and decreasing schedule impacts, as detailed in the certification processes conducted by NASA's Jet Propulsion Laboratory and Steris. Steris has also conducted many testing campaigns on behalf of JPL over the past 20 years. The main results of their campaigns are hence reported. However, even VHP has certain pitfalls that do not make it an all-encompassing sterilization modality for spacecraft hardware. Therefore, this review also investigates the state-of-the-art sterilization and cleaning techniques used in other fields, such as in the medical, food, and drug industries, for application to flight hardware. Major techniques covered include Cold Atmospheric Plasma, Electron Beam Irradiation, and Gamma Irradiation. Some techniques have proven to be good candidates for adaptation for future NASA spacecraft missions. Techniques such as gamma irradiation (rad), can broaden the scope of NASA-approved protocols and expand the currently limited toolkit. Cleaning is also an important aspect of bioburden reduction; despite the best sterilization technologies, dead microbes can interfere with and potentially invalidate the results of biosignature models of relevant celestial bodies. Therefore, cleaning techniques, such as carbon dioxide snow, can significantly contribute to the bioburden reduction process. With the development of standardized protocols for these additional sterilization and cleaning modalities – in combination with the well-known techniques with NASA and ESA approved protocols – we anticipate that future space missions may be able to achieve a higher biological standard.

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PPP.3-0012-18 IT IS TIME TO UPDATE THE BIOHAZARD TEST PROTOCOL FOR A MARS SAMPLE RETURN MISSION

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In the early 2000s, NASA envisioned a cooperative sample-return mission from Mars with CNES, and that international effort resulted in the development of a protocol to support the analysis of the samples in a containment facility. That protocol was called the "Draft Test Protocol" in that it was planned to be only the outline of the required preparations "for the safe receiving, handling, testing, distributing, and archiving of martian materials here on Earth," but not a complete listening of every procedure and test that might be required [1]. It was important that the Draft Test Protocol comprised a specific approach to the procedures to be used to conduct a biohazard test for a returned Mars sample, both to enable a critical appraisal of the protocol and to ensure that it would be following the recommendations of the Space Studies Board of the US National Academy of Science. Fast forward to the present, and NASA, with additional international partners (including ESA), is once again envisioning a Mars sample return suite of missions, which it is hoped will result in the arrival at Earth of a Mars sample near the end of the 2020s decade. The first mission in this suite is the sample collecting and caching rover (Mars 2020) which is due to be launched in two years time, setting in motion the clock that will result in the eventual sample return. If the sample will, indeed, arrive at a containment facility for analysis sometime at the end of the next decade, it is now time to revisit the Draft Test Protocol and develop a sample analysis and biohazard test plan that will allow the sample to be successfully evaluated for the presence of a biohazard, and ensure that it can be studied effectively when it returns to Earth. Ref. [1] Rummel, J.D., et al., eds. (2002) NASA/CP-2002-211842.

PPP.3-0014-18 THE INTERNATIONAL PLANETARY PROTECTION HANDBOOK (IPPH)

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In 2016, the currently ongoing Planetary Protection of Outer Solar System (PPOSS) project was accepted for funding by the European Commission under the Horizon 2020 programme. It provides an international platform and forum where science, industry and policy actors meet, discuss and produce policy recommendations on the matter of planetary protection of outer solar system bodies. A partner in PPOSS, COSPAR is in charge of assembling and publishing an International Planetary Protection Handbook (IPPH). This handbook aims to analyse the international planetary protection landscape, delineate the state-of-the-art and identify the good practices implemented in current and past missions so as to establish them as standard practice. Through desk research, industry and science team consultations (interviews and workshops) including more than ten international partners (space agencies, universities/labs, and industry), the IPPH crystallises the global status of planetary protection implementation and rationales and makes this information available for introduction, education and training purposes. Understanding potential hazards is essential to pursue Space Exploration. Moreover, avoiding unnecessary challenges coming from introducing unwanted forward invasive Earth contamination while searching for extra-terrestrial life is key to efficiently pursuing exploration. Used as a teaching tool in three or four International Planetary Protection training workshops in 2017-18, the handbook explains the do's and don't in planetary protection and, through five detailed case studies, provides all the information needed to understand and apply Planetary Protection requirements to a space mission. The IPPH is intended to be maintained and updated by COSPAR, based on the outcomes of the PPOSS project and future applicable research.

PPP.3-0015-18 CHARACTERIZATION OF DISCONTINUOUS HEAT MICROBIAL REDUCTION TECHNIQUES FOR ATLO CRITICAL PATH IMPACT RELIEF

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To combat bio-contamination risks, current heat microbial reduction specifications employ continuous, uninterrupted heat microbial reduction (HMR). HMR is a proven, validated sterilization tool both at NASA as well as in the medical device industry, but is time-consuming-heat sterilization of a hardware component can last for several days, or even weeks, from start to finish. This lengthy sterilization time causes noteworthy scheduling concerns during assembly, test, and launch operations (ATLO). Additionally, a lengthy exposure at high temperatures for an extended time increases hardware failure risk during flight. Previous studies have shown that heat-resistant organisms are not only killed during the heating ramp-up and cool-down processes, but also that allowing for discontinuous heating, or pauses in the heat sterilization process, may even improve sterilization efficacy. In response, this investigation directly comparing the current continuous HMR requirements with discontinuous HMR has found similar bacterial inactivation characteristics in B. atrophaeus spores using both continuous and discontinuous processes. The characterization and implementation of discontinuous HMR processes can not only lessen ALTO critical path impact, but can also provide increased opportunity for hardware owners to take credit for manufacturing heating processes, such as electrical circuit burn-in before delivery.

PPP.3-0016-18 SPACECRAFT-ASSOCIATED MICROORGANISMS: THEIR SYSTEMATIC IDENTIFICATION, DOCUMENTATION AND LONG-TERM CURATION

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Microorganisms isolated from robotic spacecraft have been preserved as a biological resource for studies relevant to planetary exploration and life detection since the Viking missions. This collection of microorganisms contains 5,000 isolates collected from missions to Mars where there was a requirement to quantify bioburden on spacecraft as a control measure for forward biological contamination. This collection is comprised of isolates gathered from ten Mars missions collected over a period of more than 45 years. This one of a kind collection includes specimens directly pertinent to planetary protection efforts, isolated from Viking through the current missions. Multiple copies of each isolate are preserved by freezing at -80°C with the cryo-protectant glycerol, commercial cryobeads and lyophilization. Genomic DNA resulting from the identification protocols, spacecraft and cleanroom bioassay wipes have been preserved as an additional resource.

Nearly all of the isolates that have been identified are gram-positive and more than 80% of the isolates are spore-formers. Based on 16SrRNA gene sequencing of 1,500 isolates, Bacillus is the genus found in the greatest abundance (72%), followed by Staphylococcus (6%), Paenibacillus (5%), Brevibacterium (2%), Micrococcus (2%), Sporosarcina (2%) and other genera at 1% or lower. More than 25 genera and 65 different species are represented. A significant fraction of isolates was identified as novel species candidates. The collection is rich in isolates that are resistant to microbial reduction techniques such as dry heat, vapor hydrogen peroxide, and UVC radiation.

The current approach to identify spacecraft isolates utilizes Matrix-Assisted Laser Desorption/Ionization Time-of-Flight

Mass Spectrometry (MALDI-TOF) spectra with comparisons to a custom spectral library comprised of 350 unique isolates from this collection with known 16S rRNA gene sequence information. Grouping the organisms by operational taxonomic units with 99% sequence homology, and obtaining MALDI-TOF spectra for each OTU eliminates the need to obtain a spectrum for every isolate. The use of the custom database containing 350 mass spectral profiles, improves the identification of new isolates from 7% to greater than 70%.

The spacecraft and cleanroom habitat is a unique microbial environment with little opportunity for cell division, dominated by rare hardy microorganisms that have survived desiccation and removal by cleaning. These microbes exist in a transport-driven environment that is strongly influenced by human activity and control measures. Improvements in our understanding of this spacecraft microbial archive collection was advanced through student internships and academic collaborations. These isolates can be made available for collaboration and new academic partnerships.

PPP.3-0017-18 ASSESSING EFFECTS OF UPPER ATMOSPHERE CONDITIONS ON SURVIVAL OF DEINOCOCCUS PHOENICIS.

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As missions continue to explore new celestial bodies, there is a growing need to understand how terrestrial biology reacts under these surface conditions. Europa, a Galilean moon of Jupiter, is a primary example with radiation receiving from Jupiter to its surface. Due to the stringent planetary protection requirements of Europa missions, any probability of contamination is required to be less than 1 x 10−4 permission. Along with the spore forming bacteria, known to be the most common spore forming bacteria are found to be tolerant to extreme environmental conditions. These organisms are more spore forming organisms on hardware under radiation exposure which is critical for future missions to calcul based simulation chambers or Space exposure studies on the International Space Station. Using weather balloon dried Deinococcusphoenicis 1P 10M E cells will ascend through the troposphere and stratosphere for approxim spore forming radiation resistant bacterial cells exposed to stratospheric radiation.Resultsof this study will h spore forming bacterial cells exposed to space radiation and assess forward contamination risk for future N A

This research is being conducted in collaboration with the University of California - Berkeley and the Jet Propulsion Laboratory, and is supported by the NASA's National Space Grant College and Fellowship Program and Science Mission Directorate.

PPP.3-0018-18 MICROBIAL ECOLOGY OF NASA CURATION CLEAN ROOMS

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Clean room standards like ISO 14644 [1] used for facilities that construct spacecraft and store returned samples do not explicitly account for microbial contamination. While there are associated ISO standards for monitoring and controlling bio-contamination in clean rooms [2]2 it is not always standard practice to do so. The NASA Astromaterials Acquisition and Curation Office maintains seven separate clean labs for storing extraterrestrial samples from the Moon, meteorites, cosmic dust, asteroids, comets, solar wind particles, and microparticle impact samples. These labs are routinely monitored for particulate and trace metal contamination. However, the sample collections are either non-sterile at the time of collection (e.g., meteorites) or are no longer being used to address scientific questions that could be affected by non-sterile conditions (e.g., Lunar samples). Outside of isolated studies[3] there has not been a systematic, longitudinal characterization of the microbial ecology of NASA curation clean rooms. In accordance with the advanced curation initiative[4], and to prepare for future sample return missions, we have initiated a routine microbiological monitoring program in the Antarctic Meteorite Lab. This monitoring program will be used to determine what microbes are capable of surviving in these oligotrophic environments and whether or not they are capable of altering the sample collections in any significant manner. Repeat sampling will allow us to understand how routine use of these labs affects the microbial ecology over time. We chose to begin our investigation in the Meteorite Lab because it has a lower ISO cleanliness standard (ISO 7) than most of the curation labs (ISO 6 - ISO 5) and therefore is likely to contain a higher bio-burden that we can sample without decreasing the cleanliness level of the lab. Additionally, most of the meteorites were collected from Antarctica and have been exposed to the terrestrial environment for thousands of years. Thus, it is possible that some of the organisms in this lab are transplants from the Antarctic environment. As we establish a routine sampling protocol that does not affect sample integrity we will extend our sampling efforts to the ISO 4-6 labs with a special focus on the Lunar Lab. Preliminary results from the Meteorite Lab indicate that fungi may play a larger role in clean room ecology than previously recognized. Although overall counts were comparable to other cleanroom assessments, fungal colonies comprised 83-97% of the isolates from Meteorite Lab samples. This result is especially interesting since many fungal species are capable of producing amino acids like Aib (-aminoisobutryic acid) and Iva (isovaline) that are often considered to be extra-terrestrial when identified in meteorites[5,6]. Curation facilities for the upcoming OSIRIS-REx and Hayabusa2 missions will be carefully monitored for fungal contamination to avoid inadvertent alteration of pristine carbonaceous asteroid samples. We will present culture-based and culture-independent time-series data from several NASA curation clean rooms that demonstrate how routine usage affects the microbial ecology. The results of this work will inform astrobiology and Planetary Protection efforts for upcoming missions.

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PPP.3-0019-18 MALDI-TOF MS APPLICATION TO RAPID DETECTION OF SPACECRAFT ISOLATES

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The key objective of the Planetary Protection discipline is to ensure that NASA's spacecraft meet biological cleanliness requirements and prevent inadvertent contamination of other planetary bodies, which may jeopardize a given mission's science objectives. This is achieved by assembling spacecraft in cleanrooms and monitoring microbial bioburden on spacecraft and associated surfaces. The Jet Propulsion Laboratory (JPL) has maintained the largest archive of bacterial strains isolated during the microbial monitoring of spacecraft and associated surfaces since the 1970s. Identification of these isolates was routinely performed by sequencing the 16S rRNA gene. Although this technique is an industry standard for bacterial identification, it requires time consuming laboratory work (DNA extraction, PCR, amplicon purification, sequencing, and sequence analysis) with a minimum 4-5 day turnaround, and has insufficient resolving power at the species level for some taxa. Matrix-assisted laser desorption/ionization time of flight (MALDI-TOF) mass spectrometry is widely used in clinical diagnostics and is a promising method to replace standard 16S rRNA sequencing. However, manufacturer provided databases lack bacterial isolates found in spacecraft-assembly cleanrooms. This study reports development of the first and largest custom database of MALDI-TOF MS profiles of bacterial isolates obtained from spacecraft surfaces and cleanroom environments. With the use of this accurate, custom, in-house developed database, 454 bacterial isolates were successfully identified in concurrence with their 16S rRNA sequence-based classifications. Additionally, MALDI-TOF MS was able to resolve strain level variations, identify potential novel species and distinguish between members of taxonomic groups, which is not possible using conventional 16S rRNA sequencing. MALDI-TOF MS has proved to be an accurate, rapid, and cost-effective approach for identification of bacterial isolates during the spacecraft assembly process.

PPP.3-0020-18 ASEPTIC OPERATIONS FOR POST DHMR PROCESSING OF MOMA MASS SPECTROMETER

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Mars Organic Molecule Analyzer - Mass Spectrometer (MOMA-MS) is an instrument in the MOMA instrument suite for the European Space Agency (ESA) ExoMars 2020 Rover. The rover is Planetary Protection Mission Category IVb, the first IVb mission since the Viking missions in the 1970s. Within the sample path of MOMA instrument suite the hardware surfaces of the must be sanitized to a level of 0.03 spore/m2. To meet this requirement, the MS sample path is subjected to Dry Heat Microbial Reduction (DHMR) to decrease the number of viable spores by 4 orders of magnitude from a measured 88 spores/m2 to 0.009 spores/m2. Before DHMR, the hardware is handled using standard cleanroom practices. After DHMR, planetary protection filters protect the sample path for most of integration, but when sample path exposure is required, aseptic operations are instituted and exposure times are kept to an absolute minimum. The surface area of exposure is also taken into account to determine safe exposure times. Before work begins, the ISO class 5 aseptic workspace is cleaned and tested for surface and airborne bioburden, and all tools that will contact or be used near sample path surfaces are sterilized. During the exposure activity, sterile garments are worn, sterile gloves are changed as often as necessary, and the environment is monitored with active and passive fallout for bioburden and real time airborne particle counts. Sterile tools are handled by a two person team so that the operator touches only the tool and not the exterior surfaces of the sterilization pouch, and a sterile operating field is established as a safe place to organize tools or parts during the aseptic operations. In cases where aseptic operations are not feasible, localized DHMR is used after exposure. Any breach in the planetary protection cleanliness can necessitate repeating instrument level DHMR, which not only has significant cost and schedule implications, it also become a risk to hardware that is not rated for repeated long exposures to high temperatures.

PPP.3-0021-18 THE IMPORTANCE OF CONTAMINATION KNOWLEDGE - INSIGHTS INTO MARS SAMPLE RETURN

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The Astromaterials Acquisition and Curation Office at NASA Johnson Space Center (JSC), in Houston, TX (henceforth Curation Office) manages the curation of all past, present, and future extraterrestrial samples returned by NASA missions and shared collections from international partners, preserving their integrity for future scientific study while providing the samples to the international community in a fair and unbiased way. The Curation Office also curates all reference and witness materials for each mission (e.g., flight and non-flight hardware coupons; lubricants; non-flight, flight-like, and flown witness plates). These reference and witness materials provide the scientific community with the fundamental ability to reconstruct the contamination/alteration history of the sample collection through the course of the mission, with the overall goal of strengthening the scientific conclusions drawn from the study of returned materials.

The information gained from characterizing the physical, biological, inorganic, and organic chemical properties of reference and witness materials is defined as the Contamination Knowledge (CK) of the sample collection. Unlike the data collected for Contamination Control (CC) and Planetary Protection (PP), CK is exclusively concerned with preserving reference and witness materials for study by future scientists upon sample return. Although CC and PP data collected for sample integrity and forward contamination purposes can be complementary to

CK, they are two separate data sets with distinct objectives. A robust collection of samples for CK is necessary to allow the extraterrestrial material in a returned sample to be distinguished from terrestrial contamination. Traditionally CK is utilized by sample scientists in order to accomplish the mission's scientific objectives, however this information can also be utilized by the Office of Planetary Protection to help evaluate the presence of any back contamination.

Mars 2020, the first phase of a potential multipart Mars Sample Return (MSR) campaign, is expected to contribute to NASA's Mars Exploration Program Science Goals by filling in knowledge gaps concerning: 1) the existence of past or present life on Mars, 2) the past and present climate of Mars, 3) the geology of Mars, and 4) hazards associated with human exploration of Mars [1]. Although there is debate concerning which samples will best answer these questions, the necessity for proper sample blanks is well-understood. The CC and PP requirements, driven by the restricted Class V mission designation, are the most stringent of any sample return mission in recent history. The extremely low levels of allowable terrestrial contamination on the spacecraft and rover can complicate these analyses given the detection limits of current analytical instrumentation, especially in the case of biological contamination. By collecting and curating unanalyzed samples specifically for CK, future sample scientists will not be relegated to: 1) relying on data collected using possibly obsolete tools and techniques for return sample blanks, or 2) using remnants of extracted and/or cultured samples from ATLO, which could be incompatible with the desired experimental endpoints or state-of-the-art techniques available at the time of sample return.

The addition of biological experimental endpoints to a sample return campaign's objectives broadens the requisite range in preservation environments (e.g. inert ultra-pure nitrogen gaseous environment at 18°C versus -80°C) and types of CK samples. As a result, the Curation Office will also curate the following CK samples at -80°C for the Mars 2020 mission:

1) unanalyzed swabs and wipes in sterile containers, 2) all recirculation filters from the clean rooms used for sample and caching subsystem assembly and all filters from the laminar flow benches used to assemble sample intimate hardware, and 3) witness plates collecting airborne contamination within the assembly cleanrooms.

It has been Curation Office policy since the Apollo missions to preserve as many pristine samples as possible for future scientific research [2, 3]. Although CK is required to be collected for all stages of the MSR campaign, the CK for the Mars 2020 mission is the most critical for understanding contamination in the returned samples given the intimacy between the martian samples and the Mars 2020 flight hardware. This presentation highlights the importance of CK for sample return missions as well as the traditional and novel types of CK samples required for a successful MSR campaign.

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PPP.3-0022-18 PAC-MOC-BIO ANINVESTIGATION OF DIFFERENT AIT SCENARIOS ON REQ. VERIFICATION, LOGISTIC AND QUALITY ASPECTS

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Projects such as EXOMARS 2020, Juice or Mars Sample Return and other further planned project with dedicated planetary protection constraints lead to new challenges due to simultaneously achieving extreme levels of particulate, molecular and biological cleanliness levels. The presentation will cover results from an ESA-supported investigation to collect lessons learned for mechanism assembly with the focus on quality and contamination requirements verification. The need to apply the findings in the challenge of subcontractor managing is shown.

The heritage of OHB is based on the direct contribution, such as the High Resolution Camera, the Sample Processing and Distribution System (SPDS), the optical harness and the Analytical Laboratory Drawer (ALD) developments for the ExoMars2020 mission. The contributions cover the full range of cleanliness deliverable status from visible clean components to be finally cleaned by the Customer up to components integrated in the ultra clean zone. An additional source of experience was gained by exchange and support from and for other suppliers. In this regard, aspects from manufacturer to customer covering material compatibility, cleaning, sterilization and verification, documentation had to be covered.

To cover these open challenges, OHB and IPA Fraunhofer experts signed a cooperation agreement. The combination of non-space application heritage and the laboratory infrastructure at IPA Stuttgart has initiated several valuable impulses, developments and systematic studies. One study covers the assembly of a representative mechanism in different environments, including the judgement on particulate, molecular and biological requirements achievement. The main objectives of the study were risk assesment, logistics effort, duration and quality aspects.The results sall be summarized in the presentation. The possibility to extract system engineering and design guidelines is currently in preparation at OHB and shall be briefly outlined. The key findings might lead to contributions to improve schedule, effort and mitigation action planning and might reduce cost and delays. This project was cofounded by ESA and OHB.

The cooperation of IPA and OHB System reported in the presentation, focussing on cleanliness, cleaning process development and verification methods is supported by ESA.

PANELS (P)

STATE-OF-THE-ART ASSAY TECHNOLOGIES (PPP.4)

PPP.4-0001-18 PLANETARY PROTECTION TECHNOLOGIES FOR PLANETARY SCIENCE INSTRUMENTS, SPACECRAFT, AND MISSIONS

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Planetary bodies like Mars, Europa, and Enceladus pose the question, "How to study them without contaminating them and destroying the object of study?" The natural trade-off, of course, is that the cleaner your spacecraft, the more you can explore such a body without contaminating it. As chartered by NASA Headquarters, the Planetary Protection Technology Definition Team (PPTDT) was asked to provide a report on six different tasks related to the engineering and technology challenges of implementing planetary protection requirements on solar system exploration missions: • Assessment of technical and engineering challenges to applying available microbial-reduction methods, including recontamination prevention, to spacecraft hardware and instruments, to meet current NASA requirements on preventing the forward contamination of potentially habitable worlds by future spacecraft missions (orbiters, atmospheric missions, landers, penetrators, and drills); • Identification of spacecraft and instrument materials known to be compatible with existing planetary protection protocols; • Planetary protection protocols/processes available or which appear promising, and areas ripe for technological development; • The technical and engineering challenges in ensuring that spacecraft hardware and instruments can meet organic cleanliness requirements needed to ensure high confidence in differentiating Earth contamination from extraterrestrial signals to avoid false negative as well as false positive results; • Approaches for mitigating the identified challenges, that would allow instruments to be flown successfully at the required levels of cleanliness and microbial reduction, beginning with identification of commonly used materials and spacecraft hardware that are compatible (or particularly vulnerable) to planetary protection protocols; • Engineering, technology, and scientific research and development that could be funded by NASA to provide future capabilities to field scientific instruments and spacecraft on missions that require either subsystem or system-level microbial reduction and recontamination prevention.

PPP.4-0002-18 MICROBIAL CONTAMINATION DETECTION AT LOW LEVELS BY [125]I RADIOLABELING

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This work seeks develop a new method for the determination of bioburdens (and the detection of microorganisms and life) for planetary protection purposes. It would work by the detection of the organism's protein by labeling them with a radioactive label, 125I. This would provide greater sensitivity while preserving a good turn-around time for analysis. This method will utilize the current NASA sampling techniques and thus could be directly compared against existing methods.

Radiolabeling techniques are inherently sensitive and 125I benefits from a 60 day half-life, providing greater activity and signal per unit number of labels. Additional sensitivity can be obtained by use of a Multiphoton Detection. This should enable detection to lower levels than previously possible, down to single cells.

By utilizing a universal biosignature (cell proteins), this method provides broad generality with regard to the range of organisms that can be detected and isn't restricted to any type(s) of organism, the ability of the organisms to be cultured, etc. This work would develop a quick and simple method for detecting the proteins from cells. This detection would involve:

Separation of cells/spores.

Lysis of cells.

Labeling of released proteins separation from unreacted label.

Detection by standard or multiphoton detection.

Previous work has shown the desirability of mechanical lysis methods. We will use OmniLyse mechanical lysis method from ClaremontBio Solutions which has been used successfully in NASA's Wetlab-2 project.

The method would also have applicability for testing returned samples hardware and for the testing sterilization methods as well as other Astrobiological applications. Future work could extend to species such as viruses and prions.

This work was support by NASA's Planetary Protection Program

PPP.4-0004-18 DEVELOPMENT OF METAGENOMIC APPROACH FOR ULTRA-LOW BIOMASS SAMPLES FROM SPACECRAFT SURFACES

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The inadvertent introduction of terrestrial microorganisms via spacecraft to other planetary bodies could compromise sciencific objectives of future missions, such as the search for extraterrestrial biosignatures. Given the highly specialized and extreme environment of spacecraft hardware surfaces, a unique but highly complex microbial diversity can be found on the spacecraft and associated surfaces. To monitor terrestrial microorganisms that are possible sources of forward contamination, it is important to develop a comprehensive inventory of microbes that are present on spacecraft to avoid interpreting their traces as authentic extraterrestrial biosignatures. Culture-based methods can only detect a small subset of total microorganisms present while genetic (DNA-based) identification techniques are able to capture the broadest spectrum of the microbial communities. The principal objective of this study is to establish phylogenetic diversity and functional traits by exploring the entire gene content (metagenome) of the spacecraft hardware. With the low amounts of biomass present on spacecraft hardware, existing molecular biology techniques are incapable of generating a high-quality metagenomics library. The methods presented here include the development and optimization of new laboratory protocols that are at the cutting-edge of environmental genomics technology and will have significant implications for the design and interpretation of microbial burden studies for ongoing and future Mars, sample return, and icy moon missions.

PPP.4-0005-18 TARGETED GENE(S) AMPLIFICATION-BASED NGS ANALYSIS OF LOW BIOMASS SAMPLES FROM SAF/SPACECRAFT SURFACES

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As per COSPAR PP policy, all spacefaring nations, when conducting the scientific investigations of possible extraterrestrial life forms, precursors, and remnants, are required to follow the appropriate forward contamination control procedures and met planetary protection requirements. In addition, the Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from another planet. Therefore, for certain space mission/target planet combinations, controls on contamination shall be imposed, in accordance with issuances implementing this policy. The COSPAR PP policy states that it requires technologies to clean and sterilize spacecraft systems and technologies to validate that the required cleanliness dictated by the mission's PP category has been met. All of these available technologies are focused on eradicating bacterial contaminants, but it is important to understand that low biomass samples contain microbial signatures from both Eukaryotic and Prokaryotic domain, which need to be cataloged in an unbiased manner. The amplicon based next generation sequencing methods like AmpliSeq from Ion Torrent and targeted gene(s) sequencing from Illumina, will assist in understanding cross-domain low biomass surface organisms posing a threat of forward contamination. It will also enable the development of suitable cleaning/sterilization procedures and enhance PP verification protocols. The targeted gene(s)- based method relies on polymerase chain reaction-based technology that uses a low amount of starting material for experiment initiation, which is a requirement for ultra-low biomass samples such as spacecraft surfaces. The targeted gene(s) based amplification technology makes use of specified panel design, which can be as high as 24,000 targets simultaneously studied in a single tube. It will also assist novel species discovery and study their genetic variation without the GC biases. Use of these recent technologies will deepen our understanding of microbial population associated with low biomass samples and their functional characteristics. It will also help in cataloging nucleic acid-dependent life surviving extreme conditions of the spacecraft Assembly, Testing, Launch, and Operation (ATLO) environments. The targeted gene(s) based amplification method has potential to reduce sequencing cost and processing time associated with total metagenome analysis as well as tailor to catalog the microbial genes of interest to a specific mission (e.g. psychrophilic, anaerobic, radiation resistant microbes for Europa). This novel strategy will help to measure forward microbial contamination and enable to track them on the samples returned from exploring planet(s).

PPP.4-0006-18 A PROTOTYPE TOOL FOR ASSESSING FORWARD CONTAMINATION FROM SPACE SUITS

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Crewed exploration missions dramatically increase the capability for large-scale sample collection and return activities, but they also increase the possibility and likelihood of forward contamination. Systematic research on forward contamination from uncrewed spacecraft has steadily progressed since the Viking missions, but parallel research on contamination from space suits has not. Current space suits have leakage rates as high as 100 cc gas/min.1, but it is unclear how many or what types of microbes are exiting the suits along with this gas. The Human Forward Contamination Assessment team at NASA's Johnson Space Center (JSC) has developed a prototype swab tool2 that is capable of maintaining sterility during pressure changes associated with entering and exiting vacuum. The primary objective of recent Extravehicular Activity (EVA) Swab Kit testing is to characterize the type of microorganisms typically found on spacesuit external surfaces under suit differential pressure conditions. Most humanassociated microorganisms can fit through a 0.5 to 1.0 µm gap. Understanding potential leak paths will inform future hardware design decisions. Knowing which types of microorganisms may leak from EVA suits provides a basis for subsequent studies to characterize the viability of those organisms under destination conditions, as well as how far they might spread through natural or human-influenced processes. The results of EVA suit molecular microbial community analyses will inform NASA exploration mission operations and hardware design, and help close Strategic Knowledge Gap B5, Forward Contamination to Mars We sampled suits as a secondary activity during tests conducted in two different vacuum chambers at Johnson Space Center. Samples were analyzed at Johnson Space Center and at the Jet Propulsion Laboratory using a variety of culture based techniques to grow bacteria collected from space suit surfaces during vacuum testing. We also used 16S rRNA tag sequencing and shotgun metagenomics to characterize uncultivatable microbes and environmental DNA from these surfaces.

Preliminary testing with this tool has confirmed that the design is capable of maintaining sterility while transitioning in and out of vacuum. We were unable to culture bacteria or fungi from negative control samples that were sterilized prior to testing and witnessed the entire testing procedure without being opened. Culture based results indicate more than 10 bacterial and at least one fungal species from space suit surfaces are capable of surviving up to 4 hours at vacuum. Current protocols for cleaning space suits prior to use are focused on crew health and safety rather than sterilization of the suits and thus microbiology of suit external surfaces are indistinguishable from the environment in which they are tested. In order to characterize and quantify forward contamination from space suit leakage, more controlled testing with these tools is necessary.

We have developed and tested a prototype tool for collecting samples from space suits during Extra Vehicular Activity. Preliminary testing of this tool has demonstrated that it can be used to collect samples at vacuum and that these samples will remain uncontaminated during testing. Additional testing will provide valuable insight into Planetary Protection, Astrobiology, Space Biology, ISS, and Human Research Programs needs as we prepare to send human explorers in search of life beyond Earth.

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PPP.4-0007-18 DEVELOPMENT OF A ONE-HANDED ENVIRONMENTAL SURFACE SAMPLING DEVICE

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Currently, there are several biological surface sampling kits that are designed to acquire and safely transport biological specimens. In these kits, many of the items are individually packaged and require both hands for optimal use. Since many of these items are packaged individually, the operator will generate a large amount of waste that will need to be managed during the course of a sampling mission. We have designed a sampling device to facilitate biological sampling using one-hand and reduce waste materials, which we have named the Mano Sampling Device. The advantage of this device versus currently available sampling technology is that this device acts as the actual sampler as well as the transport packaging, therefore, speeding up sampling times and reducing waste. The one-handed operation of the device will simplify sampling while wearing mission oriented protective posture (MOPP) gear in a hazardous environment. This design indicates a major step forward in biological sampling technology.

PPP.4-0008-18 ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS FOR MARS EXPLORATION: ISSUES AND CONCERNS FOR PLANETARY PROTECTION AND THE PROTECTION OF SCIENCE

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Planetary protection represents an additional set of requirements that generally have not been considered by developers of technologies for Environmental Control and Life Support Systems (ECLSS). Forward contamination concerns will affect release of gases and discharge of liquids and solids, including what may be left behind after planetary vehicles are abandoned upon return to Earth. A crew of four using a state of the art ECLSS could generate as much as 4.3 metric tons of gaseous, liquid and solid wastes and trash during a 500-day surface stay. These may present issues and concerns for both planetary protection and planetary science. Certainly, further closure of ECLSS systems will be of benefit by greater reuse of consumable products and reduced generation of waste products. It can be presumed that planetary protection will affect technology development by constraining how technologies can operate: limiting or prohibiting certain kinds of operations or processes (e.g. venting); necessitating that other kinds of operations be performed (e.g. sterilization; filtration of vent lines); prohibiting what can be brought on a mission (e.g. extremophiles); creating needs for new capabilities/ technologies (e.g. containment). Although any planned venting could include filtration to eliminate microorganisms from inadvertently exiting the spacecraft, it may be impossible to eliminate or filter habitat structural leakage. Filtration will add pressure drops impacting size of lines and ducts, affect fan size and energy requirements, and add consumable mass. Technologies that may be employed to remove biomarkers and microbial contamination from liquid and solid wastes prior to storage or release may include mineralization technologies such as incineration, super critical wet oxidation and pyrolysis. These technologies, however, come with significant penalties for mass, power and consumables. This paper will estimate the nature and amounts of materials generated during Mars transit and surface stays that may be impacted by planetary protection requirements or be controlled for the protection of planetary science.

PPP.4-0009-18 INSTRUMENTATIONS AND CAPABILITIES FOR "OMICS IN SPACE" THAT ARE REQUIRED FOR HUMAN MISSIONS

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The NASA Space Biology program funded two multi-year studies to catalogue International Space Station (ISS) environmental microbiome where samples were brought back to Earth and analyzed using molecular methods. The first Microbial Tracking (MT) experiment generated a microbial census of the ISS surfaces and atmosphere using advanced "omics" techniques, supported by traditional culture-based methods. The MT-2 experiment is measuring presence of viral and select bacterial and fungal pathogens on ISS surfaces and correlate their presence on crew. The microbial burden, diversity, and characterization of select microorganisms of ISS environmental surfaces and air particulates revealed that ISS strains exhibited more virulence than their Earth counterparts. The iTag sequencing to generate microbiome and shotgun sequencing to measure metagenome of the ISS environmental surfaces and air filtration systems showed presence of microbial members more closely related to human.

The safety of crewmembers and the maintenance of hardware are the primary goals for monitoring microorganisms in this closed habitat. The "omics" methodologies of the MT experiments will serve as the foundation for an extensive microbial census, offering significant insight into spaceflight-induced changes in the populations of beneficial and potentially harmful microbes. Bioinformatics data on the microbial diversity, antimicrobial resistance, virulence, and pathways are archived in the NASA GeneLab bioinformatics system that are open to the scientific research community.

The next generation sequencing using the MinION platform and PCR instruments were demonstrated on ISS by NASA in 2016 and were successful in sequencing libraries that had been prepared on Earth and shipped to the ISS. The limitation in this ISS demonstration study was that samples had to be prepared on Earth before sequencing could be performed on the ISS, as there are no technologies in place to process samples, extract biomolecules, and prepare libraries for NGS sequencing. However, NASA needs to develop instrumentations for extracting nucleic acids and sequencing methodologies for inflight detection and measurement of several biomolecules related to physiological and immunological effects related to spaceflight (e.g., aging, crew health, elevated antimicrobial resistance, and virulence).

The "Omics In Space (OIS)" project, funded by the Translational Research Institute for Space Health, recognizes these limitations and will be developing an automated Sample Processing Instrumentation for nucleic acid extraction in space that is streamlined, requires minimal crew time, reduces the amount of contamination between samples, and produces consistent results. In this regard, onboard ISS we will generate "omics" data related to microbiome (targeted for bacteria, fungi, and viruses) to address the microbial composition, metagenome (crew and environments) for functional characteristics, miRNA for immunological function, as well as epigenetic data to elucidate radiation-induced damage, cellular disruption, and aging of astronauts.

The development of an all-encompassing, integrated OIS bioinformatics database for closed habitat will enable various phylogeneticand pathogenic-based strategies of screening for, and identifying, specific subsets of microorganisms (e.g., dominating viral and microbial pathogens, as well as those that bear resistance traits relevant to antibiotics). This dataset will (a) create a capability for NASA to compare fluctuating microbial communities to "baseline" standards;

(b) enable more accurate assessments of crew health associated with mission planning; (c) allow evidence-based development of future bio-load management policies, particularly for long duration missions; and (d) capitalize on parallel research from non-NASA institutions efforts.

PPP.4-0010-18 REAL-TIME QUANTIFICATION OF SIZE-RESOLVED BIOAEROSOLS AND INERT PARTICLES IN SPACECRAFT ASSEMBLY CLEANROOMS.

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NASA maintains a planetary protection policy to avoid the inadvertent biological contamination of solar system bodies, that would obscure our ability to find life elsewhere, by assembling spacecraft in cleanrooms and monitoring microbial bioburden on spacecraft and associated surfaces. Though it was hypothesized that humans are the key contributors of bioaerosols and inert particles in a spacecraft assembly cleanroom, it has not yet been systematically assessed. Cleanroom certifications and cleanliness assessments are performed by monitoring and assessing particle size distribution per cubic meter of the air. The majority of particle counters assess particle size distribution and their abundance but cannot discern inert particles from bioaerosols. We performed real-time quantification of size-resolved bioaerosols and inert particles in spacecraft assembly cleanrooms using BioVigilant IMD-A® 350 system (Azbil Corporation, Tucson AZ, USA). The IMD-A 350 air monitoring system is based on optical spectroscopy that can differentiate aerosolized inert particles and bioaerosols, by targeting intrinsic fluorescence of airborne particulates. We performed sampling with 10-second resolution continuously during both six hours of normal operational activities (at work) and no activities (at rest) in six cleanrooms (ISO Classes 6, 7, and 8) at three time points at the Jet Propulsion Laboratory (JPL). A positive correlation was established between human presence and elevated bioaerosol counts. Our results show that on average, smaller size particles (0.5 and 1 micron) constitute 90.98 % (pm±0.063 SE) of the total bioaerosols detected at work, consistent across all the cleanrooms. This study represents the first continuous air monitoring of spacecraft assembly cleanrooms for simultaneous detection of bioaerosols and inert particles.

PPP.4-0011-18 MUCA MOBIL UNIT FOR CONTAMINATION ANALYSIS - NEW CONCEPT FOR ASSAY HANDLING

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Projects such as EXOMARS 2020, Juice or Mars Sample Return and other further planned project with dedicated planetary protection constraints lead to new challenges due to simultaneously achieving extreme levels of particulate, molecular and biological cleanliness levels. Beside the difficult task to translate the performance goals into requirements on prime and subco level the presentation shall focus on the topic of verification. The heritage of OHB is based on the direct contribution, such as the High Resolution Camera, the Sample Processing and Distribution System (SPDS), the optical harness and the Analytical Laboratory Drawer (ALD) developments for the ExoMars2020 mission. The contributions cover the full range of cleanliness deliverable status from visible clean components to be finally cleaned by the Customer up to components clean integrated in the ultra clean zone. The aspect of coordination of subcontractors across europa and cooperation with US subcontractors in combination with the regulations of assay taking and documentation lead to the development of the MUCA concept. MUCA shall become a mobile, flexible to use high end laboratory system to be used for at least the following aspects: Temporary operation of assay task on subcontractor side, education for planetrary protection training and hands on experience, standardisation between laboratories, on side control at test houses and launch side, lessons learned distribution. Results of a feasibility study covering aspects like necessary equipment, logistic, cleanliness levels and monitoring have been collected and shall be presented. A schedule to set MUCA in operation for national and international missions with high demands on contamination control will be shown. We believe that MUCA could provide a positive impact on standardisation between different agencies, contries and subcontractor. Key questions of limited duration between sample taking and analysis plus data handling of large assay numbers is covered. Overall MUCA sahll lead to schedule, risk and cost reductions.

The MUCA concept was created within a cooperation between OHB and the expert from the IPA Fraunhofer institut. The combination of space and non-space application heritage lead to new interesting aspects.

The concept and its applications shall be presented and we are looking for an open discussion.

PPP.4-0012-18 A GROUND SUPPORT BIO-BARRIER FOR RECONTAMINATION PREVENTION

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The planetary protection discipline is concerned with protecting celestial bodies that have the potential for life (e.g icy moons and Mars special regions) from terrestrial biological contamination. During the spacecraft assembly process subsystems undergo functional testing, a Mission Assurance task that verifies critical components can survive from launch through the duration of the mission. Despite efforts to keep spacecraft clean during ground support testing operations recontamination frequently occurs, resulting in the need to further clean the spacecraft and increasing risks to the assembly critical path schedule. In response, a ground support bio-barrier capable of protecting flight hardware continuously from an up-to 150°C bake-out sterilization and throughout the functional testing process has been designed. The bio-barrier consists of Nomex fibers combined with a PTFE weave for increased structural integrity over standard fiberglass HEPA filters, and improved electro-static discharge and heat resistant characteristics over statically-charged polymer HEPA filters, typical microbiology-standard filters. The Nomex/PTFE bio-barrier exhibited 97.07% filter efficiency for 0.3 m particles, but a doublelayered configuration presented 99.86% efficiency for 0.3 m particles. A double-layered configuration has additionally been given preliminary Contamination Control approval. Finally, the recontamination-prevention bio-barrier uses an 80/20 aluminum frame to prevent bio-barrier contact with critical spacecraft hardware. The recontamination-prevention bio-barrier can provide a safety-net against microbiological re-contamination during critical functional testing, decreasing the need for re-cleaning and reducing schedule impact risk.

PANELS (P)

DEVELOPMENT OF PHYSICS-BASED, EMPIRICAL, AND DATA ASSIMILATIVE MODELS OF THE RADIATION ENVIRONMENT (PRBEM.1)

PRBEM.1-0001-18 CALCULATION OF THE NEUTRON ALBEDO USING FLUKA: MODEL AND APPLICATIONS.

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This work presents Monte-Carlo simulations based on the Fluka code aiming to calculate the contribution of the neutron albedo at a date (representing the solar modulation) and altitude above the Earth, both of them chosen by the user. Results consist of three-parameter distribution, the energy and two angles characterizing the incident direction of the albedo particle, and are provided according to 9°x15° meshes all around the Earth at the chosen altitude. A very interesting feature of this model is the method used for filtering incident cosmic rays before reaching the Earth's atmosphere, MASHcode instead of the more classical Störmer filtering, guaranteeing a better estimate of protons at the level of the atmosphere thanks to inverse ray tracing. Such accuracy is of great importance for both applications of this models, i) the estimation of ambient neutrons for assessing the displacement damages and background level of detectors operated at LEO, and ii) the estimation of the main source of protons > 40 MeV of the inner radiation belt (CRAND). A future work will consist in using the outputs from this model to improve the CRAND process modelling in the ONERA Salammbô code.

PRBEM.1-0002-18 FIRST RESULTS CRAND MODELLING IMPROVEMENT IN THE SALAMMBô PROTON CODE, BASED ON FLUKA SIMULATIONS OF NEUTRON ALBEDO GENERATION

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The dynamics of highly energetic trapped protons (above tenth of MeV) in the Earth radiation belts are very difficult to accurately model. Many chaotic physical processes act and from time to time the external part of the belt can be wiped away or a second one may appear during strong solar flares. However during solar minimum, the occurrence of solar flares decrease and the outer bound tends to slide toward greater Lshell. In parallel, cosmic rays can reach the Earth atmosphere more easily during solar minimum, thus producing more albedo neutron that will disintegrate inside the extended protons radiation belt region, thus playing the role of an internal source. It is the co-called CRAND process (Cosmic Ray Albedo Neutron Decay). For two years now, ONERA has been collaborating with CEA on this topic, CEA focusing on the estimation of albedo neutron generation using Fluka simulations. Based on this significant breakthrough, we are now able to feed our recently upgraded CRAND model in the Salammbô proton code with more realistic distribution of albedo neutrons, both in terms of latitude and longitude, and in terms of direction of emission (elevation and azimuth). We aim at presenting at COSPAR the first results thanks to this new models coupling.

PRBEM.1-0003-18 MODELING OF THE EARTH'S RADIATION BELTS: RESPONSE TO CMEAND CIR-DRIVEN GEOMAGNETIC STORMS

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The Earth's magnetosphere responds differently to storms driven by coronal mass ejections (CME) and co-rotating interaction regions (CIR). CME-driven storms are characterized by their occurrence during solar maximum, irregular occurrence patterns, a very dense plasma sheet, stronger ring current, and less frequent enhancement of relativistic electron fluxes in the radiation belts. CIRs are usually observed during the declining phase of a solar cycle with a 27- day recurrence period and result in a less dense but hotter plasma sheet, weaker ring currents, longer intervals of strong magnetospheric convection, and higher values of relativistic electron fluxes. To understand the effects of geomagnetic activity on the inner and outer magnetosphere, CMEand CIR-driven storms should be considered separately.

In this work, we investigate the impact of both types of storms on the radiation belt environment during the Van Allen Probe era, using the Versatile Electron Radiation Belt (VERB) code. To classify storms, we use, among others, the HELCATS (HELiospheric Cataloguing, Analysis and Techniques Service) catalogs of CIR and interplanetary CME events. We use the Kp index as a measure of geomagnetic activity to parameterize wave models, diffusion coefficients, and the plasmapause location. The electron population is considered to originate from the plasma sheet, and we set up the outer boundary conditions at geostationary orbit using GOES and LANL data. We model each storm individually and compare the simulation results with spacecraft measurements (e.g. Van Allen Probes and POES) to validate the model performance. We use data assimilation methods to assist with initial and boundary conditions and the validation. The work shows, how well we understand the response of the belts to CME and CIR drivers and helps to identify the applicability of present wave models to CMEor CIR-driven storms.

PRBEM.1-0004-18 IS IT POSSIBLE TO ORGANIZE AUTOMATIC FORECASTING OF EXPECTED RADIATION HAZARDS FROM SOLAR COSMIC RAY (SCR) EVENTS FOR SPACECRAFTS IN HELIOSPHERE AND GEOMAGNETOSPHERE AND FOR AIRCRAFTS IN LOW ATMOSPHERE?

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We present method of automatically forecasting on line of expected radiation hazards from SCR event during 20 -30 minutes caused after beginning. We use model of solar cosmic ray diffusion and coupling functions for neutron monitors network with different altitudes and cut-off rigidities, including also space detectors like GOES. Another observational data for estimation of energy spectra is multiplicity of CR registration by some neutron monitors. We demonstrate algorithms for automatic estimation of the SCR event starting, determination time-evolution of SCR in space by coupling functions in the frame of spectrographic method, solving inverse problem for SCR generation in solar corona and propagation in the interplanetary space, automatic determining on the basis of CR observation data parameters of SCR generation in solar corona, escaping into solar wind, and propagation in space. We show that on the basis of these parameters it can be automatic forecasting on the basis of first about 20 - 30 one-minute data expected level of radiation hazards for full time of event (up to several days) for objects in space on different distances from the Sun, in magnetosphere at different orbits, and in low atmosphere at different altitudes and cutoff rigidities for any airline. If for some objects expected level of radiation hazards will be dangerous, after about 0.5 hour from event beginning will be formatted and sent corresponding Alert. We take into account that for the first about 0.5 hour data from event beginning, when coming mostly only small flux of high energy particles - radiation hazards expected very small in comparison with more delay time when coming main part of SCR with energy 1 GeV, formatted sufficient part of radiation hazards.

PRBEM.1-0005-18 THE RADIATION-BELT ELECTRON PHASE-SPACE-DENSITY RESPONSE

TO STREAM-INTERACTION REGIONS: MULTI-POINT OBSERVATIONS, DATAASSIMILATION, PHYSICS-BASED MODELING, AND FORECASTING

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Presented is an analysis of the phase-space density (PSD) response to stream-interaction regions (SIRs), which utilizes a reanalysis dataset principally comprised of the data-assimilative Versatile Electron Radiation Belt (VERB) code, Van Allen Probes and GOES observations. The dataset spans the period 2012-2017, and includes several SIR storms.

Using a snapshot analysis technique, the electron PSD is examined for evidence of injections, transport, acceleration, and loss by considering the instantaneous and time-averaged change over multiple adiabatic invariant values, simultaneously. The energies covered correspond to ring-current, relativistic, and ultra-relativistic electrons. Specific times are identified for every storm, where clear non-adiabatic changes were taking place, which allows one to separate cases where one mechanism may dominate over another, both external and internal to the magnetosphere, in causing the observed non-adiabatic change(s). For select cases, model simulations are conducted to test whether the observed non-adiabatic changes can be replicated through state-of-the-art modeling. This work utilizes an advanced data-driven technique to inform both our understanding, and the physics-based modeling of the radiation-belt response to the SIR.

The results of this analysis are also discussed in relation to the operational data-assimilative radiation-belt forecast model, running every 2 hours at UCLA and now also at GFZ Potsdam.

PRBEM.1-0006-18 PLANNED UPGRADES TO THE AE9/AP9-IRENE SPACE RADIATION CLIMATOLOGY MODEL

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We describe expanded capabilities in development for the AE9/AP9-IRENE space radiation climatology model suite. Version 1.6 will introduce kernels-based computation of radiation effects. Version 2.0 will see transition to a modular architecture: adding modules for solar protons and a sample solar cycle fly-through, expanding specifications in existing modules, and supporting inclusion of additional hazards in later versions. With expanding international collaboration in development, this version will also fully transition to the name International Radiation Environment Near Earth (IRENE).

PRBEM.1-0007-18 THE EUROPEAN SPACE RADIATION ENVIRONMENT MODELING SYSTEM

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A new modelling approach for the unified description of the energetic particle radiation environment and its effects - attributed from various sources - in near Earth space is presented. The European Space Radiation Environment Modelling (ESPREM) system applies a statistically robust and efficient methodology to combine existing and newly developed space radiation environment models of Trapped Particles, Solar Protons and Galactic Cosmic Rays (GCR). The architecture of ESPREM is modular, allowing the selection of various models for each particle radiation source and the integration of suitable radiation effects tools.

For the description of the trapped radiation, the widely used AE9/AP9/SPM (IRENE) model

[1] and the newly developed Trapped Energetic Particle Environment Model (TREPEM) have been integrated. TREPEM is a purely data driven, statistical model of the trapped energetic particle populations, that is built by assimilating measurements from several radiation monitors and particle detectors. The measurements are mapped onto an L* vs aeqgridcapturingf oreachgridpointthe def inedpercentiles.

For the description of the solar proton radiation environment, the Virtual Enhancements - Solar Proton Event Radiation (VESPER) model [2] was developed and integrated into ESPREM. VESPER utilizes the ESA SEPEM RDS v2.0 and employs a novel probabilistic approach for the modelling of the energetic proton environment at 1 AU attributed to Solar Proton Events (SPE). For a user-defined mission duration, VESPER produces multiple scenarios of virtual SPE flux time-series allowing the derivation of probability

functions for critical variables of interest such as the Peak Fluxes or the Cumulative differential Fluences over the spacecraft mission duration.

For the modelling of the GCR environment, ESPREM integrates Matthiä model [3] that was developed at the German Aerospace Center (DLR). The model, which is actually an effective update of the standard ISO model [4], describes the GCR spectra based on a single parameter (Wolf parameter). The values of this parameter, for different solar modulation conditions, are derived from measurements of the Advanced Composition Explorer (ACE) spacecraft and the Oulu neutron monitor count rates. ESPREM incorporates the shielding effects for both solar and galactic cosmic flux series, along the spacecraft orbit, due to the Earth's magnetosphere, using the Magnetospheric Shielding Model (MSM) [5].

ESPREM as a system integrates the radiation models with trajectory tools and a series of state-of-the-art radiation effects tools (MULASSIS, IRONSIS and MCICT). The Multi-Layered Shielding Simulation Software (MULASSIS) [6] is a simulation tool that assesses radiation shielding performance for simple user-defined shield geometries (multi-layered planar or spherical shields). IRONSSIS [7] treats 1D multi-layer shielding structures using a straight-ahead, continuous, slowing-down approximation approach, while the MCICT [8] is an internal charging analysis tool. Upon completion of the simulation, ESPREM can provide a series of outputs such as particle fluxes, ionizing and non-ionising dose, LET spectra and charging currents. The system is capable of deriving probability distributions for the various effects, from all possible sources of radiation (trapped, SEP GCR), which can then be merged statistically, assuming various degrees of intercorrelations, in order to produce confidence levels for the combined radiation effects that the satellite will encounter.

The ESPREM system is accessed by the user as a Remote Procedure Call (RPC) service or a Python library. The system's primary use case is to be deployed in a web server, making it available to users' RPC endpoints, through which they can either use any of the subcomponents independently or the full system in a pipeline mode. In the first case, the user requests to run any single sub-module of the system (models or effect tools) e.g. for a given orbit, the TREPEM model is run to produce the trajectory's average fluxes. In the pipeline mode of operation multiple tools are invoked sequentially and intermediate results are forwarded internally in the system e.g. the user provides an orbit and a geometry specification and requests the total dose from protons, in which case ESPREM will run the trajectory tool, the TREPEM, VESPER and GCR models and MULASSIS/IRONSSIS, handling all data transformations required between the tools.

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PRBEM.1-0008-18 USING THE VERB-4D CODE AS A NOWCASTING TOOL FOR MODELING ELECTRON RING CURRENT AND RADIATION BELT DYNAMICS

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The four-dimensional Versatile Electron Radiation Belt (VERB-4D) code has been developed to model combined electron ring current and electron radiation belt dynamics. The code takes into account convective transport of electrons in prescribed electric and magnetic fields, radial diffusion, local pitch angle, energy, and mixed diffusion due to resonant interactions with plasma waves (e.g. hiss, chorus, whistler mode lightning, and electromagnetic ion cyclotron waves), and electron loss into the interplanetary medium and atmosphere. In this work, we show the comparison of simulation results with satellite observations (Van Allen Probes, POES, THEMIS, etc.) over a wide energy range from 10 keV to several MeV. We show how the code can be used as a nowcasting tool of both ring current and radiation belt electron populations if only the Kp index and particle observations at geostationary orbit are given.

PRBEM.1-0009-18 SPECIFICATION OF KEV ELECTRON RADIATION ENVIRONMENT AT GEO AND MEO

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Surface charging anomalies at near-Earth orbiting satellites have been attributed to electrons of energy below 100 keV. Accurate specification of the space environment at different orbits is of a key importance. We present the operational model for low energy (< 200 keV) electrons in the inner magnetosphere, Inner Magnetosphere Particle Transport and Acceleration model (IMPTAM). This model has been operating online since March 2013 (http://fp7-spacecast.eu and imptam.fmi.fi) and it is driven by the real time solar wind and IMF parameters and by the real time Dst index. The presented model provides the low energy electron flux at all L-shells and at all satellite orbits, when necessary. IMPTAM is used to simulate the fluxes of low energy electrons inside the Earth's magnetosphere at the time of severe events measured on LANL satellites at GEO. There is no easy way to say what will be the flux of keV electrons at MEO when surface charging events are detected at GEO than to use a model. The maximal electron fluxes obtained at MEO (L = 4.6) within a few tens of minutes hours following the LANL events at GEO have been extracted to feed a database of theoretical/numerical worst-case environments for surface charging at MEO. All IMPTAM results are instantaneous, data have not been average. In order to validate the IMPTAM output at MEO, we conduct the statistical analysis of measured electron fluxes onboard Van Allen Probes (ECT HOPE (20 eV-45 keV) and ECT MagEIS (30 - 300 keV) at distances of 4.6 Re. IMPTAM eflux at MEO is used as input to SPIS, the Spacecraft Plasma Interaction System Software toolkit for spacecraft-plasma interactions and spacecraft charging modelling (http://dev.spis.org/projects/spine/home/spis). The research leading to these results was funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 637302 PROGRESS.

PRBEM.1-0010-18 SPACE IONIZING RADIATION ENVIRONMENT AND EFFECTS (SIRE2) MODEL FOR SATELLITE DESIGN

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We will describe a space radiation environments model that addresses the limitations of earlier tools. SIRE2 provides space environment and effects calculations for orbiting satellites based on the latest models of the space radiation environment. In this model the radiation environment just outside the Earth's magnetosphere consists of the galactic cosmic ray environment as described by the Badhwar-O'Neill 2014 Model and the solar energetic particle model as described by a probabilistic model developed by Robinson and Adams (2017). The description of the transmission of this environment to a satellite orbiting within the magnetosphere is based on the Smart-Shea 2005 model. The trapped radiation environment (both protons and electrons) at this satellite is described using the 2017 IRENE model. Finally, SIRE2 provides a means to transmit the radiation environment to points of interest within the satellite.

SIRE2 provides the total dose rate from protons and electrons and the Linear Energy Transfer (LET) spectrum at the point of interest within the satellite. It also provided characterizations of the radiation effects on electronic parts based on the methods used in CREME96. It has the capability to efficiently process large batches of parts in order to obtain characterizations of their response to the radiation environment. In addition, batches of environments can be created and used for parts characterizations.

SIRE2 has a graphical user interface that displays all the ways in which calculations can be set up and run. This includes choices of how the satellite's orbit is defined, what assumptions are made about the space weather conditions, how the results of the calculations are to be presented, viewed and preserved. This interface also affords access to the full capabilities of CREME96 for modeling radiation effects on electronics.

PRBEM.1-0011-18 RECURRENT NEURAL NETWORKS FOR MODELING THE GLOBAL PLASMASPHERE DYNAMICS

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Plasmasphere is a torus of cold plasma surrounding the Earth and is a very dynamic region. Its dynamics is driven by space weather, and having an accurate model of the plasmasphere is very important for wave-particle interactions and radiation belt modeling. In the recent years, feedforward neural networks have been successfully applied to reconstruct the global plasmasphere dynamics in the equatorial plane [Bortnik et al., 2016, Zhelavskaya et al., 2017, Chu et al., 2017]. These neural network-based models have been able to capture the large-scale dynamics of the plasmasphere such as plume formation and the erosion of the plasmasphere on the night side. These models explicitly took as an input the time history of various geomagnetic and solar wind activity over a certain period of time in the past and modelled the electron density as a function of these inputs and the location. These models did not take into account, however, the spatiotemporal behaviour of the electron density which could put limitations on their performance. Recently developed recurrent neural networks, specifically long short-term memory neural networks (LSTMs), are very effective at including temporal effects in the model implicitly. The time history is aggregated in the hidden nodes of an LSTM during training, and in such way, the LSTMs are capable of selecting important features of the given problem internally without the need to select optimal inputs manually. In this work, we present the results of applying LSTMs to reconstruct the global plasmasphere dynamics. To train LSTMs we use electron density database from Van Allen Probes obtained using the NURD algorithm (covering Oct 2012 - Dec 2017 [Zhelavskaya et al., 2016]). We validate the model similarly as in Zhelavskaya et al. 2017, by measuring model's performance on independent datasets withheld from the training set and by comparing the model predicted global evolution with global images of He+ distribution in the Earth's plasmasphere from the IMAGE Extreme UltraViolet (EUV) instrument. We compare the performance of RNNs to several other empirical models and demonstrate results of global density reconstruction.

PRBEM.1-0012-18 PROBABILISTIC MODELING OF THE SPACE RADIATION ENVIRONMENT

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Design of and planning for space missions must account for possible solar energetic particle (SEPs) events during these missions. Historically, missions account for SEPs by designing or planning to survive in the worst known operating environment. While this approach ensures that the satellite is protected against the worst environment on record, it usually leads to expensive over-design of the satellite. For this reason, it is important to choose a missionspecific design reference environment which will lead to the desired mission reliability while avoiding expensive over-design of the satellite.

We will describe two different probabilistic models for Solar Energetic Particle events. These models allow the user to tailor the design reference environment to his mission (characterized by its start date and duration) and to specify a confidence level for reliable mission operations which he wishes to achieve.

The first model is an episode-integrated fluence model. It is intended to estimate the highest dose that could be accumulated over periods ranging from a few weeks to several years. It is valid through 2053. The second model is a peak mission flux model. This model can be used for mission durations ranging from 10's of minutes to many years. It is also valid through 2053. It is used for estimating peak single event effect rates in satellite electronics. Both models use the probabilistic modeling techniques developed by Xapsos et al. (1998). For short missions (10s of minutes), the peak flux model uses a new data driven approach to create the reference environment. For longer missions it follows the method of Xapsos, making use of an extended database.

Reference: Xapsos, M. A., Summers, G. P. and Burke, E. A. (1998) 'Probability model for peak fluxes of solar proton events', IEEE Transactions on Nuclear Science, 45(6 PART 1), pp. 2948-2953. doi: 10.1109/23.736551.

PRBEM.1-0013-18 APPLICATION OF NARMAX METHODOLOGY TO THE FORECAST OF RADIATION ENVIRONMENT IN THE GEOSPACE.

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Among methodologies, used in the field of System Science the Nonlinear AutoRegressive Moving Average models with eXogenous inputs (NARMAX) represents a powerful approach to system identification that already resulted in the development of a few space weather forecasting models. The results of NARMAX applications to the forecast of fluxes of energetic electrons at GEO and modelling of key magnetospheric plasma emissions that affect dynamics of these electrons are reviewed. The challenges in the future development of NARMAX based forecasting tools that will be able to forecast fluxes of relativistic electrons within the whole region of radiation belts are discussed.

PRBEM.1-0014-18 LONG-TERM VERB CODE SIMULATIONS OF RELATIVISTIC AND ULTRARELATIVISTIC ELECTRONS

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The dynamics of the outer radiation belts is controlled by several physical processes. One of the dominant process that drives acceleration and loss is radial diffusion which affect the electrons in a wide energy range. Another important mechanisms are localized energy and pitch-angle diffusion due to wave-particle interactions. Recent observations and modeling showed that the dynamics of the relativistic and ultra-relativistic electron populations can be quite different. This difference is a combination of many factors where electromagnetic ion cyclotron (EMIC) waves play an important role.

In this study, we perform several long-term simulations with the Versatile Electron Radiation Belt (VERB) code, and we compare results of the simulation with the Van Allen Probes observations. We investigate the sensitivity of the several parameterizations of the radial diffusion [e.g. Brautigam and Albert, 2000; Ozeke et al., 2014; Ali et al., 2016; Liu et al., 2016] and the effect of the EMIC waves on the radiation belts modeling. Incorporation of the EMIC waves in the long-term simulations is a challenging task due the the sporadic nature of the EMIC wave occurrence. We investigate different geomagnetic indexes and solar wind parameters as the potential drivers of the waves in our simulations. The comparison shows that simulations with obtained model of EMIC waves presence provide a better agreement with the observations.

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PRBEM.2-0001-18 SPACE SCIENCE ON THE EXPERIMENTAL ALBERTAN SATELLITE #1 (EXALTA-1) CUBESAT MISSION

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Cube-satellite (CubeSat) platforms are increasingly being considered for scientific research, with the goal of achieving future constellation class missions for studies of geospace. We describe the design, validation, test, and initial on-orbit results from the University of Alberta Experimental Albertan Satellite 1 (Ex-Alta-1) Cube Satellite, launched in 2017 from the International Space Station as part of the QB50 constellation mission. The payload includes a miniature, lowmass, low-power, and low-magnetic noise boom-mounted fluxgate magnetometer flown, a multineedle Langmuir Probe, and a radiation dosimeter. The miniature magnetometer achieves a magnetic noise floor of 150-200pT/Hz at 1Hz, consumes 400mW of power, has a mass of 121g (sensor and boom), stows on the hull, and deploys on a 60cm boom from a three-unit CubeSat reducing the noise from the onboard reaction wheel to less than 1.5nT at the sensor. The magnetometer's capabilities are being demonstrated and validated in space with flight on ExAlta-1 with a view to its use for monitoring plasma waves at high resolution for space science, magnetosphere-ionosphere coupling, and space radiation studies. We present on-orbit data from the magnetometer boom-deployment and initial operations of the fluxgate sensor and illustrate the potential scientific returns and utility of using CubeSats carrying such fluxgate magnetometers to constitute a magnetospheric constellation mission. We further present results from the dosimeter which characterises the radiation from the low Earth orbit of the Ex-Alta-1 CubeSat.

PRBEM.2-0002-18 CUBESAT MISSIONS TO STUDY RADIATION BELT ELECTRON DYNAMICS AND LOSS

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Interest in CubeSats has grown dramatically in the past decade within the space physics community. While CubeSats are generally accepted now to be useful tools for education and technology development/demonstration, their ability to provide scientific value is often still questioned. Radiation belt physics, however, is one area in which the scientific utility of these small platforms has been demonstrated and continues to offer great promise. Here we'll present some highlights from recent, along with upcoming, radiation belt-related CubeSat missions. The Colorado Student Space Weather Experiment (CSSWE) CubeSat, launched in 2012 and designed, built, and operated by students at University of Colorado, was one of the first of now a long line of successful CubeSats designed to study radiation belt dynamics. Results from CSSWE will be presented, with an emphasis on how these measurements have been combined with those from balloons and larger satellite missions to better understand radiation belt electron acceleration and loss processes. A status update of the more recent Compact Radiation belt Explorer (CeREs) CubeSat, built at NASA/Goddard and scheduled for an April 2018 launch, will also be presented. Finally, we'll discuss a plan to move beyond low Earth orbit (LEO) with the upcoming GTOsat CubeSat currently in development, which will fly in a geosynchronous transfer orbit providing energetic electron measurements through the heart of the radiation belts. Radiation belt studies are a prime example of how small, low-cost spacecraft can be used to provide valuable scientific measurements and complement larger missions.

PRBEM.2-0003-18 THE RELATIVISTIC ELECTRON ATMOSPHERIC LOSS (REAL) CUBESAT

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The Relativistic Electron Atmospheric Loss (REAL) CubeSat mission will characterize different modes of atmospheric loss by making high time resolution measurements of the electron pitch angle and energy distributions, in low Earth orbit (LEO), over a wide energy range, from keV to MeV. LEO is ideal for measuring precipitation since the atmospheric loss cone is larger (60 deg) than at the equator (few degrees). In particular, it is possible to measure the pitch angle distribution within the loss cone, revealing information about the scattering process. Significant progress has been made in identifying the plasma waves that drive atmospheric precipitation [e.g., Thorne, 2010 for review]. However, the physical "modes" in which these act is not well specified: electrons may be scattered slowly through a diffusive process [e.g., Shprits et al., 2008 review], or rapidly through nonlinear processes [e.g., Albert, 2000; Bortnik et al., 2008, Omura et al., 2015]. The physical mode determines the scattering rate and thus the impact on the radiation belts. Therefore, it is important to establish where and how frequently loss mechanisms act in different modes for particles of different energies. REAL will investigate the physical mechanisms responsible for scattering radiation belt electrons into the atmosphere by determining when and where different precipitation loss modes (diffusion, strong diffusion, and nonlinear scattering) occur. The pitch angle-resolved measurements will also allow us to distinguish between precipitating, quasi-trapped, and trapped populations of electrons, thus more accurately quantifying the electron loss rate from the radiation belts.

PRBEM.2-0004-18 SMALL SCALE MAGNETOSPHERIC AND IONOSPHERIC PLASMA EXPERIMENTS (SNIPE) MISSION FOR MAGNETOSPHERIC AND IONOSPHERIC RESEARCH

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In order to resolve the spatial and temporal variations of the various microscale plasma structures on the topside ionosphere, SNIPE mission consisted of four 6u nanosatellites (12 kg) will be launched into a polar orbit at an altitude of 500-600 km. Two pairs of satellites will be deployed on orbit and the distances between each satellite will be from 10 to 100 km controlled by a formation flying algorithm. The SNIPE mission is equipped with scientific payloads which can measure the following geophysical parameters: density/temperature of cold ionospheric electrons, energetic electron flux of hundreds keV, and magnetic field vectors. All the payloads will have high temporal resolution of 16 Hz. This mission is planned to launch in 2020. We have developed a 6U nanosatellite bus system as the basic platform for the SNIPE mission. Three basic plasma instruments shall be installed on all of each spacecraft, solid state telescope (SST), langmuir probe (LP), and fluxgate magnetometer (MAG). The SNIPE mission's scientific goals are as following; (1) electron microbursts, (2) trough and polar cap patches, (3) equatorial plasma bubbles/blobs/MSTIDs, (4) electro-magnetic ion cyclotron (EMIC) waves, and (5) field aligned current (FAC). Electron microbursts are observed at 50-70 degrees of latitude during the storm recovery phase, mainly at local dawn sector. Through the electron microburst observation experiment of the SNIPE mission, we expect to obtain the spatial scale and energy dispersion of electron microbursts. The multiple satellite LPs' observations with high sampling rates in high temporal (less than 1 second) and spatial (10 km - 100 km) resolutions enable us to comprehensively investigate the sub-auroral trough morphology, especially latitudinal and longitudinal small-scale (< 100 km) structures, and to understand the behavior of the small-scale temporal (less than 1 second) and spatial (10 km - 100 km) variations of the trough during geomagnetic storms. Using formation flying SNIPE satellites, we would also expect to discern the spatial and temporal structures of EMIC and to analyze the correlation between proton/electron precipitation and EMIC waves by using multi-satellites' observations such as SNIPE, GOES, Arase, VAP and other ground stations.

PRBEM.2-0005-18 THE DEMONSTRATION AND SCIENCE EXPERIMENTS (DSX) MISSION

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In 2018, the Air Force Research Laboratory will launch its Demonstration and Science Experiments (DSX) mission to investigate wave-particle interactions and the particle and space environment in medium Earth orbit (MEO). The DSX spacecraft includes three experiment packages. The Wave Particle Interaction Experiment (WPIx) will perform active and passive investigations involving VLF waves and their interaction with plasma and energetic electrons in MEO. The Space Weather Experiment (SWx) includes five particle instruments to survey the MEO electron and proton environment. The Space Environmental Effects Experiment (SFx) will investigate effects of the MEO environment on electronics and materials. We will describe the capabilities of the DSX science payloads, planned science campaigns, and opportunities for collaborative studies such as conjunction observations and far-field measurements.

PRBEM.2-0006-18 THE COMPACT RADIATION BELT EXPLORER, CERES: A CUBESAT MISSION TO STUDY ELECTRON MICROBURSTS

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Recently CubeSats have become robust and sophisticated enough to enable investigation of important scientific problems. I will describe the CubeSat mission,CeREs (Compact Radiation belt Explorer). CeREs will be launched into a high inclination low earth orbit. CeRES carries onboard, the MERiT, Miniaturized Electron pRoton Telescope, an innovative compact solid state particle telescope. CeREs will study electron microbursts, which are an important loss mechanism in Earth's radiation belts as well as electron dynamics of the radiation belts in general.

PRBEM.2-0007-18 A REVISED LOOK AT RELATIVISTIC ELECTRONS IN THE INNER ZONE AND SLOT REGION

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We describe a new procedure for estimating and removing inner zone background contamination in the Van Allen Probes MagEIS electron measurements. This new procedure is based on the underlying assumption that the primary source of background contamination at L<3, energetic inner belt protons, is relatively stable. This allows us to build a model of the background contamination by binning the MagEIS histogram data from each detector in time and L, when the measurements are known to be background-dominated. While this new procedure is inherently limited in several aspects (e.g., temporal cadence, energy coverage, spatial coverage), it is demonstrated to be an improvement upon the routine background corrections that are part of the standard data processing. In particular, we are able to extract more foreground signal out of the relativistic electron data in the inner zone, which reveals that the 1 MeV injection reported in Claudepierre et al., [2017] is distributed more broadly in L than was previously thought, and persists in the inner zone longer than was previously thought. We discuss these new results and

compare with more recent data that also shows 1 MeV electron injections into the inner zone during the September 2017 shock event.

REFERENCE: Claudepierre, S. G., et al., (2017), The hidden dynamics of relativistic electrons (0.7-1.5 MeV) in the inner zone and slot region, J. Geophys. Res. Space Physics, 122, doi:10.1002/2016JA023719.

PRBEM.2-0008-18 OBSERVATIONS OF THE INNER MAGNETOSPHERE FROM THE ARASE SATELLITE

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Geospace Exploation Project; ERG addresses what mechanisms cause acceleration, transportation and loss of MeV electrons of the radiation belts and evolutions of space storms. Cross-energy and cross-regional couplings are key concepts for the project. In order to address questions, the project has been organized by three research teams; satellite observations, ground-based observations, and modeling/data-analysis studies, and interdisciplinary research are realized for comprehensive understanding of geospace. The Arase satellite was successfully launched on December 20, 2016. After the initial operation including maneuvers, Arase has started normal observations since March, 2017. Arase has observed several geomagnetic storms driven by coronal hole streams and CMEs, and several interesting features are observed associated with geomagnetic disturbances. The six particle instruments; LEP-e/LEP-i/MEPe/MEP-i/HEP/XEP have shown large enhancement as well as loss of wide energy electrons and ions and variations as well as changes of pitch angle and energy spectrum. The two field/wave instruments: PWE and MGF observed several kinds of plasma waves such as chorus, hiss, EMIC as well as large scale electric and magnetic field variations. The project has collaborated with the international projects, EISCAT, SuperDARN and other ground-based observations, and various data are obtained from such international collaborations. Moreover, multi-point satellite observations by collaboration with other satellites; Van Allen Probes, THEMIS and MMS have been going. In this presentation, we will report overview and initial highlights for the first year and discuss importance of synergies of multi-satellites and ground-based observations that are realized by international collaborations.

PRBEM.2-0009-18 OBSERVATIONS OF THE TRAPPED AND PRECIPITATING IONIZING RADIATION FROM THE LEO ORBIT

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We discuss the observations of the locally trapped and precipitating particles from the LEO orbit. Observations from this vantage point provide a unique opportunity to resolve the drift and bounce loss cone, understand the loss processes in the radiation belts and measure precipitating fluxes that can change upper atmospheric chemistry. We report on the first results obtained from the Electron Losses and Fields INvestigation on board the Lomonosov satellite (ELFIN-L). The main objective of the project is to determine the rate of storm-time relativistic electron precipitation during geomagnetic storms and to understand the mechanisms responsible for the precipitation. ELFIN-L provides in-situ measurements of the trapped electron fluxes and electron fluxes in the loss cone over the period of six months from June until December 2016. Orientation of the ELFIN-L instruments allows us to sample both trapped and precipitating fluxes on a three-axis stabilized spacecraft. By measuring the electron precipitation rate and determining the dominant loss mechanism of relativistic electrons during storms, ELFIN-L allows us to quantify electron losses as a function of energy for use in global predictive models of the near-Earth radiation environment.

PRBEM.2-0010-18 OBSERVATIONS OF TRAPPED ELECTRONS AND POSITRONS WITH ENERGY MORE THEN 50 MEV IN THE INNER RADIATION BELT WITH THE PAMELA MAGNETIC SPECTROMETER

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Trapped electrons and positrons with energy above 50 MeV were observed in PAMELA experiment on board Resurs DK satellite. The instrument consists of magnetic spectrometer, imaging calorimeter, time of flight system, anticoincidence and neutron detectors that provide unique particle identification and background rejection. The satellite orbit with altitude 350- 600km and inclination 70 degrees crosses the inner radiation belt in South Atlantic Anomaly. PAMELA was collecting data since June 2006 till January 2016. The trapped electrons and positrons were selected on the basis of a trajectory simulation in the Earth magnetic field. Features of energy spectra of trapped electrons and positrons were analyzed.

PRBEM.2-0011-18 RECENT AND UPCOMING OBSERVATIONS OF THE CARACTéRISATION ET MODéLISATION DE L'ENVIRONNEMENT (CARMEN) MISSION

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We have developed a series of instruments for energetic particle measurements, associated with component test beds "MEX". The aim of this program is to check and improve space radiation engineering models and techniques. The first series of instruments, "ICARE" has flown on the MIR space station (SPICA mission), the ISS (SPICA-S mission) and the SAC-C low Earth polar orbiting satellite (ICARE mission 2001-2011) in cooperation with the Argentinian space agency CONAE. A second series of instruments "ICARE-NG" was and is flown:

CARMEN-1 mission on CONAE's SAC-D, 650 km, 98°, 2011-2015, along with three "SODAD" space micro-debris detectors

CARMEN-2 mission on the JASON-2 satellite (CNES, JPL, EUMETSAT, NOAA), 1336 km, 66°, 2008-now, along with JAXA's LPT energetic particle detector

CARMEN-3 mission on the JASON-3 satellite in the same orbit as JASON-2, launched 17 January 2016, along with a plasma detector "AMBRE", and JAXA's LPT again.

The ICARE-NG spectrometer composed of a set of three fully depleted silicon solid state detectors used in single and coincident mode. The on-board measurements consist in accumulating energy loss spectra in the junctions over a programmable accumulation period. The spectra are generated through signal amplitude classification using 8 bit ADCs and resulting in 128/256 channels histograms. The discriminators reference levels, amplifier gain and accumulation time for the spectra are programmable to provide for possible on-board tuning optimization.

Ground level calibrations have been made at ONERA-DESP using radioactive source emitting alpha particles in order to determine the exact correspondence between channel number and particle energy. To obtain the response functions to particles, a detailed sectoring analysis of the satellite associated with GEANT4/MCNP-X calculations has been performed to characterize the geometrical factors of the each detector for p+ as well as for ewith different energies.

The component test bed "MEX" is equipped with two different types of active dosimeters, P-MOS silicon dosimeters and OSL (optically stimulated luminescence). Those dosimeters provide independent measurements of ionizing and displacement damage doses and consolidate spectrometers' observations.

The data sets obtained cover more than one solar cycle. Dynamics of the radiation belts, effects of solar particle events, coronal mass ejections and coronal holes were observed. Spectrometer measurements and dosimeter readings were used to evaluate current engineering models, and helped in developing improved ones, along with "space weather" radiation belt indices. The paper will provide a comprehensive review of detector features and mission results.

PRBEM.2-0012-18 INTERNAL CHARGING IN MEO USING THE SURF SENSOR

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The SURF instrument is a shielded current sensor with fA/cm-2 sensitivity which measures the key space weather hazard of internal charging in a very direct fashion. One such sensor has been operating in a GPS-like medium earth orbit (MEO) on the Giove-A spacecraft for a full solar cycle with only a few interruptions. Using three stacked shielded plates we observe internal charging currents due to electron energies from about 500keV to >3MeV. These currents have been converted to differential fluxes using plate response functions alongside some assumptions about spectral shape. No dead-time corrections are required since there is no counting process involved. In addition there is negligible contamination from protons even during intense solar particle events. The simplicity of the instrument and careful reference irradiations before flight mean that the results are highly reliable. We will present data obtained over the solar cycle and review periods of particular interest including the electron desert period in 2009 and the recent upsurge in internal charging events in the decline from solar maximum. We also describe a new model of the outer belt, MOBE-DIC, which has been developed from the SURF data which is intended for engineering applications. Furthermore reference is made to an earlier data set from the very first SURF instrument in geostationary transfer orbit which found significant inner belt charging currents which is at odds with recent Van Allen Probes measurements from this region and thus that data might be more significant than first thought. Looking to the future a further SURF instrument should be launched on DSX in June 2018 so further results from MEO should soon be available.

PRBEM.2-0013-18 MULTIPOINT ENERGETIC ELECTRON AND PROTON MEASUREMENTS FROM THE GLOBAL POSITIONING SYSTEM CONSTELLATION

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The Global Positioning System (GPS) satellites are distributed across six orbital planes and follow near-circular orbits, with a 12 hour period, at an altitude of approximately 20200 km. The six orbital planes are distributed around the Earth and are nominally inclined at 55 degrees. Energetic particle detectors have been flown on the GPS constellation for more than two decades; by February 2016 there were 23 GPS satellites equipped with energetic particle instrumentation. Electron data from the Combined X-ray Dosimeter (CXD), which is flown on 21 GPS satellites, has been cross-calibrated against data from the Van Allen Probes mission, demonstrating its utility for scientific research and radiation environment specification. Energetic particle data from these instruments were publicly released in 2017, including the crosscalibrated electron fluxes. Recently the CXD energetic proton data has been cross-calibrated against GOES Space Environment Monitor data using a set of Solar Energetic Particle (SEP) events. We will describe the GPS constellation from the perspective of its use as a monitor for space weather, including the electron radiation belts and SEPs. We will review the crosscalibration of the particle data and will discuss the advances enabled in understanding Earth's radiation environment by the availability of these data.

PRBEM.2-0014-18 COMPREHENSIVE OBSERVATIONS OF EMIC WAVES DURING THE FOUR GEM QARBM CHALLENGE INTERVALS: COMBINING WAVE DATA FROM SPACECRAFT AND GROUND OBSERVATORIES WITH POES PROTON PRECIPITATION DATA

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This study presents observations of EMIC waves from multiple data sources during the four challenge events in 2013 selected by the GEM focus group on Quantitative Assessment of Radiation Belt Modeling: March 17-18 (Stormtime Enhancement), May 31-June 2 (Stormtime Dropout), September 19-20 (Non-storm Enhancement), and September 23-25 (Non-storm Dropout). In addition to EMIC wave data from the Van Allen Probes, GOES, and THEMIS spacecraft in the near-equatorial magnetosphere and from several arrays of ground-based search coil magnetometers worldwide, we show localized ring current proton precipitation data from low-altitude POES spacecraft. Each of these data sets provides only limited spatial coverage, but their combination shows consistent occurrence patterns and reveals some events that would not be identified as significant using near-equatorial spacecraft alone. Relativistic and ultrarelativistic electron flux observations from the REPT instrument on the Van Allen Probes during the two dropout intervals and one enhancement interval show several cases during which EMIC waves are plausible candidates for flux dropouts that are localized in L.

PRBEM.2-0015-18 CHORUS ELEMENT PROPERTIES: STATISTICS OF SWEEP RATE AND WAVE POWER

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Using novel signal processing techniques, we have developed autonomous algorithms that can analyze Van Allen Probes waveform observations to determine the characteristics of individual chorus elements. In particular, the methods allow us to determine the frequency/time sweep rate of chorus elements for a large number of events without the need for manual identification of the elements. This enables statistical studies of the properties of the individual chorus elements which has been limited in the past to small numbers of events identified and analysed by hand. We present the basics of the technique and show initial results of the statistics on the range and character of chorus element sweep rate and correlations with other plasma properties. We also show initial work on understanding the power in chorus elements by themselves as compared spectral averages over time and frequency.

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PRBEM.2-0016-18 EMIC WAVE DRIVEN ELECTRON PRECIPITATION - ENERGETIC, RELATIVISTIC, ULTRARELATIVISTIC, OR ALL OF THE ABOVE?

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It has long been predicted through theory that Electromagnetic Ion Cyclotron Waves (EMIC) should drive significant energetic electron precipitation from the radiation belts into the lower ionosphere. Recently, ground based observations of EMIC waves and ionospheric disturbances have been combined with Low-Earth Orbit precipitation measurements made by the POES constellation to conclusively identify hundreds to thousands of examples of EMIC driven electron scattering into the atmosphere [e.g., Hendry et al., doi:10.1002/2015JA022224, 2016]. However, this large set of events appear to have significant fluxes of electrons with energies of hundreds of keV, which is generally lower than that expected by theory based on first order cyclotron resonance. Differential electron fluxes tend to peak at 250 keV, with only 11% of the events peaking in the 1-4 MeV range [Hendry et al., doi:10.1002/2016GL071807, 2017]. These experimental observations appear to confirm the theory of Non-Resonant Interactions with EMIC waves with “sharp edges” [Chen et al., doi:10.1002/2016JA022813, 2016].

At the same time, there is a growing body of satellite observations suggesting that EMIC waves are efficient scatters of 2-8 MeV ultra-relativistic electrons [e.g., Usanova et al., doi:10.1029/2013GL059024, 2014]. These observations are supported by theory [e. g., Shprits et al., doi:10.1038/ncomms12883,

2016], where cyclotron resonance is most efficient at ultra-relativistic energies, and can lead to non-reversible electron “dropouts” in the trapped fluxes populations. Multiple case studies have been presented [e.g., Shprits et al., doi:10.1002/2016GL072258, 2017; Aseev et al., doi:10.1002/2017JA024485, 2017], and there appears to be growing conviction in the commu- nity around the importance of these waves in this energy range. However, at this time there is a lack of any clear observations of the ultra-relativistic electron precipitation - despite dramatic changes in the trapped fluxes being predicted.

In this presentation we attempt to apply multiple ground-based experimental datasets to test if the observations are indeed consistent with the presence of ultra-relativistic electron precipitation. Specifically, we examine the wide beam riometer at Halley (Antarctica), and the EISCAT incoherent radar measurements from Tromsø (Norway), along with observations from the low-Earth orbiting POES satellites.

PRBEM.2-0017-18 THE FASCINATING DYNAMICS OF THE HIGH-ENERGY VAN ALLEN RADIATION BELTS

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High-energy particles contained within the Van Allen belts can be dangerous to sensitive electronics in space, and can affect human activity on the Earth's surface. Precipitating radiation leaving the radiation belts for the Earth's atmosphere can play a role in terrestrial weather and climate systems. Over the nearly six years of high-energy particle measurements obtained by the Relativistic Electron Proton Telescope (REPT) instrument onboard NASA's Van Allen Probes mission, a fascinating array of variation and dynamics can be observed in the outer belts. Here we present several key results showing how the belts can be accelerated up to these very high energies. We also show that it is difficult to generalize from one event to the next, since the resulting dynamics are a complex interplay between various acceleration and loss mechanisms. No two storm events or non-storm events are quite alike, and as such we point out the need for event-specific simulation efforts to enhance our understanding of the full system.

PRBEM.2-0018-18 CALIBRATION OF THE GOES 13/15 HIGH-ENERGY PROTON DETECTORS BASED ON THE PAMELA SOLAR ENERGETIC PARTICLE OBSERVATIONS

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The Energetic Proton, Electron, and Alpha Detector (EPEAD) and High Energy Proton and Alpha Detector (HEPAD) instruments on the Geostationary Operational Environmental Satellite (GOES) spacecraft have served over many years as monitors of the solar particle intensities, surveying the Sun and measuring in situ its effect on the near-Earth solar-terrestrial environment. However, the reconstruction of the differential energy spectra is affected by large uncertainties related to the poor energy resolution, the small geometrical factor, and the high contamination by out-of-acceptance particles. In this work, the high-quality data set from the Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics (PAMELA) space mission is used to calibrate the high-energy (>80 MeV) proton channels of the EPEAD and the HEPAD sensors on board the GOES 13 and 15, bringing the measured spectral intensities inline with those registered by PAMELA. Suggested corrections significantly reduce the uncertainties on the response of GOES detectors, thus improving the reliability of the spectroscopic observations of solar energetic particle events.

PRBEM.2-0019-18 THE CLUSTER II MISSION, RECENT OBSERVATIONS AND INSTRUMENT CALIBRATIONS

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For over 16 years, the Cluster mission passes through radiation belts of the Earth at least once every two days for several hours, measuring the energetic electron intensity at energies from 40 to 400 keV by RAPID/IES instrument. This vast amount of observations has previously been considered as rather useless due to contamination by penetrating energetic particles. In this study, we assess the efficiency with which aluminum shielding of RAPID/IES detector filters out bombarding particles. For this we used a radiation transport code (Geant4). In our simulations, we employ the incident particle energy distribution of the AE9/AP9 radiation belt models. We identify the Roederer L-values and energy channels that should be used with caution and show an example of misinterpreting the data. We propose methods to correct the data in contaminated regions. After applying the corrections we compare the data with electron observations from the Van Allen Probes/MagEIS. The comparison shows that the data from the RAPID/IES measured in the radiation belts is still useful for scientific applications and show examples.

PRBEM.2-0020-18 SPLITTING OF THE OUTER RADIATION BELT DURING SUBSTORMS AT SOLAR ACTIVITY MINIMUM AS SEEN BY CORONAS-PHOTON SATELLITE INSTRUMENTS

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The satellite telescope of electrons and protons STEP-F and the solar X-ray spectrophotometer SphinX, placed in close proximity to each other, have collected data on particle fluxes aboard circular low Earth orbit CORONAS-Photon satellite during deep minimum of solar activity, which took place in 2009. Whilst STEP-F, comprising a set of silicon PIN and scintillation sensors, served as detector for direct registration for particles, the SphinX has detected not only soft X-rays of solar corona but also bremsstrahlung and line emission in bandwidth of X-rays arising as a result of interaction of high energy electrons with the satellite's housings and instrument's frames. These emissions provide a number of new information on the physics of radiation belts.

In this research we discuss phenomena of outer radiation belt splitting during weak geomagnetic substorms of May and August 2009, detected by both instruments. We make use of the data on particle fluxes observed at L1 Lagrange point and geostationary GOES satellites for context analysis. Double-peaked L-profile of the outer radiation belt and increase of electron fluxes were recorded by STEP-F and SphinX instruments during recovery phase of weak geomagnetic storm on May 8, 2009. STEP-F recorded also barely perceptible outer belt splitting on August 5 2009, after arrival of interplanetary shock.

As far as instruments' fields of view were orthogonally oriented, this allowed to record particle beam at onset of May's substorm by SphinX instrument only that prompted to suggest different mechanisms of populating enhanced electron fluxes during the onset and recovery phases of substorm. At onset of substorm processes of rapid radial diffusion of narrowly directed lowenergy electron fluxes from the boundary layers of the Earth's magnetosphere to the region of steady particle capture prevailed. During the main phase of storm the pitch-angle scattering caused the emptying of outer radiation belt, which was observed both at low altitudes and at altitudes of geostationary satellites.

PANELS (P)

SCIENTIFIC BALLOONING: RECENT DEVELOPMENTS IN TECHNOLOGY AND INSTRUMENTATION (PSB.1)

PSB.1-0001-18 OVERVIEW OF THE NASA SCIENTIFIC BALLOON ACTIVITIES

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NASA's Balloon Program has incorporated several changes over the past four years to improve upon safety of operations and to incorporate advanced technologies to achieve more science. Balloon launch campaigns have been conducted domestically and internationally including the re-initiation of Palestine, Texas as a launch location. The Wallops Arc Second Pointer has become qualified as a balloon support system and has become the fine pointing system for several balloon science missions. The development of the super pressure heavy-lift balloon remains at the forefront of the technology development efforts with three southern hemisphere test flights flown from New Zealand. More efficient balloon power systems and higher bandwidth telecommunications systems have been in development to offer greater reliability at lower mass. The current state of NASA's scientific balloon program, its operations, and technology development will be presented, along with plans for the future.

PSB.1-0002-18 10-YEAR SCIENTIFIC BALLOONING IN TAIKI

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Since 2008, Japan Aerospace Exploration Agency (JAXA) has conducted scientific ballooning at Taiki Aerospace Research Field (TARF) in Hokkaido. In these 10 years, we carried out 30 balloon-borne experiments. Using wide field of TARF to advantage, we can launch larger balloons than before which enable us to realize much complex and the cutting-edge experiments. On the other hand, due to the recent unstable stratospheric wind condition, we can provide short duration flights, mostly less than two hours. Therefore, flight opportunities in Taiki are not suitable for high-statistical astronomy or cosmic-ray experiments, and atmospheric observations and space engineering demonstrations become dominant objectives in the domestic balloon flights.

In this presentation, we summarize JAXA's 10-year scientific ballooning at TARF. We also introduce our overseas activities which is complementary to the domestic ballooning and technology developments for future space science.

PSB.1-0003-18 SWEDISH BALLOON ACTIVITIES SINCE LAST COSPAR ASSEMBLY

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Since the last COSPAR assembly in Moscow, Swedish Space Corporation (SSC) has worked with several balloon missions from its Esrange facility in the north of Sweden. A total of 57 balloons have been launched since August 2014, and 51 of these have been launched and operated by SSC, with the rest being flown by CNES and a US university. The missions have been from several fields of science, e.g. astrophysics, aerodynamics and meteorology, as well as educational and technical flights, and some flights for commercial customers. The flights have been throughout the full envelope of balloon missions, from a few kg to 2 ton payload, from 2 hour flights to 7 days and from 10 to 40 km altitude. The Swedish National Space Agency funded one of the flights within the Swedish balloon programme, and has one more mission currently planned in that programme. For the agency flight, SSC also provided all flight equipment as well as the payload, except the scientific instrument. In the coming 5 years, several balloon missions are planned for users from all over the world. Balloon missions performed by SSC are also being planned to be launched from locations globally.

PSB.1-0004-18 HEMERA - AN OPPORTUNITY FOR SCIENCE USING STRATOSPHERIC BALLOONS

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HEMERA is an European infrastructure for scientific ballooning. The objectives of HEMERA are to provide balloon access to the troposphere and stratosphere for scientific and technological research, to enlarge the fields of research conducted with balloons, to improve the balloon service offered to the users and to reduce costs by standardization, use of synergies and industrialization through joint ventures. Partners are space agencies and space access providers, research centers, universities and relevant industry. The infrastructure is funded by the Horizon 2020 framework program of the European Union. HEMERA offers to users a possibility to fly small to medium payloads at no cost on CNES or SSC gondolas under Zero Pressure Balloons and Sounding Balloons. Technical details of the offer and the access process will be described.

PSB.1-0005-18 FRENCH BALLOON ACTIVITIES NATIONAL REPORT 2016–2019

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The French Centre National d'Etudes Spatiales (CNES) goes on supporting a significant balloon program and infrastructure, for scientific and technological purposes. Designed to be mobile, the CNES balloon systems and operation means can be deployed and operated worldwide, at several latitudes. The extended range of vehicles and payload gondola support provided by CNES allow addressing several kinds of missions such as astronomy, atmospheric physics and chemistry, stratospheric and tropospheric meteorology. The main undertaking of the past decade was to deeply renovate the CNES balloons command and control systems and flight operation processes to comply with more stringent Safety constraints and with growing performance and reliability requirements. This is done for large zero pressure balloons (ZPB), and in progress for the other lines of products. Since 2014, 18 successful scientific flights of heavy ZPBs have been carried out from Timmins (Canada), Kiruna (Sweden), and Alice Spring (Australia). In the field of long duration balloons, CNES decided, in june 2016, the development of the STRATEOLE 2 project, for the study of the low stratosphere in equatorial regions (UTLS). Based on the use of fleets of small super pressure balloons (SPB) flying up to 3 months each, the program consists in two launch periods in late 2020 and 2023. The related infrastructure will be available no later than end of 2018, paving the way to a new capacity for long duration flights in general. A synthesis of the launch campaigns of the past two years will be presented: Regarding ZPB flights, a focus will be made on the results of the AUSTRAL 2017 flights from Alice Springs, Aiustralia, were 3 successful flights could be performed in 2 weeks (a record !); A status will be given about the preparation of the launch campaign of the FIREBALL UV payload will be given. An outlook of the new systems currently developed at CNES will be given, in particular regarding the SPB system for Strateole 2 and the preparation of the qualification launch campaign, as well as

the perspectives for new developments and collaborations, such as the CNES participation to the European HEMERA H2020 Infraia project on balloon services, accepted by EU in August 2017.

PSB.1-0006-18 SCIENTIFIC BALLOONING IN INDIA: RECENT ACTIVITIES AND DEVELOPMENTS OF THE TIFR BALLOON FACILITY, HYDERABAD

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The Balloon Facility of Tata Institute of Fundamental Research (TIFR-BF), Hyderabad launches zero pressure scientific balloons every year during October-April for the study of various scientific applications, especially in the field of Astronomy (Infrared and X-Ray), high energy physics, Earth's magnetic field and atmospheric science studies, etc. Recently, TIFR-BF provided the launch support for different balloon campaigns such as Tropical Tropopause Dynamics (TTD) to study the water vapour content in Upper Tropospheric and Lower Stratospheric (UTLS) region over Hyderabad and a balloon flight campaign to study the Asian Tropopause Aerosol Layer (BATAL) during the Indian summer monsoon season in collaboration with different national and international research laboratories. The BATAL campaign was the first campaign to conduct balloon launches during Indian summer monsoon (South-West monsoon) season with different sizes of zero pressure plastic balloons. TIFR-BF also floated a small zero pressure balloon of volume 300 cubic meters at UTLS region for a few hours. In recent times, TIFR-BF also designed and fabricated a zero pressure balloon with payload carrying capacity upto 3 ton using four layers of 25 microns film, and also designed and fabricated small oblate spheroid shaped balloons of volume ranging from 10 to 100 cubic meters for testing of newly developed satellite payloads in laboratory at different environmental conditions. In this paper, we present the summary of balloon launches conducted during the recent times, design and fabrication of zero pressure balloons along with the latest developments in balloon components and control instrumentation.

PSB.1-0007-18 SCIENTIFIC BALLOON ACTIVITIES IN BRAZIL: NATIONAL REPORT

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In this talk I will present the latest developments in scientific balloon activities in Brazil, and prospects for the future. Since the last COSPAR Scientific Assembly, the activities at INPE, Brazil's National Institute for Space Research, have been concentrated in the development of the protoMIRAX experiment and its balloon gondola. protoMIRAX is a prototype of the space experiment MIRAX (Monitor e Imageador de Raios X - Monitor and Imager of X Rays) that is currently under revision by INPE and the Brazilian Space Agency. protoMIRAX is a hard X-ray (30 to 200 keV) coded-mask imager with an angular resolution of 1.75 degrees in a 20 x 20 degrees fully-coded field-of-view. The detector plane comprises and array of 13 x 13 planar CdZnTe detectors with dimensions 10mm x 10mm x 2mm. The X-ray imager is housed in a balloon gondola with a complete attitude control and pointing system developed in a partnership between INPE and COMPSIS, a private company in Sao Jose dos Campos, Brazil. The development of protoMIRAX has given the Ballon Launching Center at INPE the opportunity to upgrade its technology and prepare for the provision of important services to the scientific ballooning communities both in Brazil and abroad. I will also present some recent initiatives carried out in Brazilian universities and centers to conduct astrobiology-related and atmospheric experiments in small balloons.

PSB.1-0008-18 WORLD VIEW BALLOON PROGRAM

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World View® is pioneering a new frontier at the edge of space and leading the way in the emerging stratospheric economy. As an active, full-service commercial launch provider, World View's technology is already opening up new realms of possibility for commercial customers around the world. World View's disruptive Stratollite flight platform enables previously unthinkable applications at a fraction of the cost of existing technology. Stratollites serve a variety of mission functions - from short duration research flights to long-duration flights over specific areas of interest - and serve a broad range of critical commercial needs and applications. This paper presents an overview of Worldview's capabilities, the innovative technologies, and summary of operations to date.

PSB.1-0009-18 USING METEOROLOGICAL BALLOONS TO EDUCATE A NEW GENERATION OF SCIENTISTS BY DEVELOPING NEW PROFESSIONAL INSTRUMENTS FOR ATMOSPHERIC SCIENCE AND AURORAL PHYSICS

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The Undergraduate Student Instrumentation Project is an educational initiative released by the NASA Science Mission Directorate that solicits university proposals to develop Earth or space science payloads to be flown on a NASA suborbital vehicle. The initiative engages undergraduate students in STEM related majors in a full fledged, hands-on project while simultaneously developing technical and project management skills that will be necessary in their future careers in STEM related fields. The USIP group at the University of Houston is wrapping up its third round of funding, with five ambitious field campaigns now under its belt. The mission of the UH USIP is to design, build, and fly instruments on board high altitude latex balloons to study atmospheric and auroral phenomenon near the Arctic Circle. The three campaigns that will be discussed in this paper were conducted during the second and third rounds of USIP, or what we simply call USIP-II. The three campaigns USIP-II took part in was the NASA/Dartmouth BARREL-4 campaign in Kiruna, Sweden, and the USIP-II-UHab campaigns in Fairbanks, Alaska, which were planned and conducted by the USIP students. The instruments designed by this USIP group include a Total Electron Content(TEC) detector, a Very Low Frequency(VLF) radio receiver, a digital to analog IRIG-B Time Code encoder, an atmospheric extremophile organism collection device, a balloon-borne imaging Spectroscope, various Gaseous Compound detectors, a balloon-borne Star Tracker device, and a ground based all-sky imager for detecting atmospheric airglow.

PSB.1-0010-18 INSTRUMENTAL DEVELOPMENTS OF THE METEOROLOGICAL-BALLOON BORNE DETECTORS FOR SPACE EXPLORATION

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Measurement of extraterrestrial radiation and atmospheric radiation due to cosmic rays are being conducted on regular basis by Indian Centre for Space Physics, Kolkata over past several years. Light-weight radiation detectors like crystal scintillator detectors, GM counters are used on board small meteorological balloons which serves as the primary instrument for this purpose and are carried near the top of the atmosphere (42 km) using meteorological balloons. These main detectors are supported by several other ancillary instruments developed in a modular approach, to gather and extract sensible data and to execute the execute the experiments seamlessly. Here we briefly discuss the goals and technicalities of the mission operations and describe the instrumental modules in details to some extent.

PSB.1-0011-18 BALLOON-BORNE TURBULENCE MEASUREMENTS IN THE TROPOSPHERE AND STRATOSPHERE USING LITOS

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Gravity waves play a key role for the understanding atmospheric dynamics as they transport energy and momentum from the troposphere into the middle atmosphere. Parts of the gravity waves dissipate already in the stratosphere, producing smaller and smaller spatial structures down to scales of millimeters. Therefore, these turbulent processes can be best resolved by in-situ measurements. We developed the balloon-borne instrument LITOS (Leibniz-Institute Turbulence Observations in the Stratosphere) to infer kinetic energy dissipation rates by measuring the inner scale of turbulence at spatial scales of typically a few centimeters.

We will demonstrate the concept of LITOS and show case studies from recent measurements in Northern Scandinavia and at our institute location in Germany. A special focus is on general aspects of balloon-borne wave and turbulence measurements, like the ambiguity of horizontal and vertical wave scales and influences of subcritical and supercritical flow around the balloon on the ascent rate. Additionally, we will demonstrate the potential influence of wake turbulence created by the payload suspension or the balloon itself as well as strategies to mitigate these influences. These concepts are expected to be important for many high-resolved sounding methods.

PSB.1-0012-18 SIMULATED RADIATION FROM CRAB PULSAR DETECTED IN A LIGHTWEIGHT PHOSWICH DETECTOR ON BOARD METEOROLOGICAL BALLOON

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In the course to study the detector capability and observation limit under specific conditions, we calculated the detectable radiation from the Crab pulsar in a light-weight, 5”-diameter phoswich detector inboard meteorological balloon along with the background radiation in the detector. For this purpose we simulated the source radiation for the atmospheric absorption and detector response using Geant4 simulation toolkit. We also compared the calculated radiation with observed radiation in a small balloon borne experiment with the similar detector configuration conducted by Indian Centre for Space Physics, India. The height and angular dependence of the detector was taken care during the comparison using the actual sensor data from the mission. Here we present the comparative estimation of the light curve, spectrum and the overall sky image due to the source and background radiations.

PSB.1-0013-18 LOW COST BALLOON BORNE SCIENCE PROGRAMME OF ICSP IN NEAR SPACE AND ITS FUTURE GOALS

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Indian Centre for Space Physics has been flying low-cost mainly meteorological balloons (both rubber and polythene) for about 10 years and successfully completed 109 such missions. Some of them even had multiple balloons in order to achive longer flights at specific heights. We carry main instruments (geiger counters, bicrons, phoswiches and other X-ray detectors), gps units, degree-of-freedom measuring units, sun sensors etc. The payload is typically less than 5 kilogram and we typically reach about 40km, height being about 42km. We recover all the payloads and thus our recurring cost is less than 500 USD per flight. We have no pointing devices or ballasts as in larger and expensive counterparts. We do not require larger space for launching either. Yet, we have achieved major scientific goals such as (a) monitoring cosmic ray variations year after year (b) solar flare light curves and spectra (c) X-rays from Crab nebula and its pulses (d) e+epair annihilation lines, (e) gamma ray bursts etc. We often traced mysterious radiations spread in 20-22 km height for days on. Based on out inputs we compute the aviation safety and radiation hazards. We believe that our pioneering method may be a very useful tool to test cansats, nanosats and cubesats prior to their flights.

PSB.1-0014-18 E3TRATOS MISSION MONITORING CO2 FROM THE GROUND TO THE STRATOSPHERE IN COLOMBIA

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CO2 is one of the most common and important trace gases in the atmosphere-ocean-Earth system, is the most important greenhouse gas (GHG) associated with human activities and the second most important gas in global warming after the water vapor. This gas has anthropogenic and natural sources. Monitor the spatial and temporal variation of the CO2 concentration on both, global and local scale is a main duty concerned to the environmental authorities. The global monitoring of CO2 has been achieved by the use of space missions like NASA's Orbiting Carbon Observatory-2 and local scale measurements are assured by the exploding number of scientific stations. In developing countries, like Colombia, accessing these measurements is a quite difficult task. If satellite data repositories are no open, local authorities have budget issues to obtain the required data. Otherwise, local measurements are more difficult to obtain because the high costs of the required instrumentation and logistics fees that are proportional to the number of measuring stations. In Colombia we found a very weak network of scientific stations monitoring atmospheric variables with less than 3000 weather stations covering a surface of 1,142 million of square kilometers. Here we present the status of the "E3Tratos"

mission, which is the first stratospheric balloon research project with scientific payload that is being developed at the Universidad Industrial de Santander in Colombia, South America and that will

be launched by the fall of 2018. The main objective of the mission is to launch lowcost and autonomous scientific instrumentation towards the stratosphere and thus observe the surface of the Earth from the upper limit of the atmosphere at approximately 35 km in height. The displacement of the balloon and its payload will allow measuring meteorological variables and GHGs along its ascending route. The portability capabilities of the instrumentation seek to validate future low-price high efficiency scientific stations that will serve to ameliorate the local monitoring of GHGs in developing countries. We will show the final design as well as the characterization of some of the implemented subsystems that includes: Scientific instrumentation based on high resolution cameras in the visible, a portable meteorological station, an atmospheric CO2 concentration sensor, control electronics based on reduced-board computers that control the entire experiment, a radio link that, together with a station on the ground, will allow monitoring the position of the probe balloon and receive the telemetry data, The mechanical interfaces composed of a gondola that will serve as a mechanical interface to house the payload (< 3500 g) and a propulsion-recovery system based on a stratospheric probe balloon (3000 gram) and a parachute. We present the final design of the instrument capable of measuring in-situ the concentration of GHGs. The design of the CO2 concentration sensor is based on the tunable diode laser spectroscopy technique TDLS that consists of varying the emission wavelength of a near-infrared room temperature laser diode through the modulation of the current signal that polarizes the laser diode. This variation of the current allows changing the wavelength of the laser diode over a bandwidth of less than one nanometer. The bandwidth and the central wavelength of emission of the laser diode are previously selected (2004 nm for CO2) in order to be able to sample a strong atmospheric absorption band that is due to the exclusive presence of CO2. A two-mirror multipass absorption cell that is operated open to the atmosphere receives the modulated beam, absorption on the beam due to the atmospheric gases is then measured at the multipass cell output with In-GAs photodiode. Direct-differential detection in conjunction with the cell to record the atmospheric spectra in situ, give us access to the molecular line shape with no distortions. Then, by reconstructing the full molecular line shape with a nonlinear least-squares fit to retrieve the mixing ratios, atmospheric CO2 concentration will be monitored over large ranges in pressure, temperature, and concentration with an achieved precision error within a few percents. The instrument will be capable to work under hard environment conditions. Future works will focus on monitor of other GHGs. This will be achieved changing the central emission of the selected diode laser.

PSB.1-0015-18 A LIGHT-WEIGHT DEVICE FOR PAYLOAD ATTITUDE MEASUREMENT USING MICRO-ELECTRONIC INERTIA-MEASUREMENT UNIT SUITABLE FOR SMALL BALLOON BORNE MISSIONS

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Small meteorological weather balloon borne payloads cannot accommodate conventional pointing device due to the restriction on payload weight. Thus it is subjected to rotate freely around an axis and also suffers other random motions and oscillations due to wind gusts and drag forces. These motions enables it to scan a part of the sky depending on the payload construction and detector collimator. In particular, for the detectors to study radiations from astrophysical sources, we need to know the instantaneous the direction of the detector to locate the source of the data. For this purpose we use an attitude and heading reference system using micro-electronic modules, to determine the payload attitude. Here in this work we describe the design and work of such a device made to measure the attitude of a payload on board weather balloons.

PSB.1-0016-18 DEVELOPMENT AND EVALUATION OF A QUASI DECENT-CONTROL TYPE PAYLOAD SYSTEM FOR SMALL SOUNDING BALLOONS

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In-situ stratospheric observation up to 30 km altitude by using small sounding balloons has been increasing as a transport equipment in the recent years. A small rubber balloon with a diameter of about 3 m is used with small observing sensor devices, being separated at a target altitude and usually landed with a parachute for recovery. By using a small rubber balloon, inexpensive and small-scale experiments become possible with somewhat freehand launching opportunities. However, as there is no vast flat land in crowded small island area of Japan, tracking and recovering of such sounding balloons in the area of urban, mountainous areas, and oceans are difficult, or it needs extra equipments and efforts for preventing a lost of the instruments. For this reason, the use of sounding balloons has not been advanced in small-scale balloon projects.

In order to solve the geographical constraints and realize efficient operation, our laboratory has been working on development of a sounding balloon system mounted with quasi decentcontrol type payload. The operation method is to perform a soft landing guidance working with a parafoil with on-board servo-motor control system while selecting the multiple reachable landing points among pre-set safety landing point candidates on the payload. As a final goal, we prepare a payload system with a sensor mass of 500 g and the total payload size of 60 mm cube. Throughout these evaluating flight tests, we aim to develop the entire decent-control system along with our main target. Our laboratory developed prototype payload system and performance experiments were carried out. As a result, we obtained a simple performance evaluation with a glide ratio of about 3 as well as a turning radius of about 15 m, resulting in a design validity of the developed system. On the other hand, we found, flight evaluation was only very basic at that time due to flight altitude shortage and lack of some sensors and destruction of the system caused by rotational motion during its landing.

Currently, we are developing new payload system based on the tasks found in the previous experiments. And, we will evaluate flight performance through manual flight control experiment from 100 m altitudes. In this presentation, we will present our recent activities to make challenging small-ballon devices, results of the parafoil system to be used for manual control flight test, and future scientific applications with microphones for infrasound sensing in middle atmosphere.

PSB.1-0017-18 SMILE-II+: THE 2018 BALLOON CAMPAIGN IN AUSTRALIA OF MEV GAMMA-RAY TELESCOPE

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SMILE(MeV gamma-ray telescope)

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The observations of celestial nuclear gamma-rays in the MeV energy band provide more understanding of various phenomena such as nucleosynthesis in supernovae and merger of neutron stars. However, the observation in this band is very difficult due to huge background and unclear imaging. The background is created by the interactions of the cosmic particles with the satellite body. The current telescopes, based on coded aperture imaging or classical Compton imaging, cannot overcome this problem, because these telescopes cannot measure two angles of the incident gamma-ray, event by event.

We have developed an electron-tracking Compton camera (ETCC) as a next generation telescope. In comparison with the classical Compton imaging, the ETCC measures a 3D track of a recoil electron using a gaseous detector, and provides a two-dimensional point spread function defined by two angles of the incident gamma-ray. If a satellite with an ETCC having an effective area of 200 cm^2 and half power radius (HPR) observes all sky during 1 year, the detection sensitivity will reach to 1 mCrab.

We have promoted Sub-MeV gamma-ray Imaging Loaded-on-balloon Experiment (SMILE) to certificate the performance of ETCC. We carry out a 1-day balloon observation of Australia in spring in 2018 (SMILE-II+) supported by ISAS/JAXA. We certificate the capability of imaging spectroscopy by observing the Crab nebula and the positron-electron annihilation line in the galactic center region as bright celestial objects. The field of view of ETCC is 4 sr and the both effective observation time of these objects are over 5 hours. For detection of these objects over 5 significances, an ETCC requires HPR of 10 degree (662 keV) and an effective area of 3 cm^2 (511 keV). We develope SMILE-II+ ETCC and measure the HPR and the effective area in order to certificate to meet the requirement.

In this talk, we present a flight report and a preliminary result of SMILE-II+.

PSB.1-0018-18 PERFORMANCE OF SMILE-2+ ELECTRON-TRACKING COMPTON CAMERA (ETCC)

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MeV gamma-ray astronomy does not advance in the last 20 years, though there are many science treasures. This reason is conventional MeV gamma-ray telescopes without an accurate imaging capability, and the environment with huge backgrounds. We developed an electron-tracking Compton camera (ETCC) with an accurate imaging by a well-defined point spread function (PSF), and we are planning "Sub-MeV gamma-ray Imaging Loaded-on-balloon Experiment" (SMILE) leading to the satellite observation since 2006.

We launch a 1-day flight at Alice Springs, Australia at April, 2018 to demonstrate the imaging capability of the ETCC by the brightest objects (SMILE-2+). The observation targets are Crab nebula and annihilation line from the Galactic Center region. It requires the effective area of 4 cm^2 (200 keV) and 3 cm^2 (511 keV) and PSF (in which 50% of the events are included) of 10 degrees (662 keV). The SMILE-2+ ETCC consists of a 30-cm-cubic gaseous detector, which measures the energy and direction of a recoil electron, and the pixel scintillator arrays surrounding the gaseous detector, which measure the energy and hit position of a scattered gamma-ray. We measure the effective area and the PSF of the ETCC in the laboratory using RI sources, to confirm that the ETCC satisfy the requirements.

In the future observation, we will start scientific observations using the long duration balloons with a ETCC having an effective area of 20 cm^2 (200 keV) and 15 cm^2 (511 keV) and a PSF of 5 degrees (SMILE-3). For this purpose, we will use two ETCCs filled by a CF4 with a pressure of 3 atm. The effective area of SMILE-3 increases by 8 times of that value of SMILE-2+ because the probability of Compton-scattering is proportional to the electron density of the scattering target. Finally, we aim to a satellite with an effective area of 200 cm^2 and HPR of a few degrees for 1 MeV gamma-ray, which would reach approximately 0.1 mCrab.

In this talk, we present the measured performances of SMILE-2+ ETCC and the expected observations by the long duration balloons and a satellite in the future.

PSB.1-0019-18 GRAINE PROJECT AND A 2018 BALLOON-BORNE EXPERIMENT

Satoru Takahashi, satoru@radix.h.kobe-u.ac.jp Kobe University, Tsurukabuto, Nada, Kobe, Japan GRAINE collaboration (2018)

Shigeki Aoki (1), Ikeda Chusaku (2), Kaname Hamada (2), Toshio Hara (1), Atsushi Iyono (3),

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Observations of high-energy cosmic γ-rays provide us with direct information of high-energy phenomena in the universe. Fermi-LAT is observing a γ-ray sky and offering new insights. On the other hand, past and current observations have some limitations. Improvements in an angular resolution and polarization sensitivity are one of keys for a breakthrough of the limitations.

We are developing GRAINE project, the project of a 10 MeV – 100 GeV cosmic γ-ray observations with a precise (0.08 degree @ 1 – 2 GeV) and polarization sensitive large aperture area (~10 m2) emulsion telescope by repeating long duration balloon flights.

A feasibility and performance of the emulsion γ-ray telescope were demonstrated using accelerator beams with γ-rays / electrons / muons and atmospheric γ-rays at mountain height.

In 2011, the first balloon-borne, emulsion γ-ray telescope experiment was successfully performed with a 125 cm^2 aperture area and 4.3 hour flight duration on JAXA scientific ballooning at TARF Japan. By the flight data analysis, we demonstrated a feasibility of the balloon-borne emulsion γ-ray telescope experiment.

In 2015, we had a JAXA scientific ballooning with a 3780 cm^2 aperture area and 14.4 hour flight duration in Australia. Overall performance of the telescope is being demonstrated by the flight data analysis.

In April 2018, we have a JAXA scientific ballooning with a ~0.4 m2 aperture and >~18 hour flight duration in Australia for a demonstration with a detection and imaging of a known γ-ray source, Vela pulsar. In 2021 or later, with a 10 m2 and >24 hour flight duration, we aim to start scientific observations.

An overview and status of the GRAINE project and the 2018 balloon-borne experiment are presented.

PSB.1-0020-18 IN-FLIGHT PERFORMANCE OF THE PILOT BALLOON-BORNE EXPERIMENT

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Measuring precisely the faint polarization of the Far-Infrared and sub-millimetre sky is one of the next observational challenges of modern astronomy and CMB cosmology. I will describe the concept and science goals of the PILOT balloon-borne instrument, dedicated to measuring the linear polarization of the faint interstellar diffuse dust emission in the Far-Infrared in our Galaxy and nearby galaxies. I will present the in-flight performance of the experiment, as measured during the two successful flights of PILOT from Timmins, Canada in September 2015 and from Alice Springs, Australia in April 2017. Finally, I will show the first polarization maps obtained and discuss preliminary results and future objectives.

PSB.1-0021-18 EXPLORING NEW DIRECTIONS IN GAMMA RAY ASTROPHYSICS WITH COSI

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The Compton Spectrometer and Imager (COSI) wide-field gamma-ray telescope (0.2-5 MeV) is designed to probe the origins of Galactic positrons, uncover sites of nucleosynthesis in the Galaxy, and perform pioneering studies of gamma-ray polarization. COSI is the first science payload designed to fly on NASA's 18 MCF superpressure balloon. COSI underwent a successful 46-day science flight in 2016, the first science payload to launch from New Zealand. I will discuss the science goals and status of results of COSI, the technological advances of the instrument, future goals for the COSI program, and the potential of NASA's superpressure balloon program.

PSB.1-0022-18 SPECTRAL ANALYSIS OF THE CRAB WITH THE COMPTON SPECTROMETER AND IMAGER

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The Compton Spectrometer and Imager (COSI) is a balloon-borne, soft gamma-ray (0.2-5 MeV) telescope designed to study astrophysical sources, including compact objects. COSI utilizes a compact Compton telescope design with 12 germanium detectors and is inherently sensitive to polarization. In May 2016, COSI was launched from Wanaka, New Zealand, and completed a successful 46-day flight on NASA's Superpressure balloon. The Crab Nebula is among the sources detected during the 2016 flight. We present an update on our spectral analysis of the Crab, and describe the spectral analysis pipeline we have developed for COSI. We have constructed an accurate instrument model as required for the response matrix. By carefully selecting background events, we are able to fit background-subtracted spectra in XSPEC, a well known spectral fitting program. We have also developed a model of the atmosphere above COSI to include in our spectral fits. Furthermore, we will discuss prospects for measuring the Crab polarization with COSI.

PSB.1-0023-18 POGO+ STRATOSPHERIC BALLOON MISSION FROM ESRANGE, SWEDEN, TO VICTORIA ISLAND, CANADA

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PoGO+ was a stratospheric balloon project with a cosmic ray experiment from KTH, Stockholm, Sweden, that was launched on July 12th, 2016 for a 7 day flight from Sweden to Canada. The payload mass was 1728 kg and an Aerostar SF-39.57 balloon was used to reach the float altitude of 40 km. In 2013 a similar experiment flew from Esrange to Norilsk in Russia in a circumpolar flight that lasted 2 weeks. That balloon was called PoGOLite. The experiment on PoGO+ was a balloon-borne hard X-ray polarimeter operating in the 25 - 240 keV energy band from a stabilised observation platform. Observations were conducted from a stabilised stratospheric balloon platform at an altitude of approximately 40 km. The primary targets were the Crab - a pulsar and associated wind nebula in the constellation of Taurus, 6500 light years from Earth, and Cygnus X-1 - a black hole binary system. A custom attitude control system kept the polarimeter field-of-view aligned to targets of interest, compensating for sidereal motion and perturbations such as torsional forces in the balloon rigging. After a launch at 03:17 UTC, the balloon reached float altitude after almost 10 hours, due to a cold stratosphere with slow ascent. A slower than anticipated wind took the balloon over the Atlantic for a landing in Canada on July 18th at 22:26 UTC. Landing latitude was 71.84747 N, longitude 110.885 E on Victoria Island. The mission was very successful with all systems both scientific and support and balloon systems working nominal during the complete flight. A huge amount of scientific data was collected during the flight that will be analysed. The flight lasted 7 days and this was longer than expected resulting in more scientific data. The landing and recovery was performed nominal and the scientific data were recovered and delivered to the science team within 12 days after landing. The mission was managed by SSC and SSC was also responsible for the gondola structure, housekeeping and communication systems, power systems and part of the balloon flight systems. SSC was handling the launch, flight and recovery operations. KTH was responsible for the instrument, X-ray polarimeter, including all subsystems for controlling and monitoring the systems including thermal management. DST Control, Sweden was responsible for the dual axis pointing system. New Mexico State University, USA, was responsible for part of the balloon flight systems.

PSB.1-0024-18 THE EUSO-SPB2 MISSION

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The Extreme Universe Space Observatory Super Pressure Balloon second mission (EUSOSPB2) is currently in preparation. This long duration mission will measure fluorescence and Cherenkov signals from high-energy cosmic-ray showers and search for Cherenkov signals from up-going showers from tau neutrinos. The instrument features three optical telescopes. Two of them are designed to detect direct Cherenkov light near the direction of the Earth's limb, while the third one uses the fluorescence technique to measure near horizontal showers. The launch date is planned for 2021 from the NASA launch pad located in Wanaka, New Zealand. This balloon mission will also test techniques and methods for the Probe of Extreme Multi Messenger Astronomy (POEMMA) space mission, currently studied under a NASA sponsored conceptual design.

PSB.1-0025-18 EUSO-SPB1: A BALLOON BORN FLUORESCENCE TELESCOPE FOR COSMIC RAY DETECTION

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The measurement of ultra-high energy cosmic rays from space via the fluorescence method is very compelling because the observable area can be very large. The development of an instrument with this capability is the goal of the Extreme Universe Space Observatory collaboration. In April 2017 the collaboration made a major step forward with the launch of the Extreme Universe Space Observatory on board a Super Pressure Balloon (EUSO-SPB1). The instrument was designed to measure cosmic rays for the first time via their fluorescence signal by looking down on the atmosphere. The instrument was flown as a NASA mission of opportunity from Wanaka, NZ on the 27th of April 2017 with a planned flight duration as long as 100 days. The telescope viewed the atmosphere from an altitude of 33 km.

The flight terminated prematurely after 12 days, about 300 km SE of Easter Island. We will present the instrument, the mission and preliminary results of the ongoing data analysis. A discussion of a second EUSO-SPB mission is presented in a separate contribution.

PSB.1-0026-18 CALIBRATION OF THE EXTREME UNIVERSE SPACE OBSERVATORY SUPER PRESSURE BALLOON INSTRUMENT

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To make radiometric measurements of the light generated in extensive air showers (EASs), it was necessary to calibrate the Extreme Universe Space Observatory Super Pressure Balloon (EUSO-SPB) instrument before its flight. This was accomplished in several steps. First a flat-field calibration was done in Golden, Colorado. Next the instrument was moved to the Telescope Array site near Delta, UT where it was calibrated using a laser and a light-emitting diode (LED). Finally the flat field calibration was repeated in Wanaka prior to the launch.

The first flat-field measurements were made at the Colorado School of Mines in Golden, CO. This was done in a darkened room. A Tyvek-covered screen was installed 4.65 m in front the

EUSO-SPB instrument, filling its field of view. This screen was illuminated by a UV LED, operated in a pulsed mode and mounted in the center of the front lens of the instrument. A second flat-field calibration was performed outside the instrument preparation hanger at the Wanaka, NZ airport. This time the instrument was suspended from a crane with the entrance aperture facing the ground. A Tyvek screen was spread on the ground beneath the

instrument filling its aperture. It was also illuminated by the LED installed in the center of the front lens of the instrument. The results of both calibrations will be reported.

The calibration measurements at the Telescope Array site with the instrument was placed on Black Rock Mesa, viewing west and away from distant city and village lights. A laser was located at a 24 km in front of the EUSO-SPB. From this location the laser fired pulses of UV light into the sky. The light scattered from these pulses was recorded by EUSO-SPB. This provided a test the instrument trigger, the geometrical reconstruction algorithm for the EASs, and a radiometric calibration that depended on an understanding of the scattering mechanism in the atmosphere. In addition, a UV LED was placed on a tower at distance of 45.11 meters in front of EUSO-SPB to provide an absolute radiometric calibration of a few points on the focal surface of the instrument. These calibrations, combined with the flat-field calibrations enabled EUSO SPB to launch with the capability to make absolute radiometric measurements of the light emitted by EASs in the atmosphere below the balloon that result from the interaction of very high energy cosmic rays in the atmosphere. Such measurements would also be required to reconstruct the energy of any cosmic rays observed.

PSB.1-0027-18 ON X-RAY OBSERVATION OF EXTRATERRESTRIAL SOURCES USING LIGHTWEIGHT DETECTORS ON BOARD METEOROLOGICAL BALLOONS

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In the process of space exploration in X-rays with small balloon borne detectors, we designed a radiation detector using a 5″ diameter phoswich scintillator detector. The detector can be carried up to a height of about 42 km above the atmosphere using a plastic meteorological balloon where radiation detection from extraterrestrial objects are possible. Here in this paper we present the design considerations and characterization of the detector used for this purpose. Using the data from an experiment designed to detect radiation from Crab pulsar, we discuss about the background radiation in the detector in such experimental environment which is very crucial for these kind of experiments. We empirically modeled the background at various altitudes of the payload which are to be used in spectral analysis when actual measurement of background is not possible. Considering the background radiation level and limitations on the detector we also calculate the minimum detection limit for radiation sources in this experiment.

We also present results of radiation detection from Crab pulsar in this experiment. We show that the data clearly gives $\sim$ 33 ms pulse signature.

PSB.1-0028-18 GETTING READY FOR THE THIRD SCIENCE FLIGHT OF SUNRISE

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SUNRISE is a balloon-borne, stratospheric solar observatory dedicated to the investigation of the structure and dynamics of the Sun's magnetic field and its interaction with convective plasma flows and waves. The previous science flights of SUNRISE in 2009 and 2013 have led to many new scientific results, so far described in around 90 refereed publications. This success has shown the huge potential of the SUNRISE concept and the recovery of the largely intact payload offers the opportunity for a third flight.

The scientific instrumentation of SUNRISE 3 will have extended capabilities in particular to measure magnetic fields, plasma velocities and temperatures with increased sensitivity and over a larger height range in the solar atmosphere, from the convectively dominated photosphere up to the still poorly understood chromosphere. The latter is the key interaction region between magnetic field, waves and radiation and plays a central role in transporting energy to the outer layers of the solar atmosphere including the corona.

SUNRISE 3 will carry 2 new grating-based spectro-polarimeters with slit-scanning and context imaging with slitjaw cameras. The SUNRISE UV Spectro-polarimeter and Imager (SUSI) will explore the rich near-UV range between 300 nm and 430 nm which is poorly accessible from the ground. The SUNRISE Chromospheric Infrared spectro-Polarimeter (SCIP) will sample 2 spectral windows in the near-infrared, containing many spectral lines highly sensitive to magnetic fields at different formation heights. In addition to the two new instruments the Imaging Magnetograph eXperiment (IMaX), an etalon-based tunable filtergraph and spectropolarimeter flown on both previous missions, will be upgraded to IMaX+, enhancing its cadence and giving access to 2 spectral lines in the visible spectral range. All three instruments will allow investigating both the photosphere and the chromosphere and will ideally complement each other in terms of sensitivity, height coverage and resolution.

A new gondola with a sophisticated attitude control system including roll damping will provide improved pointing/tracking performance. Upgraded image stabilization with higher bandwidth will further reduce residual jitter, maximizing the quality of the science data.

SUNRISE 3 is a joint project of the German Max-Planck-Institut für Sonnensystemforschung together with the Spanish SUNRISE consortium, the Johns Hopkins University Applied Physics Laboratory, USA, the German Kiepenheuer Institut für Sonnenphysik, the National Astronomical Observatory of Japan and the Japan Aerospace eXploraion Agency (JAXA).

PSB.1-0029-18 SUNRISE CHROMOSPHERIC INFRARED SPECTROPOLARIMETER (SCIP) FOR THE SUNRISE BALLOON-BORNE SOLAR OBSERVATORY

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The SUNRISE balloon-borne solar observatory carries a 1 m aperture optical telescope, and allows us to perform seeing-free continuous observations at visible-IR wavelengths from an altitude higher than 35 km. In the past two flights, in 2009 and 2013, observations mainly focused on fine structures of photospheric magnetic fields. For the third flight planned for 2021, we are developing a new instrument for conducting spectro-polarimetry of spectral lines formed over a larger height range in the solar atmosphere from the photosphere to the chromosphere. Targets of the spectro-polarimetric observation are (1) to determine 3D magnetic structure from the photosphere to the chromosphere, (2) to trace MHD waves from the photosphere to the chromosphere, and (3) to reveal the mechanism driving chromospheric jets, by measuring heightand time-dependent velocities and magnetic

fields. To achieve these goals, a spectro-polarimeter called SCIP (Sunrise Chromospheric Infrared spectroPolarimeter) is designed to observe nearinfrared spectrum lines sensitive to solar magnetic fields. The spatial and spectral resolutions are 0.2 arcsec and 200,000, respectively, while 0.03% polarimetric sensitivity is achieved within a 10 sec integration time. The optical system employs an Echelle grating and off-axis aspheric mirrors to observe the two wavelength ranges centered at 850 nm and 770 nm simultaneously by two cameras. Polarimetric measurements are performed using a rotating waveplate and polarization beam-splitters in front of the cameras. For detecting minute polarization signals with good precision, we carefully assess the temperature dependence of polarization optics, and make the opto-structural design that minimizes the thermal deformation of the spectrograph optics. Another key technique is to attain good (better than 30 msec) synchronization among the rotating phase of the waveplate, read-out timing of cameras, and step timing of a slit-scanning mirror. On-board accumulation and data processing are also critical because we cannot store all the raw data read-out from the cameras. We demonstrate that we can reduce the data down to almost 10% with loss-less image compression and without sacrificing polarimetric information in the data. The SCIP instrument is developed by internal collaboration among Japanese institutes including Japan Aerospace Exploration Agency (JAXA), the Spanish Sunrise consortium, and the German Max Planck Institute for Solar System Research (MPS) with a leadership of the National Astronomical Observatory of Japan (NAOJ).

PSB.1-0030-18 THE LARGE BALLOON REFLECTOR (LBR): GAME CHANGING APPROACH TO REALIZING LARGE SPACE AND NEAR-SPACE APERTURES

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The Large Balloon Reflector (LBR) development and test program provides a path forward to the realization of 10+ meter telescopes in near-space and serves as a pathfinder for larger space based apertures. In particular, LBR is a progenitor of the TeraHertz Space Telescope (TST) concept to be submitted to the upcoming Astronomy and Astrophysics Decadal Survey. As a demonstration of the scientific potential of an LBR in near space, we propose a series of flight tests with a 5 meter LBR. The performance of LBR will be validated by performing spectroscopic observations of sources with line strengths determined previously using smaller telescopes and through total power measurements of the Sun, Moon, and planets. The proposed investigation builds upon studies of LBR funded by the NASA Innovative Advanced Concepts (NIAC) program. Both NIAC Phase 1 and 2 studies have been completed (Walker 2014) and key technologies for the flight system validated. A number of LBR subsystems share heritage with the Stratospheric TeraHertz Observatory (STO) which was successfully flown from Antarctica during the 2016-2017 austral summer

PSB.1-0031-18 THE GUSTO BALLOON MISSION

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The Galactic/Extra-Galactic ULDB Spectroscopic Terahertz Observatory (GUSTO) is a NASA Explorer Mission of Opportunity mission led by PI Dr. Christopher Walker of the University of Arizona. The project goal is to develop a Terahertz observatory and balloon-borne platform for conducting a spectroscopic survey of the Milky Way (MW) and Large Magellanic Cloud (LMC) to determine the composition energetics and dynamics of the Interstellar Medium (ISM).

The University of Arizona will provide the GUSTO 0.9-m aperture telescope and instrument, which will incorporate an array of 3x8 cryogenic Terahertz superconducting heterodyne receivers built in a collaborative effort with the Massachusetts Institute of Technology, Arizona State University, SRON Netherlands Institute for Space Research, Virginia Diodes (VDI), and Ball Aerospace. The Johns Hopkins University Applied Physics Laboratory (JHU/APL) will provide the gondola with all its subsystems: Avionics, Guidance and Control, and Power. JHU/APL will also provide day-to-day project management, mission systems engineering.

GUSTO will launch from McMurdo Antarctica in December 2021 and is designed to stay aloft for 100 days or more by utilizing the 100-day flight potential of the new Super Pressure Balloon (SPB), provided by NASA's Balloon Program Office (BPO). During the flight the mission will measure the THz emission from three important interstellar lines: [CII], [OI], and [NII] at 158, 63, and 205 microns, respectively, spread throughout the Milky Way and the neighboring Large Magellanic Cloud. GUSTO will provide the first complete study of the life cycle of the interstellar medium, the gas and dust from which all stars and planets are formed.

GUSTO will employ a development approach that uses flight heritage from the Stratospheric Terahertz Observatory (STO) and the Balloon Observation Platform for Planetary Science (BOPPS) and other prior balloon missions.

PSB.1-0032-18 BALLOONS ARRAY TO TRACK AND INSPECT UPGOING HADRON AND NEUTRINO AIRSHOWERS

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Balloons offer a peculiar sky view at few or tens km altitudes. For instance following UHE neutrino astrophysics by ICECUBE we should expect once every few cube km volume, a PeVs tau neutrino (born by flavor mixing in cosmic flight) rarely crossing the Earth cord. These upgoing tau neutrinos, their eventual interaction on external terrestrial crust, it is making inside the soil an Ultra Relativistic Tau lepton, whose exit upward Earth and whose decay in air atmosphere lead to upward tau airshower. An unique PeV-EeV tau shine in air billions of secondaries amplifying its discover by huge number and widest area disk. Because such PeV EeV cannot be atmospheric they offer a guaranteed noise free Neutrino Astronomy. On the other horizon edges the escape of downward horizontal Cosmic Ray Airshower offer a well known abundant hadronic and nuclear signature. These events are ruled by energy and by nuclear composition. Their signature (slath depth) growth it is logaritmically related to their nuclear spectra. Moreover the terrestrial magnetic field offer an additional bending filter of the charged (mostly electron pairs) secondaries, leading to a wide airshower angle spread. At tens km altitude the poor dense air do not make longer electron random walk: therefore one expect (along East-West axis) an ideal geomagnetic spectrometer able to spread in a thin cone the upgoing horizontal hadronic atrshowers. These effects must be better recorded by (scintillators, Cherenkov optical, Radio.) detector array. The building of such array long tail (km tail lenght) balloon system possibly in coordinate flight may open a new era of both UHECR and UHE neutrino Astrophysics and Astronomy. A rich Anita-like balloon array spread every few ten km distance and located at tens km altitude with a hundreds meter long tail elements may disentangle UHECR composition and tau neutrino signal in area and mass volume well comparable and often much superior to AUGER-TA ground array detectors and to ICECUBE neutrino mass detector. references: 1) D.Fargion, Discovering Ultra High Energy Neutrinos by Horizontal and Upward tau Air-Showers. Astrophys.J, 570:909-925, (2002). 2) D.Fargion et al., Upward Tau Airshower from Earth, Astrophys.J. 613; 1285-1301,(2004). 3) D.Fargion, Vertical Array in Space. PoS(EPS-HEP) 104, (2009).

PSB.1-0033-18 THE LARGE BALLOON REFLECTOR (LBR): ARCHITECTURE AND CONCEPT OF OPERATIONS

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Southwest Research Institute (SwRI) and the University of Arizona (UA) have been focused on the development and demonstration of the technologies required to realize a spherical large balloon reflector (LBR) antenna. The focus has been on a suborbital, balloon borne, 10 meter class balloon reflector suitable for operation for radio to THz frequencies. Looking up and out into deep space, the LBR could serve as a telescope. The realization of a low cost large, near-space 10 meter class reflector for THz astronomy and microwave/millimeter-wave remote sensing and telecommunications has long been a goal of NASA and the DoD. Looking down, the LBR can be used for remote sensing or telecommunication activities. In particular, for the DoD, such a facility could be used to host high resolution, millimeter-wave radar, chemical detection equipment, and serve as a high bandwidth, telecommunications hub, thus, providing our warfighters with invaluable intelligence. This paper addresses the overall system architecture, testing, analysis and concept of operations.

PSB.1-0034-18 CNES STRATOSPHERIC BALLOONS FOR SCIENCE AND APPLICATION TO THE PILOT EXPERIMENT FOR ASTRONOMY

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After more than five years of development and qualification, the CNES (French Space Agency) Zero Pressure Balloon (ZPB) operational activities resumed in 2014 with a new improved system: NOSYCA (New Operational System for the Control of Aerostats). This system is especially adapted to the Zero Pressure Balloons (ZPB) and allows to fly up to 40 km high with a scientific gondola up to a bit more than 1 ton. NOSYCA complies with the safety rules (fail safe architecture) and is fully qualified. We can implement two S-Band stations to extend our flight area. In addition to the NOSYCA balloon system, our flight train is adapted for heavy payload flights, especially with a new large parachute. This improvement allows us to fly big scientific gondolas including one or a few instruments for climate observation or astronomy. CNES has now a new operational stratospheric balloon system fully compliant with the safety regulations and the air traffic control rules. The launching system allows to launch big scientific gondolas (up to 1,06 ton) with a limited sensitivity to ground winds. This allows scientific ZPB campaigns in various countries in the world, located in the 2 hemispheres, and lets room for further improvements of performance of our actual flight configuration and flight duration. CNES organizes 1 big ZPB campaign every year, either in Canada, in Sweden or in Australia (so far), depending on scientist requirements for observations. 3 scientific campaigns have been successfully led with this system, in Canada, in 2015 (6 flights in 4 weeks), in Sweden in 2016 (2 flights in 10 days), and in Australia in 2017 (3 flights in 2 weeks) and the next one in Canada is being prepared for 2018. In addition, CNES has developed a concept of generic and certified mechanical platform, allowing to implement a wide range of instruments, alone or together to constitute scientific gondolas, and adaptable but reliable generic ground segments to conduct the flights in the best way to optimize scientific observations. This concept, offers various services to instruments (electrical power, command-control, heating, doors, real-time coarse or fine pointing.). CNES has also developed a generic pointing system including an accurate daytime stellar sensor and high bandwidth closed loop devices, allowing a one arc second pointing accuracy for astronomy missions. The presentation will focus on the CNES AUSTRAL 2017 campaign in Australia, that illustrates the current performances of this operational system for stratospheric balloon flights. To concretely show this, we will talk about one of the major scientific flights which happened there, and allowed to beat records: the second flight of the PILOT gondola, dedicated to study the magnetic field in and out of our galaxy, and the interstellar dust which limits the observations of the Cosmic Background. PILOT (Polarized Instrument for the Long-wavelength Observations of the Tenuous interstellar medium) is a balloon-borne astronomy experiment to study and characterize the polarization of dust emission in the diffuse interstellar medium in our Galaxy and nearby galaxies. PILOT is able to measure the polarization properties of dust emission in the Far Infra-Red (at 1.2 THz). Future cosmology space missions will concentrate on

measuring the polarization of the Cosmic Microwave Background, which potentially carries invaluable information about the earliest phases of the evolution of our universe. Such ambitious projects will ultimately be limited by the sensitivity of the instrument and by the accuracy at which polarized foreground emission from our own Galaxy can be subtracted out. Experiments under stratospheric balloons are useful to technically and scientifically prepare future experiments onboard satellites, complement the set of data obtained by satellites, and allow some measurements not feasible from ground. For example, none of the Herschel satellite instrument was sensitive to polarization, the Planck satellite did obtain polarization measurements only at lower frequencies, and submillimeter infrared signals emitted from dust cannot be measured from ground. A stratospheric balloon-borne experiment like PILOT is a good tool to complete the available set of data. PILOT has already flown twice under a CNES stratospheric balloon, in both hemispheres, with improvements of the instrument performances and of the observation strategy between the 2 flights. The conditions of these flights will be presented in this talk, while the performances of the experiment, and scientific results already obtained, will be presented by J.P. Bernard et al. in other talks.

PSB.1-0035-18 COST-EFFECTIVE HIGH-ALTITUDE SCIENTIFIC BALLOON DEVELOPMENT AND ITS FLIGHT TEST WHILE CONSIDERING SEA-RECOVERY OPERATION

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The high altitude scientific balloon has been used for decades in advanced aerospace countries such as United States, France, and Italy to carry out various research objectives. One of the great strengths of the high altitude scientific balloon is the relatively low development and operating costs since they can be retrieved after completion of a flight mission. However, considering the environmental conditions in Republic of Korea, having a lot of inaccessible mountainous terrain, high population density, and surrounded by sea-water, the landing and recovery areas for the separated balloon system are limited. In this study, a zero pressure balloon prototype considering sea-recovery was developed in order to secure flight safety and to improve its the recovery success rate. In the future, operational reliability of the balloon system will be verified throughout multiple flight tests, and its sea-recovery operation procedure will be established.

PSB.1-0036-18 DESIGN, FABRICATION AND LAUNCH OF SMALL ZERO PRESSURE PLASTIC BALLOONS FOR FLOATING AT UPPER TROPOSPHERE AND LOWER STRATOSPHERE REGION FOR ATMOSPHERIC SCIENCE EXPERIMENTS

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The Balloon Facility of Tata Institute of Fundamental Resarch (TIFR-BF), Hyderabad designed, fabricated small zero pressure plastic balloons with volumes of 300 m3, 1200 m3 and 3000 m3. These balloons were launched from TIFR-BF to study the Asian Tropopause Aerosol Layer (ATAL) in collaboration with different research institutes and laboratories during Indian Summer Monsoon Seasons (ISMS). These are the first ever, balloon-borne experiments to study the chemical composition of the Upper Troposphere and Lower Stratosphere (UTLS) region in India. The balloons with volumes of 300 m3 and 1200 m3 were especially, designed in such a way that it can be floating at UTLS region for several hours. It is very crucial to maintain the required altitude in order to collect the aerosol samples at a very cold temperature region of tropics, for this we added a ballast module in these balloon experiments to get more data points at the same level. And also it is very difficult to conduct plastic balloon launches during ISMS due to high surface wind conditions, so we adopted to new hybrid static launch method for these launches. Balloon design, fabrication, launch and floating at designed altitude for these flights are discussed in this paper.

PSB.1-0037-18 DEVELOPMENT OF A SUPER-PRESSURE BALLOON WITH A DIAMONDSHAPED NET - GROUND INFLATION TEST OF AN IMPROVED MODEL BALLOON OF 2,000 CUBIC METERS

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Currently, we have been developing a novel type of super-pressure balloon for ultra-long duration flight of which envelope is covered with a diamond-shaped net of high-tensile fibers. Thanks to tensile forces developed in the net, stresses in the balloon envelope are effectively reduced and consequently thin polyethylene film with a thickness of 10-20 µm will suffice for the envelope, thus improving the payload capability of the balloon compared to the lobed-pumpkin type super-pressure balloon. Our ultimate goal is developing a 300,000 m3 balloon with a payload capacity of 900 kg at the altitude of 37 km. The development of the proposed superpressure balloon commenced in 2010 with a 10 m3 prototype balloon. After the verification of the first prototype balloon, we have evaluated the performances of a series of model balloons of the proposed type gradually enlarging their volumes; some of the results were reported in the past COSPAR assemblies, including a flight test of a 3,000 m3 balloon in the tandem balloon configuration with a 15,000 m3 zero-pressure balloon carried out in 2012. The paper discusses the development progress of the proposed balloon that has been achieved since the previous reporting at the 2012 COSPAR assembly. Focuses are on results of a ground testing of a 2,000 m3 model balloon of which performance is enhanced by redesigning the gore shape and also by devising a new fixing method of the net onto the balloon envelope.

PSB.1-0038-18 OZONE AND AEROSOL MONITORING BY QUASI-LAGRANGIAN DRIFTING BALLOONS OVER THE MEDITERRANEAN SEA AND IDEAS FOR TRANSOCEANIC CAMPAIGNS

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This work presents balloon-borne measurements from summer regional field campaigns in the western Mediterranean basin performed in the framework of the project ChArMEx (the Chemistry and Aerosol Mediterranean Experiment; 2010-2020; see special issue https://www.atmoschem-phys.net/special_issue334.html), and some ideas for new transoceanic campaigns.

Due to long-range transport from surrounding continents with contrasted emissions, the lower troposphere over this regional sea is subject to high levels of both aerosols including desert dust and gaseous pollutants such as ozone (O_3), with a maximum during the long dry and sunny Mediterranean summer season. Moreover, strong climate change in the region is expected to develop positive feedbacks on pollution levels (e.g., the net decrease in solar radiation by aerosols has been shown to reduce evaporation and subsequently regional precipitation that scavenge aerosols) and the Mediterranean type of climate is expected to expand over a large part of Europe.

Based on developments of boundary-layer pressurized balloons (BLPBs; Doerenbecher et al. (Bull. Amer. Meteor. Soc., 2016) and dedicated scientific payloads, we were able to perform original quasi-Lagrangian monitoring of O_3 and desert dust aerosols over the sea. The strategy included the combination of classical sounding balloons and drifting BLPBs to document both their vertical distribution and long-range transport. Three test flights

of a BLPB with O3 measurements, launched in June 2012 from Martigues on the French Mediterranean coast, and a total of 13 BLPBs with O3 measurements and 10 with dust measurements by the new Light Optical Aerosol Counter/sizer (LOAC), launched between mid-June and early August 2013 from Mediterranean islands, namely Minorca (Spain) or Ile du Levant (France), were successfully performed. Drifting altitudes ranged between 0.25 and 3.2 km above sea level for O3 measurements, and between 2.0 and 3.3 for mineral dust. The longest flight exceeded 1000 km and lasted more than 32 h.

We present the drifting balloon and its basic payload, and the instruments developed for ChArMEx: a modified electrochemical ozone sonde and the new optical particle counter/sizer LOAC with dual scattering angle measurements allowing identification of dust particles (Renard et al., Atmos. Meas. Tech., 2016a and b). Numerous tests and validations were performed, including comparisons with collocated airborne measurements, sounding balloons, and remote sensing measurements.

Ozone data are analyzed to examine O3 diurnal variations in the marine atmospheric boundary layer and in the free troposphere above. By selecting flight segments with the best probability of pure Lagrangian conditions, we report O3 photochemical production in both the boundary layer and the free troposphere, at rates of 1 2 ppbv/h, significantly lower than those previously reported over land in the same region. More details can be found in Gheusi et al. (Atmos. Meas. Tech., 2016).

Several desert dust events were monitored. LOAC data could be fitted by a 3-mode log-normal distribution at roughly 0.2, 4 and 30 µm in modal diameter. We did not observe any significant evolution of the size distribution during the flights. The presence of such large particles several days after emissions is unexpected given their theoretical sedimentation velocity. An indirect evidence of the presence of charged particles has been derived from the LOAC measurements and we speculate that electrical forces might counteract gravitational settling of the coarse particles. More details can be found in Renard et al. (Atmos. Chem. Phys., 2018).

Over the Mediterranean, the duration of measurements was limited by the size of the basin. However at least 4-5 days of measurements are in principle possible in the present configuration thanks to a programmable on-off procedure to save energy (and electrolyte in the case of O3), allowing, for instance, transatlantic flights from Africa in the desert dust loaded Atlantic tradewinds. On-going miniaturization of LOAC, and new mini sensors (e.g. for NO2) should allow 1-wk transpacific flights to study the very long-range transport of both dust and pollution from China across the North Pacific during springtime. Air mass trajectories suggest that up to 5-km ceiling altitudes of BLPBs should be targeted.

PSB.1-0039-18 FLIGHT TEST OF A SMALL-SCALE SUPER-PRESSURE BALLOON

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A small-scale super-pressure balloon was tested in north China in september, 2017. The test balloon was a prototype for long duration balloon in further flights. The volume of the balloon was around 7000 cubic meters and the payload was around 50 kilogram. The cruising attitude of the balloon was around 25 kilometers, which lay in the quasi-zero wind layer. The main purpose was to verify the design and fabrication of the super-pressure balloon with tendons attached to the envelope. The flight test also explored the possibility of achieving long duration flight within short distance by taking advantage of the quasi-zero wind layer. In the fight test, the cruising velocity maintained within 3 meters per second for several hours. Important data such as temperature and differential pressure of the balloon was obtained and analyzed. Design methods were revised and further tests were planned.

PSB.1-0040-18 THERMAL-DYNAMIC PERFORMANCE OF A SUPER-PRESSURE BALLOON IN ASCENDING AND FLOATING PROCESS

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A super-pressure balloon was successfully launched by the Academy of Opto-electronics, Chinese Academy of Sciences, on September 10, 2017. The volume of the super-pressure balloon was around 7,000 m3, with a suspended load of 100 kg. A total of 20 kg of ballast were carried on this flight to pressurize the balloon and adjust the ascending rate of the balloon. After a 110 min ascending process, the balloon reached its designed floating altitude at 25 km. During the ascending process, the ballast were dropped in several increments until all of it was expended. The balloon afloat at around 25 km for near 6 hours before the terminate command was executed and began to fell.

The thermal environment of the balloon varies greatly during the ascending and floating process, and the thermal and dynamic performance of the balloon coupled closely with each other, the coupled performance of the thermal and dynamic characteristics of the balloon is of vital importance to the safe flight and accomplishment of designed mission. A comprehensive understanding of the thermal-dynamic performance of the balloon could be useful for the guidance of balloon design, fabricate and flight experiment.

This paper will present an investigation into the thermal-dynamic performance of the superpressure balloon during ascending and floating process, through theoretical analysis, numerical calculation and analysis of the flight data from this launched super-pressure balloon.

PSB.1-0041-18 THE LARGE BALLOON REFLECTOR (LBR): ANALYSIS OF A 10M SUBORBITAL BALLOON-BORNE TELESCOPE

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The Large Balloon Reflector (LBR) is a 10m sub-orbital balloon-borne telescope suitable for operation from the radio to THz frequencies. LBR was developed by the team of Southwest Research Institute (SwRI) and the University of Arizona (UA) under funding for Phase I and Phase II of the NASA Innovative Advanced Concepts (NIAC) program. The telescope is itself a balloon, spherical in shape, metalized on one side and anchored to the top of a carrier balloon. The carrier balloon serves as both the launch vehicle and a radome for the telescope while also providing protection from the surrounding environment to stabilize the reflector. NASA's Zero Pressure (ZP) and Super Pressure (SP) balloons provide a means of transporting and maintaining payloads of 2-3 tons to near space where the telescope will be free of 99% of the Earth's atmospheric absorption to observe the far-infrared/THz spectrum. The analysis presented in this paper regards the thermal environment of the LBR and the shape fidelity of the sphere. The temperature variations of the LBR system throughout the diurnal cycle will impact the shape of the spherical telescope. The analysis demonstrated the extent of the temperature variations across multiple thermal environments, such as the polar region and midlatitudes, and suggests techniques for compensating for shape distortions across the surface of the sphere.

PSB.1-0042-18 NUMERICAL INVESTIGATION ON THE FLUID-STRUCTURE INTERACTION OF HIGH-ALTITUDE TETHERED BALLOON

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This paper presents the results of a study to determine the fluid-structure interaction of flying a tethered balloon at an altitude of 20 km. The vehicle is a spherically shaped, constant volume, helium filled balloon with a ballonet. The balloon is restrained with a tether during the launch, operation, and recovery phases of the mission. The high-altitude tethered balloon placed in the stratosphere flow field is a flexible body with low rigidity and so can be taken as an elastic membrane structure. The distribution of the flow field around the balloon is closely related to its shape. When the balloon is partly inflated or in case of strong wind, the balloon has a large deformation, resulting in the non-dynamic coupling of the peripheral flow field of the balloon and its deformation. For the solution of this problem, the iteration method was introduced, and the three-dimensional flow around the balloon was studied numerically by FLUENT software and means of SIMPLE method based on the Finite Volume Method. In the numerical simulation of the elastic deformation, the moment theory of thin shell was introduced. A comparison between the pressure distribution and aerodynamic parameters was provided, when the aeroelastic deformation was considered for static zero-pressure body. The relations between the deformation and the changes of flow parameters and aerodynamic loads were also analyzed.

The results show that the flexible deformation of the balloon changes the surrounding flow field, resulting in a significant change in the aerodynamic load distribution on the surface; causing a change in the pressure differential between the inner and the outer of the balloon, which in turn leads to a large change in the stress in the balloon. The static pressure at the upwind side of the head area of the balloon is higher, resulting in the head being dented, while the static pressure at the top is negative, causing the pressure differential to increase and the balloon skin to expand outward.

PSB.1-0043-18 A NAVIGATION SYSTEM THAT ENABLES AN AIRCRAFT TO BE FLOWN UNDER A STRATOSPHERIC BALLOON

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We will describe a system that was designed to locate, track and navigate an aircraft under a stratospheric balloon in flight. This system was designed for the Extreme Space Observatory (EUSO) balloon flights in order to place calibration light sources within the field of view of the EUSO instrument during its flight in order to perform an in-flight calibration.

The system consists of a radio beacon located on the balloon that transmits its GPS coordinates at a 5 second cadence. The radio signals from this beacon are received by a software-defined radio onboard the aircraft which is interfaced to a laptop computer. This computer runs a realtime program that displays the balloon coordinates and the coordinates of the aircraft from a second GPS receiver in the aircraft. Additionally, the program also actively propagates the position of both the aircraft and balloon forward in time, based on the most recent coordinates.

On the screen of the computer there is a coordinate display showing the position of the balloon relative to the location and heading of the aircraft and a second display giving the location of the aircraft in a projected geographic coordinate system centered on the balloon and oriented with the x axis being latitude and the y axis being longitude. The program also calculates and overlays the field of view of the EUSO instrument on both displays. The design and use of this navigation system will be explained. Both test and balloon flight results will be shown.

PSB.1-0044-18 STOP MODELING IN SUPPORT OF 1-METER APERTURE BALLOON BASED TELESCOPE

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Balloon based telescopes represent an opportunity to observe science in an environment with almost no atmospheric effects. However, balloon based platforms include a wide range of thermal environments as well as pointing a lightweight telescope over a large elevation range. The Gondola for High Altitude Planetary Science (GHAPS) was designed to provide nearly diffraction limited performance observations over the visible and infrared spectrum with a 1- meter aperture. To achieve such performance, detailed Structural Thermal Optical Performance (STOP) was used to predict telescope performance. Software was built to automate the process of analysis, enabling thermal, structural and optical analyses to be executed quickly with less effort. The end results was the capability to analyze both generic operating conditions and Design Reference Mission conditions, producing predictions that could be used to evaluate the quality of science return.

PSB.1-0045-18 ELECTRONIC INSTRUMENTATION CAPABILITIES FOR SCIENTIFIC BALLOONING IN INDIA

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The Balloon Facility of Tata Institute of Fundamental Research in India launches scientific balloons for research in the field of astronomy and atmospheric sciences. The balloon facility has the capability to design, fabricate and launch zero-pressure balloons upto stratospheric altitudes. The Control Instrumentation group for Balloon Augmentation (CIBA) at the balloon facility handles all electronics related to telemetry, telecommand, tracking, real-time data display and storage, air-safety and payload recovery. In the recent past, CIBA has also designed and developed several customized electronics to meet specific experimental objectives. In this paper, we present details of the recent developments in instrumentation and their performance in balloon flights. Our future up-gradation plans will also be discussed.

PSB.1-0046-18 THE SOLAR POWER SYSTEM FOR THE 2017 EXTREME UNIVERSE SPACE OBSERVATORY SUPER PRESSURE BALLOON FLIGHT

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We will describe the design and testing of the solar power system for the Extreme Universe Space Observatory Super-Pressure Balloon (EUSO-SPB) experiment that was launched from Wanaka, New Zealand in the spring of 2017. The solar power system performed well during the 12 day flight. We also report on its performance during this flight.

The solar power system consisted of a 24 volt battery pack composed of Odyssey PC1200 batteries charged by SunSaver MPPT charging controllers connected to arrays of SunCat solar panels.

Because the high altitude winds could carry the balloon north near the equator or south to Antarctica, we simulated flights at latitudes ranging from 0 to -67 at times ranging from the vernal equinox to the summer solstice. Based on this simulation we then determined the size of the solar power system and the optimum tilt of the solar panels. The results of this study will be described.

Rather than flying a rotator to keep one plane array of solar panels pointed at the sun, EUSO SPB1 had arrays of solar panels on all four sides of the gondola. Each side was tilted 14 degrees to maximize the power produced by the solar panels. Each array was connected

its own charging controller. These controllers had to operate in lock step in order to de-conflict their control functions. We will describe how this was accomplished.

The charging controller outputs were connected to the battery pack in parallel. A shunt and voltage divider were used to monitor the battery voltage and the current flowing into and out of the battery through the CSBF Science Stack. An array of DPDT relays were used to distribute the power to the instrument's subsystems. One pole of each relay switched the power while the other monitored the state of the relay. These relays were operated and monitored with the CSBF Science Stack.

The batteries use absorbed glass mat valve regulated lead acid technology and are designed to provide the high currents needed for cranking engines. In our application these batteries must provide a much lower current over the night. Extensive testing was required to gain experience with the performance of the batteries operated in this way. We will show the test results.

PSB.1-0047-18 APPLICATION OF SOLAR CELLS ON A HIGH ALTITUDE STRATOSPHERE BALLOON

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The use of solar cells can effectively reduce the stratosphere balloon load and increase its theoretical flight time. To guide the application of solar cells on the stratosphere balloon, a calculation model was developed. A configuration analysis model with the consideration of HIT solar cell parameters and the lithium-ion battery parameters was developed. It was based on the solar radiation model and the working model of the PV energy system. The influences of the balloon geometry, size and operation parameters, such as operation latitude, seasons, flight direction, and speed, etc. were analyzed. It can be used to analyze the energy balance of the balloon. A simulation was conducted to a specified balloon. The result indicated that the general design of the PV energy system could be easily determined with this calculation model. In order to study the practical performance of solar cells on the stratosphere balloon and verify the calculation model, a stratosphere balloon was designed to carry out a solar cell flight test experiment at an altitude of 20 km. The test used a 1-square-meter HIT solar module. In response to this, a dedicated circuit was designed to collect real-time battery voltage and current data, and access to the solar cell I-V curve. At the same time, the solar cell operating temperature and its corresponding solar radiation data was measured. According to this, the working efficiency of the solar cell on the stratosphere balloon was obtained, and the working performance data of the solar cell that varies with the flight of the stratosphere balloon was summarized. The experiment confirmed that the theoretical calculation model of solar cell performance was consistent with the measured results. This test provides practical data that support for the application of solar cells to stratosphere balloons.

PSB.1-0048-18 MOTION COMPENSATION, THERMAL CONTROL AND WAVEFRONT SENSING ON THE THAI-SPICE PAYLOAD

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At altitudes of 33 - 38 km, balloon-borne telescopes occupy a regime in which the Fried parameter is greater than 2 m. Telescopes with apertures up to the Fried parameter should be able to achieve diffraction-limited images. THAI-SPICE (Testbed for High Acuity Imaging - Stable Photometry, Image-motion Compensation Experiment) is a NASA-sponsored balloon program that will address two factors that can degrade image acuity: thermal gradients across the telescope and stability of the focal plane.

To study thermal gradients, THAI-SPICE will model the effectiveness of sun-shields, earthshields and optical telescope assembly (OTA) enclosures. Preliminary modeling suggests that a telescope's day/night thermal excursions can be reduced from over 50 K (without shielding) to less than 2 K (with passive shielding) and achieve steady-state temperatures as low as 180

K. Given the prospects for 100-day super-pressure balloon missions, the ability to passively cool a telescope is critical for infrared observations, and the reduction of temporal and spatial gradients eliminates one of the most significant obstacles to maintaining telescope alignment and mirror figure. THAI-SPICE will fly several instrumented OTA enclosures to test thermal models in the stratosphere.

To address image stability, THAI-SPICE will fly a 50-cm aperture telescope with pointing stabilized at the few arc-second level. Image motion on the focal plane will be characterized with a combination of inertial and optical sensors. To stabilize the focal plane at the 50 mas level, THAI-SPICE will use a solid-state tip-tilt correction device.

THAI-SPICE will also demonstrate a curvature wavefront sensor (CWS) to monitor aberrations in the balloon-borne telescope in-flight. The immediate goal is to quantify alignment errors and mirror aberrations as a function of the elevation angle, temperature field and other factors. An eventual goal will be to control a secondary mirror on a hexapod (or possibly a deformable mirror) to reduce aberrations. We will report on lab experiments in which we compare a CWS and a Shack-Hartmann array in head-to-head tests. THAI-SPICE is expected to have its first flight from Ft Sumner, NM in September 2019.

PSB.1-0050-18 UV OBSERVATIONS FROM HIGH ALTITUDE BALLOON PLATFORM

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Balloon experiments provide a great springboard for instrument development for future space missions. The lower cost and the flexibility in launch timings and flight duration make highaltitude balloon experiments a wonderful testbed for space technology. Wavelengths below 400 nm are difficult to observe from ground-based observatories, but at balloon floating altitudes observations above 280 nm, as well as between 200 and 220 nm, become possible, the latter due to the narrowing of O3 and O2 absorption bands. One of the major challenges for observations from the high altitude balloon platform is the platform stability and pointing accuracy of the platform. We have developed a pointing system to achieve observations from the balloon platform. The pointing and stability of the system are carried out as two-fold (coarse and fine pointing) operation, using inertial measurement sensors and a star sensor, respectively. The attitude sensor obtains the pointing information and corrects the position to an accuracy of

±0.24° using servo motors. The star sensor works in the inner loop, providing much finer accuracy of around 30". We have developed a UV telescope to fly on high altitude balloon platform which is a prime focus telescope to fly on a 5 kg payload capacity balloon. A fiber is used to fed the light collected by the telescope to the spectrograph. The spectrograph is based on Czerny-Turner design, to work in the wavelength range of 250 - 400 nm. The main science objective is to take the UV spectrum of bright objects. Here we will describe the instrumentation involved in the high altitude balloon experiment and the design and development of one of the UV payloads to fly on the balloon platform.

PSB.1-0051-18 UNINTENTIONAL IGNITION DURING A GROUND TEST OF A HEAVY LIFT HYDROGEN ZERO PRESSURE BALLOON FOLLOWING TERMINATION

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World View is leading the way in the emerging stratospheric economy, unlocking affordable new applications with the introduction of the un-crewed Stratollite flight vehicle, and pioneering new perspectives. World View is a Tucson based company that launches large balloons into the Stratosphere to test scientific payloads. Recently World View has been exploring the use of hydrogen to replace helium as the lift gas for stratospheric ballooning. An RD effort was undertaken to design the hardware and processes for a hydrogen-safe fill system, launch system, payload and balloon systems. A series of four ground tests using moored balloons with successively increasing lift (30 kgf to 11,000 kgf) were conducted to evaluate the safety and efficacy of these systems. The planned termination for each test balloon involved the venting of hydrogen by the tearing of one of the gore panels of the balloon. In all but the final test, the hydrogen vented as expected, safely ending each test. The balloon was successfully gored in the last test, but approximately 10 seconds after goring of the balloon, the hydrogen-air mixture just above the balloon ignited, which almost instantaneously capsized the balloon, and sent a strong pressure wave out from the center of the ignition. No personnel were harmed during the event (sufficient safety procedures were in place for the termination process), but there was some superficial damage to the nearby buildings. This paper will present the results of the findings from this test, so that the ballooning community can take our experience into account when looking at hydrogen as a lift gas alternative to helium.

PSB.1-0052-18 THE CNES AéROCLIPPER BALLOON CAMPAIGN OF GUAM 2017

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The AeroClipper developed by the French Space Agency (Centre National d'Etudes Spatiales - CNES) is a quasi-lagrangian device drifting with surface wind at about 20-30m above the ocean surface. It is a new and original device for real-time and continuous observation of air-sea surface parameters in open ocean remote regions. This device enables the sampling of the variability of surface parameters in particular under convective systems toward which it is attracted. The AeroClipper is therefore an ideal instrument to monitor Tropical Cyclones (TCs) in which they are likely to converge and provide original observations to evaluate and improve our current understanding and diagnostics of TCs as well as their representation in numerical models. One experiment took place in October 2017 from Guam Island, American territory located in the Western Pacific Ocean, in the framework of a scientific project in cooperation with the CNES and the Laboratory of Dynamic Meteorology (LMD).The AeroClipper demonstrates its capability to be captured by an Ocean Indian cyclone, as two models have converged, without damages, in the eye of Dora cyclone during the 2007 VASCO campaign. This paper will present the improvements of this AeroClipper system as well as the results of the 2017 Guam campaign.

PSB.1-0053-18 PLANETARY SCIENCE AT INFRARED WAVELENGTHS USING A BALLOONBORNE OBSERVATORY - FINDINGS FROM THE GONDOLA FOR HIGHALTITUDE PLANETARY SCIENCE (GHAPS) PROJECT

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The Gondola for High Altitude Planetary Science (GHAPS) was an observing asset under development by NASA's Planetary Science Division that would be hosted on stratospheric balloon missions intended for use by the broad planetary science community. A balloon-borne observatory like GHAPS could complement other ground and space-based telescopes, by virtue of low-cost access to near space and long duration flights. As specified in the 2016 GHAPS SIDT Report [1], not all decadal-class science questions will be amenable to study from the stratospheric GHAPS telescope, but certain questions are well suited to the advantages afforded by long-duration balloon missions in the upper stratosphere. In

particular, the lower terrestrial water content above stratospheric altitudes allows unique studies of ocean worlds and comets, whose main composition is water, as well as studies of carbon dioxide, which is not possible from the ground. The versatility of the mission and potential to host a wide variety of science (backend) instruments would allow the study of any celestial body (planets, moons and small bodies), both through imaging and spectroscopy. The SIDT Report helped: (1) define the scope of science investigations, derive the science requirements and instrument concepts, (2) prioritize the instruments according to science priorities that address Planetary Science Decadal Survey questions, and (3) generate a report that is broadly disseminated to the planetary science community. The GHAPS team created and examined different design reference missions, and characterized the different instrument requirements and challenges to a successful mission. In this presentation, we discuss potential science goals with GHAPS at infrared wavelengths, sensitivity expected for low-resolution (icy features) and high-resolution (gas features) studies, trade studies, as well as the core challenges observed during the mission development.

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[1] Chanover, N. J.; Aslam, S.; DiSanti, M. A.; Hibbitts, C. A.; Honniball, C. I.; Paganini, L.; Parker, A.; Skrutskie, M. F.; Young, E. F., Results from the Science Instrument Definition Team for the Gondola for High Altitude Planetary Science Project, American Astronomical Society, DPS meeting 48, id.123.31

PSB.1-0054-18 REPORT ON VENUS BALLOON OPTIONS FROM THE NASA VENUS AERIAL VEHICLE STUDY

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This paper summarizes the approach and results from a NASA-sponsored study on Venus aerial vehicles with a focus on the buoyant platforms that were considered. This study consisted of two multi-day workshops with intervening time for science and engineering analysis and involved a cross-disciplinary team of scientists, engineers and technologists drawn from NASA centers, industry and universities. The purpose was to identify what science could be obtained from different platforms, quantify the resource needs of mass, power and volume, assess the technological maturity of those platforms and provide guidance on required technology development investments to achieve flight readiness. The specific platforms considered were superpressure balloons, different types of variable altitude balloons, airplanes and a hybrid vehicle where lift is generated by both aerodynamic and buoyant forces. A key finding of the study was that variable altitude platforms provide a significant increase in scientific data return compared to constant-altitude superpressure balloons while requiring a potentially modest increase in mass, power and complexity. This paper provides the quantitative science and engineering data that justifies this conclusion along with the analysis methodology and underlying assumptions. It concludes by presenting the technology development roadmap matched to future mission opportunities along with a discussion of key technical challenges for each buoyant vehicle option.

PSB.1-0055-18 BALLOON-BASED INFRASOUND SENSORS FOR SEISMOLOGY ON VENUS

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The scientific investigation of the interior of Venus has for long been rendered impossible by the presence of extremely high temperature and pressure conditions on the planet's surface. Such extreme conditions restrict the lifetimes of surface missions to a few hours at best, which is far from sufficient for a seismological investigation, a key requirement for understanding a planet's interior.

However, with a highly dense atmosphere (90 atmosphere surface pressure) and relatively benign conditions in the middle and upper atmosphere, Venus is an ideal candidate for scientific ballooning. The remote detection of seismic waves is a particularly novel application for scientific ballooning on Venus. Seismic disturbances are known to generate infrasonic waves (frequencies < 20 Hz) by coupling energy from ground motion into the atmosphere. These waves have already been detected from earthquakes and volcanic activity from terrestrial stations on

Earth. On Venus, the coupling between the solid planet and the atmosphere is 60 times better than on Earth, owing to its high surface pressure. Therefore, sensitive and highly-accurate barometers can be deployed from free-flying balloons to detect seismically generated infrasonic waves. This technology was recently demonstrated by the authors in Pahrump, Nevada in an experiment where infrasonic waves from artificially created seismic disturbances were detected on barometers suspended from balloons. The success of this initiative heralds the prospect of investigating Venus' interior without having to land on the surface and survive for extended periods of time.

In this presentation, we will present our technique for the detection and characterization of infrasonic waves from seismic activity. We will also describe our progress from sensor development and deployment to a comprehensive analysis campaign involving signal processing, fusion of ground motion and barometric data, and simulations. Finally, we will discuss our path forward, which includes the expansion of balloon-based infrasound to study climatological and surface-atmosphere interaction phenomena. Our results will clearly demonstrate that infrasound sensors are a prime candidate for performing high-impact scientific ballooning, especially in inaccessible and harsh terrestrial environments, such as Venus.

PSB.1-0056-18 THE BIOPAUSE PROJECT: SCIENTIFIC BALLOON EXPERIMENTS FOR SAMPLING STRATOSPHERIC BIOAEROSOL

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The location of "biopause", the upper boundary of the biosphere, and the biological flux across the biopause on Earth are the key to understand the universality and distribution as well as the origin and evolution of life in the universe. The most direct information to elucidate the biopause is the distribution and dynamicity of life in the middle atmosphere. We carried out a scientific project named "Biopause" using JAXA's scientific balloons in order to grasp the dynamics of biological flux in the stratosphere, i.e. the lower middle atmosphere, comprehensively. Our first balloon experiment was conducted on June 8, 2016 and collected aerosol particles in the stratosphere using a newly developed descending inertial impactor. We estimated the number density of the stratospheric microbes including the unculturable ones for the first time in the world. In this presentation, we report the new results of the balloon experiment in this year and the initial results of the sample analysis.

PSB.1-0057-18 ESTIMATION OF THE DEPTHS OF THE UPPER AND LOWER BOUNDARIES OF THE MAGNETOACTIVE LAYER OF THE LITHOSPHERE

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Studies of the deep structure and structure of the earth's lithosphere, its geothermy, petrology, the depth of the lower boundary of its magnetoactive layer are relevant. There are ways to study the parameters of the lithosphere by interpreting the physical models of the solid Earth based on the thermal, magnetic and gravitational fields. The anomalous magnetic field (AMF) is particularly effective in studying the magnetoactive layer of the lithosphere, its upper and lower boundaries. The basic information about AMF was obtained as a result of aeromagnetic and satellite magnetic surveys. Satellite magnetic surveys do not contain signals generated by deep sources with dimensions smaller than the survey height. Aerial surveys are performed at low altitude (hundreds of meters) and because of the intense local magnetic anomalies, AMF maps do not take into account deep magnetic sources. This does not make it possible to determine the true depth of occurrence of the lower boundary of the magnetoactive layer from the AMF maps. However, the geomagnetic field of the upper boundary of the magnetoactive layer is well represented in aeromagnetic survey data (AMF maps), and the upper limit of the magnetoactive layer of the lithosphere is reliably determined from them. The geomagnetic field of the center of gravity of the magnetoactive layer is well represented by magnetic survey data at altitudes of 20-40 km and reliably determines the position of the center of mass of this layer. The lower boundary of this layer is reliably determined from the depth of the upper boundary of the layer and the obtained data of its center of mass. This is important for estimating the depth of the Curie isotherm, which is used to construct the temperature scale of the rocks of the lithosphere used in geothermy and petrology. The technique of balloon gradient magnetic surveys was developed and mastered in practice by means of stratospheric balloons at altitudes of 20-40 km.

PSB.1-0058-18 ASTROPHYSICS SUB-PANEL 1

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PSB.1-0060-18 ASTROPHYSICS SUB-PANEL 3

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PSB.1-0061-18 VALIDATION TEST RESULTS OF THE RADIO COMMUNICATIONS SYSTEM FOR THE "E3TRATOS" MISSION, A STRATOSPHERIC BALLOON EXPERIMENT IN COLOMBIA.

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The E3Tratos mission is a research project led by the School of Electrical, Electronic and Telecommunications Engineering of the Universidad Industrial de Santander (UIS) that seeks to launch the first stratospheric probe balloon from Bucaramanga (Colombia) with scientific instrumentation developed by researchers from the UIS university to monitor greenhouse gases in the atmosphere and obtain images of Santander region from the stratosphere. This work shows the progress and partial results obtained in the design and implementation of the communications system on board the balloon which is composed by 3 subsystems: 1. image transmission, telemetry transmission and atmospheric variables captured during the flight and 3. Payload geo-referenced position. The system is complemented by a ground station that will receive the data and will be supported by the local amateur radio network.

The functional model consists of four stages: data acquisition, power stage, communications and ground station. The communications stage operates in VHF, since it is the standard that is most used by radio amateurs, we will transmit GPS position and meteorological information measured by the stratospheric balloon payload.

The low-cost on-board communication system is designed according to a block structure consisting of a microcontroller, digital synthesizer, oscillator, RF amplifiers and filters. The microcontroller is implemented in an embedded system that has a four-core ARM processor with state-of-the-art features. The communication blocks are responsible for processing the signal and send it through an antenna. The ground station consists of an antenna designed and tuned to the frequency and bandwidth according to the recommendations ITU (International Teleconnections Unit), the remaining functional blocks of the ground station will be designed using software-defined radio (GNU Radio).

We show results on the different stages of the experiment design and implementation that lead us to validate the full communications system. Transmission results were obtained performing links with straight line sight at different distances, since a few meters up to 20 kilometers. These results are very promising to the success of the "ET3ratos" mission.

PANELS (P)

SATELLITE DYNAMICS FOR EARTH AND SOLAR SYSTEM SCIENCES AND APPLICATIONS (PSD.1)

PSD.1-0001-18 SUMMARY OF THE GRACE MISSION: ACCOMPLISHMENTS AND FUTURE ACTIONS

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The twin satellites of the Gravity Recovery and Climate Experiment (GRACE), which were launched on March 17, 2002, operated for more than 15 years. The mission objectives are to sense the spatial and temporal variations of the Earth's mass through its effects on the gravity field at the GRACE satellite altitude. The 15-year record of GRACE measurements recorded the seasonal cycle of mass transport between the oceans, land, cryosphere and atmosphere; its inter-annual variability; and the climate driven secular, or long period, mass transport signals. The three axis accelerometer measurements have recorded atmospheric neutral density variations through two solar cycles and altitude change from 495 km at mission initiation to 300 km at mission end. The global perspective and the accuracy of the measurements provided paradigm shifting insight into the Earth system interactions. Following a loss of battery capability, the nominal mission ended on October 10, 2017, when efforts to return to the science operations mode on exiting from the latest solar occultation period were unsuccessful. The last data collected was for the month of June, 2017. This early mission end will dictate a break of approximately one year between the GRACE and GRACE FO Missions, whose launch date is April, 2018. This presentation will review the mission accomplishments, describe the issues that influence the operations philosophy during the late mission years and the impact on data quality, discuss the future actions regarding the mission data and discuss the issues related to establishing continuity with the GRACE FO mission.

PSD.1-0002-18 COMBINATION SERVICE FOR TIME-VARIABLE GRAVITY FIELD SOLUTIONS (COST-G) - TRANSITION FROM AN EGSIEM PROTOTYPE SERVICE INTO A PRODUCT CENTER OF THE IGFS

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The European Gravity Service for Improved Emergency Management (EGSIEM) was a project of the Horizon 2020 Framework Programme for Research and Innovation funded for three years (2015 - 2017). One of the main objectives was to establish a prototype service to combine monthly gravity field solutions from the past GRACE mission in order to deliver improved gravity field solutions for applications in Earth and environmental science research. Five analysis centers have contributed to these prototype service activities, where combinations on the solution level and more rigorous combinations on the normal equation level were performed. We present the achievements made so far and report the successful transition from the prototype phase into regular operation. As a Product Center of the International Gravity Field Service (IGFS) of the International Association of Geodesy (IAG), the Combination Service for Time-variable Gravity Field Solutions (COST-G) will continue the activities initiated by the EGSIEM project for the upcoming GRACE Follow-On mission.

PSD.1-0003-18 MULTI-APPROACH GRAVITY FIELD MODELS FROM SWARM GPS DATA

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Although the knowledge of the gravity of the Earth has improved considerably with the CHAMP, GRACE and GOCE satellite missions, the geophysical community has identified the need for continued monitoring of its time-variable component with the purpose of estimating the hydrological and glaciological yearly cycles and long-term trends. The GRACE mission stopped its observation of the time variable gravity field at the end of 2017. The currently foreseen launch of GRACE Follow-On will be early 2018, such that a gap arises. This project aims at providing high-quality gravity field models from Swarm data that constitute an alternative source of gravimetric data, which could help alleviate this gap, as well as the short gaps that are present in the final stages of the GRACE mission. Independent from the existence of gravimetric data from dedicated satellite missions, the gravity field models derived from Swarm GPS data constitute an independent source of information about Earth's gravity field for e.g. monitoring of large mass transport processes.

Recently, the geodetic community has realized that the combination of the different gravity field solutions is superior to any individual model. We intend to exploit this fact and deliver the highest quality gravity field models, resulting from the combination of four different gravity field estimation approaches. In addition, we intend to evaluate the possibly added value of kinematic baseline solutions for the lower pair of Swarm satellites, which fly in a pendulum formation. To this aim, two different kinematic baseline solutions will be studied. In addition, two different models of non-gravitational forces will be used as well as observed non-gravitational accelerations for Swarm-C to assess the importance of separating conservative from non-conservative forces.

PSD.1-0004-18 ABSOLUTE AND RELATIVE ORBIT DETERMINATION FOR THE CHAMPGRACE CONSTELLATION

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This research investigates a satellite constellation consisting of two different missions, the CHAllenging Minisatellite Payload (CHAMP) satellite and the Gravity Recovery And Climate Experiment (GRACE) twin satellites. They provide us three dual-satellites formations: an in-line or along-track stable GRACE-A and -B formation for which two satellites are 220 km apart, and two high-dynamic CHAMP/GRACE formations whose baseline lengths could vary from about 120 km to 7500 km during the selected 24-hours orbit arcs. The three satellites are equipped with BlackJack space-borne high-precision dual-frequency Global Positioning System (GPS) receivers. They provide high-low satellite-to-satellite GPS tracking data to conduct Precise Orbit Determination (POD) and Precise Baseline Determination (PBD) for this constellation. A few impact factors are analyzed in this research. These factors include the large cross-talk interference on the CHAMP GPS main navigation antenna due to the functioning of its GPS occultation antenna, and quite different perturbation levels for high-dynamic and low-dynamic formations. The relative dynamics for two CHAMP/GRACE formations are stronger than for the stable GRACE twin satellites. To obtain precise POD and PBD solutions for this constellation simultaneously, an Iterative Extended Kalman Filter (IEKF) including a subset GPS carrier phase integer ambiguity fixing strategy is implemented. It can be set such that the ambiguities for GRACE twin satellites baseline are fixed with higher preference. Results indicate that the implementations of the so-called Code Residual Variation (CRV) patterns for CHAMP improves the GPS observations modeling accuracy on each tracking frequency. Tailored relative dynamics constraints are properly set for each formation. The use of external independent Satellite Laser Ranging (SLR) data for validating absolute orbits proves a line-of-sight orbit precision level of 2-3 cm for each satellite. Moreover, the relative dynamics constraints between CHAMP and GRACE and the ambiguity fixing for their baselines are also beneficial for further improvement of the absolute orbit for CHAMP. Eventually for the CHAMP/GRACE formation the consistency between kinematic and reduced-dynamic baselines is of the order of 1-3 cm in each individual direction when its length is within 4000 km. For the GRACE formation it is of the order of only a few mm. Comparison between GRACE reduced-dynamic baseline solutions and its on-board K-Band Ranging (KBR) system observations shows a good agreement of about 0.7 mm.

PSD.1-0005-18 THE COPERNICUS POD SERVICE: ARCHITECTURE, RESULTS AND IMPACT ON SCIENCE

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The Copernicus POD (Precise Orbit Determination) Service is part of the Copernicus Processing Data Ground Segment (PDGS) of the Sentinel-1, -2 and -3 missions (part of the European Copernicus Programme). A GMV-led consortium has developed, and it is operating the Copernicus POD Service being in charge of generating precise orbital products and auxiliary data files for their use as part of the processing chains of the respective Sentinel PDGS.

Currently there are five Sentinel satellites in orbit (S-1 AB, S-2 AB and S-3A); S-3B is expected to be launched in April 2018, and it will complete the constellation of these three missions. Future CD satellites are not expected before 2020.

Sentinel-1 requires high accurate orbits for InSAR processing; accuracies of 10 cm (2D) RMS in less than 3 hours and 5 cm (3D) RMS in less than 20 days. Sentinel-2 is an optical mission, which does not requires high accuracy orbital products - 1 meter (2D) RMS in less than 30 minutes; however the goal of the Copernicus POD Service is to obtain the same accuracy as for Sentinel-1. Finally Sentinel-3 is an altimetry mission, which requires accuracies in the radial component of the order of 8-10 cm (radial) RMS in less than 30 minutes, 3-4 cm (radial) RMS in less than 36 hours and finally 2-3 cm (radial) RMS in less than 25 days.

These satellites are all equipped with dual frequency geodetic-grade GPS receivers (on future CD satellite it will be a GPS+GALILEO receiver). Additionally, Sentinel-3 is equipped with a laser retro reflector for Satellite Laser Ranging (SLR) and a receiver for DORIS tracking.

By using similar orbital parametrizations, processing schemes, and inputs, the architecture of the Copernicus POD Service maximizes the synergies among the different missions to simplify the design and operations, and to obtain similar accuracy results across the three missions.

Quality control of the CPOD orbits is done by direct cross-comparison with independent orbit solutions provided by the Copernicus POD Quality Working Group (AIUB, CNES, DLR, EUMETSAT, ESOC, TU Delft, TUM .), each of them using a different POD strategy. With

S-3, SLR and DORIS provide independent means to validate the orbit.

This paper presents the Copernicus POD Service in terms of architecture, operations and orbital accuracy achieved by the different orbit products of the different missions. In particular it describes the architecture of the system, interfaces with the different centres (including the provider of GPS orbits and clocks and with the ILRS community), the physical models and POD strategy used, and the experience from processing routinely these different missions. This description if complemented with recent developments to process the new L2C GPS signals, and the future needs to process Galileo signals which will be available on the future CD satellites.

Then it describes the accuracy assessment of the products, and the different methodologies used for this, including the role of the Copernicus POD Quality Working Group. Finally, it describes the products generated to support scientific studies in areas like orbit modelling, ionospheric research, InSAR, altimetry, etc.

PSD.1-0006-18 AN INTER-AGENCY COMPARISON OF NON-GRAVITATIONAL FORCE MODELING FOR SENTINEL-3A

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One of the main objectives of the Sentinel-3 ESA Earth Observation Mission, jointly operated by ESA and EUMETSAT, is to measure sea surface topography in the frame of the Copernicus ocean and land observation services. It consists of the two satellites Sentinel-3A (launched on February 16, 2016) and -3B (expected launch in April 2018) in Sun-synchronous, near-polar orbits at an altitude of around 815 km. Altimetry measurements are conducted with a synthetic aperture radar altimeter and require the knowledge of precise and accurate satellite orbits.

The Sentinel-3 precise orbit determination (POD) relies on data tracked by the on-board geodetic-grade dual-frequency GPS receiver and the DORIS instrument. A laser retroreflector array allows validating the orbits by means of Satellite Laser Ranging (SLR). Within the Copernicus POD Quality Working Group (QWG) precise orbits from different agencies are routinely compared for validation purposes. All members of the QWG employ a reduced-dynamic POD scheme, involving models for gravitational and non-gravitational forces, as well as empirical and/or pseudo-stochastic orbit parameters to absorb modeling deficiencies.

The great demands on Sentinel-3 orbit accuracy require that empirical and pseudo-stochastic orbit parameters should be used

with utmost care as they might degrade the radial orbit leveling, directly affecting the derived altimetry measurements. This implies especially the need for sophisticated and detailed models of non-gravitational forces, including aerodynamic accelerations, solar radiation pressure and Earth radiation pressure. In this presentation the non-gravitational modeling details of different QWG members are compared for Sentinel-3A. Besides a direct comparison of the modeled accelerations, the impact on POD is analyzed by comparing empirical orbit parameters and by means of SLR.

PSD.1-0007-18 IMPROVED BOX-WING MODELLING FOR THE LOW EARTH ORBITING SENTINEL SATELLITES

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The Sentinel-1,-2, and -3 mission are part of the European Copernicus Programme. The low Earth orbiting satellites are designed for specific Earth observation applications, e.g., InSAR, optical imaging, and radar altimetry. The satellites are all equipped with geodetic-grade GPS receivers allowing for precise orbit determination on the few cm level. Such high accuracies are strongly required in particular for Sentinel-1 (C-band SAR) and Sentinel-3 (radar altimetry).

Precise orbit products for all three missions are generated from the Copernicus POD (Precise Orbit Determination) Service as part of the Copernicus Processing Data Ground Segment (PDGS). A GMV-led consortium is operating the Copernicus POD Service and it is delivering the orbital and auxiliary products.

The precise orbit determination procedure relies on sophisticated models for the gravitational and non-gravitational forces acting on the satellites. Box-wing models for the satellites are commonly used to apply the non-gravitational forces based on the direction and area of the individual surfaces and if applicable of their optical properties. As long as the satellites have simple shapes the box-wing models are fully sufficient for a precise modelling. However, if a satellite has a complex shape where self-shadowing significantly impacts the resulting nongravitational accelerations the box-wing modelling is limited.

Compared to other low-Earth orbiting satellites Sentinel-1 has a quite complex shape with selfshadowing of, e.g., the solar panel on the back of the SAR antenna. In the case of Sentinel-2 the solar panel is also shadowing one side of the satellite. Therefore, an improved box-wing modelling taking the self-shadowing into account is proposed to improve the orbit parameter estimation and the orbit determination results. Affected satellite surfaces are scaled based on the incident angle of the sun or the angle of the atmospheric drag acting on the satellite.

The proposed improved box-wing modelling is presented in detail. Improved results for Sentinel1 and Sentinel-2 are shown in terms of estimated orbit parameters, cross-comparisons to other orbit solutions provided by the Copernicus POD QWG (Quality Working Group) and in terms of orbit extrapolations.

PSD.1-0008-18 NON-GRAVITATIONAL FORCES ACTING ON SPACECRAFT: IMPACT OF DIFFERENT ATMOSPHERIC MODELS ON LEO ORBITS.

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Keywords: non-gravitational forces, LEO POD, atmospheric model, airdrag, atmospheric drag.

The current accuracy in the orbit determination of artificial satellites heavily depends on a detailed modeling of non-gravitational forces. Although the use of empirical orbit parameters may compensate for unaccounted forces, a direct modeling of the non-gravitational forces increases both the quality and reliability of the orbits.

Non-gravitational perturbations are caused by particles interacting with the spacecraft surface. The largest force acting on a Low Earth Orbiter (LEO) below 800 km is airdrag followed by direct solar radiation pressure, Earth radiation pressure (i.e. reflected solar light and emitted thermal radiation) and finally the spacecraft thermal re-emission. The modelling of these forces was first performed half a century ago, but has undergone substantial improvements during the last decades. Recent atmospheric models and a better knowledge of solar activity constitute important advances, while high precision horizontal wind models and a better understanding of the gas-surface interaction between the satellite surface and the atmosphere are key parameters of airdrag modelling. In addition, precise measurement of the Earth local albedo/emissivity from CERES mission and accurate optical properties of the spacecraft surface lead to realistic computations of the photon surface interactions.

Airdrag is the most unpredictable non-gravitational force. The uncertainties in the atmospheric models (especially the density) are considered the primary source of error in the computation of airdrag. Therefore, this contribution will focus on the impact of the atmospheric and horizontal wind models on LEO orbits. We use the Bernese GNSS Software to compute the aforementioned non-gravitational forces. We will assess the orbit quality of different LEOs (GOCE, Sentinel-3A and GRACE) for each of the three most recent atmospheric models (NRLMSISE-00, JB2008 and DTM2013), both with and without scaling factor estimation. In order to support our results, statistics of the reduced-dynamics orbit fit will be shown, as well as external validations based on K/Ka-band ranging and satellite laser ranging measurements.

PSD.1-0009-18 GPS-DERIVED THERMOSPHERIC DENSITY DATA FOR THE SWARM SATELLITES

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The Swarm constellation consists of three identical satellites which fly in low Earth orbits to study the dynamics of the Earth's magnetic field. To geo-locate the onboard scientific instrument observations, the satellites are equipped with high-quality GPS receivers for precise orbit determination at the few cm level. The Swarm payload also includes an accelerometer, in order to derive information about the atmospheric density and wind. Unfortunately, the Swarm accelerometer measurements suffer from a variety of unexpected disturbances, which severely affects their usefulness. An alternative approach has therefore been developed where the non-gravitational accelerations are estimated directly from the high-quality GPS data using a Kalman filter approach. These estimated accelerations are used to generate low resolution densities for all Swarm satellites, and to correct and augment the accelerometer observations, currently available for Swarm-C only, to generate higher resolution densities.

This presentation describes the strategy that is used to estimate thermospheric densities from the GPS observations and gives an assessment of the obtainable resolution and accuracy. The resulting GPS-derived densities for the entire mission are presented and compared with thermospheric density model observations. For the most recently derived Swarm density data, these comparisons suggest a new deep solar minimum, similar to the one in 2008.

PSD.1-0010-18 EFFECT OF IONOSPHERIC AERODYNAMICS ON THE MOTION OF LOW EARTH ORBIT OBJECTS

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An accurate understanding of all the forces affecting the dynamics of Low Earth Orbit (LEO) objects is essential for providing precise orbit prediction and determination capabilities that address some of the challenges posed by the modern space environment. A key force influencing the motion of LEO object is their aerodynamic interaction with the local space environment. An aspect of LEO aerodynamics often neglected is the force resulting from the charged interaction between objects and the ionosphere i.e. ionospheric aerodynamics. Based on Particlein-Cell (PIC) simulations and atmospheric model outputs, this work examines the significance of ionospheric aerodynamics to the motion of LEO objects. Results highlight the potential importance of including ionospheric aerodynamics in forces models; preliminary observations indicating ionospheric drag may cause a 5%-35% increase in net drag along an orbit for a -3V 3U CubeSat class object at approximately 460 km altitude. The implications of findings in this work to the active satellite control (formation keeping, de-orbit, etc) are briefly discussed.

PSD.1-0011-18 ACTIVE USE OF IONOSPHERIC AERODYNAMICS FOR THE CONTROL OF SATELLITES

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Aerodynamic accelerations in Low Earth Orbit (LEO) are becoming more popular as a propellantless means of controlling formations of miniaturised satellites. For example, Planet, a Silicon Valley based company, routinely use differences in the drag acceleration acting on their CubeSats to establish constellations.

However, the component of drag due to a charged object interacting with the ionosphere is commonly neglected. Recently, studies have shown that ionospheric drag may cause a net increase in aerodynamic force of 5%-35%. Furthermore, the influence of ionospheric aerodynamics increases with, and can be controlled by, the spacecraft's electrical potential relative to the surrounding plasma.

UNSW Canberra is driving research into ionosphere aerodynamics and this work is the first effort in implementing active use of ionospheric aerodynamics for the control of spacecraft.

High fidelity orbit propagation software with inputs from the GITM, NRLMSISE-00, and IRI2012 atmospheric models are used to assess ionospheric drag enhanced manoeuvring based on the time required to achieve rendezvous, planar rephrasing, collision avoidance, and re-entry over varying initial orbital and environmental conditions.

PSD.1-0012-18 THE EFFECT OF SOLAR FORCING INDUCED ATMOSPHERIC PERTURBATIONS ON LEO SATELLITES' NOMINAL AERODYNAMIC DRAG

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The upper atmosphere changes significantly in temperature, density and composition as a result of solar cycle and storm interval variations due to the amount of absorbed solar radiation from solar energetic events. Satellite orbits are consequently affected by this scenario, especially those in low Earth orbit (LEO). Atmospheric drag is the strongest force perturbing the motion of satellites in LEO, and could cause re-entry of satellites, difficulty in identifying and tracking of the satellites and other space objects, manuvering and prediction of lifetime and re-entry. In this paper, we present the model of atmospheric drag effect on the trajectory of hypothetical and real LEO satellites of different ballistic coefficients. We investigated long-term trend in atmospheric drag on LEO satellites (due to solar forcing induced atmospheric perturbations and heating) at different phases of the solar cycle, and during short interval of strong geomagnetic disturbances or storms. We also show the dependence of orbital decay on the satellites ballistic coefficients, severity of solar cycle and phase and the extent of geomagnetic perturbations.

PSD.1-0013-18 CONTRIBUTION OF DORIS IN UNVEILING SYSTEMATIC ERRORS IN ALTIMETER SATELLITES' PRECISE ORBITS

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The continuous record of sea surface height measurements was initiated in 1992 by the TOPEX/Poseidon (NASA/CNES) mission and continued in 2001, 2008 and 2016 with the successive launches of the reference Jason-1 (CNES/NASA), OSTM/Jason-2 and Jason-3 (CNES/NASA/EUMETSAT/NOAA) satellites, respectively. The complementary missions Envisat and CryoSat-2 (ESA), HY-2A

(CNSA), Saral/AltiKa (ISRO/CNES), Sentinel-3A/B (ESA) fly in different orbits with lower altitudes and higher inclinations. This altimeter constellation of 10 satellites will keep expanding in the future with the extension of the three families Jason-CS, Sentinel-3 and HY-2 with 11 more satellites by 2030, not counting the next generation radar altimeter U.S.-French SWOT mission. All these Low-Earth Orbiters (LEOs) are at least equipped with a DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite) receiver in addition to a laser retroreflector array, and most of them also carry a GPS (Global Positioning System) dual-frequency receiver, to support their Precision Orbit Determination (POD) requirements.

The CNES POD group delivers homogeneous precise orbit solutions for these independent altimeter missions. This paper presents our plans for updating our POD standards and investigating improvements to modeling or mitigating remaining sources of orbit error. In particular, we show results from independent validation of SLR station biases, long-wavelength time-variable gravity recovery before the GRACE era, as well as geocenter motion determination, leveraging the long-time history of LEO satellites that are tracked using DORIS measurements.

PSD.1-0014-18 IMPACT OF VARIOUS MODELS ON ORBITS OF JASON SATELLITES

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Precise orbits of altimetry satellites are a basis for global and regional sea level investigations, since they provide positions of an altimeter, from which the distance to the sea surface is measured. High accuracy is required for satellite orbits, since any radial error maps directly in sea level height. In this paper, we show the impact of some effects on the orbits of altimetry satellites Jason-1, Jason-2 and Jason-3. In particular, we show the impact of the new ITRS realisations ITRF2014, DTRF2014 and JTRF2014 on Jason-2 orbit, as compared to using a previous ITRS realization for SLR stations - SLRF2008. Additionally, the impact of the refined satellite attitude handling on orbits is exemplary shown for Jason-2. We investigate the advantage of using DORIS observations in addition to SLR measurements for precise orbit determination of Jason satellites. Improved macromodels of Jason satellites improve orbit quality additionally. Importance of non-tidal loading modelling is shown as well. Furthermore, we study the impact of various perturbing forces on Jason satellites. The impact of these effects on the root-mean-square and mean fits of observations, single-satellite sea surface height (SSH) crossover differences, mean and standard deviations of the radial errors, as well as geographically correlated mean SSH errors is investigated.

PSD.1-0015-18 CAN WE IMPROVE THE ATMOSPHERIC DELAY CORRECTIONS FOR SATELLITE LASER RANGING?

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Unlike in microwave-based techniques where weak tropospheric modelling can be compensated to a large extent by estimating residual delays, the observation geometry in satellite laser ranging (SLR) hinders such a treatment. Therefore the a priori tropospheric delays should be known as good as possible. We revisit the modeling of the atmospheric delay in SLR data analysis focusing on zenith delays, the mapping function and the gradients with the aim to improve orbit determination and parameter estimation. Firstly data from the model levels of ERA Interim reanalysis are employed to homogenize the in situ meteorological data recorded in the measurement data. Doing so several stations show up with non-negligible biases and jumps in their pressure series. Secondly by rigorous ray-tracing in ERA Interim, the so-called Potsdam Mapping Functions (PMF) for laser frequencies is determined. The differences between PMF and the latest standard in SLR mapping functions, FCULa, can be as large as 3 mm at 20 degree elevation. Thirdly gradient components of first and second order based on the ray-traced delays are estimated. As gradients from the tropospheric model are neglected in standard SLR analysis, errors as large as 30 mm at 20 degree elevation may be induced. The homogenized meteorological data, the PMF and the gradients are applied in Precise Orbit Determination for eight years of LAGEOS-1 and -2 SLR observations. The impact of these refinements in terms of orbital fits and their effect on reference frame and station coordinates are assessed.

PSD.1-0016-18 POSTER INTRODUCTION ROUND

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Poster Introduction Round

PSD.1-0017-18 TEST OF PULSAR NAVIGATION WITH INSIGHT-HXMT

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Pulsar Navigation, which utilizes pulsar observations to determine the position or orbit of a spacecraft, has attracted more and more attentions. In this work we report our first results testing pulsar navigation with Insight-HXMT observations. Insight HXMT, which is launched in 2017, comprises of three x-ray telescopes covering the energy band 1-250keV. A new pulsar navigation algorithm has been proposed for orbit determination. With 5-day-long observations of the Crab pulsar, the orbit was determined successfully within 10 kilometres.

PSD.1-0018-18 AN INVESTIGATION INTO CUBATURE KALMAN FILTER PERFORMANCE FOR ORBIT DETERMINATION APPLICATION

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The purpose of this work is to discuss the Cubature Kalman Filter (CKF) performance when applied to a high nonlinear problem: artificial satellites orbit determination, using real Global Positioning System (GPS) data. The CKF is a discrete-time nonlinear Bayesian filter based on a third-degree spherical-radial cubature rule, which allows to numerically computing multivariate moment integrals in the Bayesian filter. In particular, it also provides a set of cubature points scaling linearly with the state vector dimension. As a result, the CKF yields a systematic solution for high dimensional nonlinear filtering problems, such as the orbit determination addressed here. In this work, the application consists of determining the orbit of an artificial satellite, using real data from the GPS receivers. This is a nonlinear problem, with respect to the dynamics and measurements equations, in which the disturbing forces are not easily modeled. The problem of orbit determination consists essentially of estimating values that completely specify the body trajectory in the space, processing a set of observations that can be collected through a tracking network grounded on Earth or through sensors, like space GPS receivers onboard the satellite. The GPS is a widespread system that allows computation of orbits for artificial Earth satellites by providing many redundant measurements. Throughout an onboard GPS receiver, it is possible to obtain nonlinear measurements (pseudoranges) that can be processed to estimate the orbital state. The standard differential equations describing the orbital motion and the GPS measurements equations are adapted for the nonlinear filter so that the CKF algorithm is also used for estimating the orbital state. The assessment to be presented will be based on the robustness of the filter, concerning convergence speed when the measurements are scattered. The results from CKF will be compared to the unscented Kalman filter (UKF) results for the same problem, in computational terms such as convergence and accuracy. Based on the analysis of such criteria, the advantages and drawbacks of the implementations are presented.

PSD.1-0019-18 OPTIMAL EARTH COVERAGE ANALYSIS OF SATELLITES IN FORMATION

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Optimal Earth Coverage Analysis of Satellites in Formation

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The concept of spacecraft flying in formation has indeed revolutionized the way satellite is being used today. Most often, a single fully-functional spacecraft is unable to cater for all the demands required by multi-hierarchical satellite operators and users especially when optimal Earth coverage region is desired. Formation flying spacecraft is capable of offering indigenous solutions to constraint Earth surface coverage problem while greatly improvised the applicability and their usability in the sense that longer satellite lifetime were possible, operational redundancy can be achieved and multi-tasking mission objectives could be accomplished. So far, there have been very few researches associated with the satellite formation flying for an optimal Earth coverage. In this paper, we conducted a performance measure analysis for two satellites flying as an example in close formation in low Earth orbit. Their respective ground track coverage areas were assessed and analysed in detail to extract valuable properties such as average instantaneous overlapping area (IOA), maximum coverage distance and formation altitude influence on satellite coverage performance measures in relation to different orbital configurations. Parametric studies involving effect of varying formation distance and altitude on the resulting overlapping coverage area were done in order to gain an understanding of the trend which later can be exploited to optimize the potential of optimal spacecraft formation flying for the purpose of Earth observation mission ground coverage. In the proposed model, a specific orbit inclination with no great perturbation effects were proposed together with the deduced spacecraft formation flying governing equations. Determination of overlapping coverage area parameter is numerically computed using the model of double overlap configuration type which is calculated for a period of one orbital cycle. Preliminary results showed significant influence of formation distance on the resulting overlap area if compared to the effect of changing altitude. However, there exists dynamic relationships between formation altitude and formation distance for the determination of overlapping coverage area. For instance, higher altitude formation flying with small separation between spacecraft resulted in larger overlapping area as compared to lower altitude with small separation spacecraft formation. The results were subsequently analysed using 3-dimensional graph to investigate each variable's trend towards acquisition of optimum Earth surface coverage region. Finally, the findings allow to establish the correlation between the deduced spacecraft formation flying governing equations and the optimal parametric ground coverage relations.

PSD.1-0020-18 FUEL-OPTIMAL CONTROL FOR SPACECRAFT FORMATION FLYING AND RECONFIGURATION PROPELLED USING ELECTROMAGNETIC FORCES.

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With the development of small satellite technique, a spacecraft capable of producing higherthan-natural electrostatic charges may keep desired relative distances and orientations via the Lorentz-force interaction with a planetary magnetic field. This paper presented Hybrid combination of Lorentz forces provided by modulating spacecraft's electrostatic charge (magnetic and electric fields), using a Cartesian coordinates-based description of the spacecraft's relative states. Numerical simulation results are provided to demonstrate the functionality of the proposed controller to correct the drift due to J2 perturbations. We have used two different examples of formation flying satellites, the first example (TanDEM-X - TERRA SAR X) have relative poison about 3 km, the second (CLOUDSATCALIPSO) have about 600 km. The obtained results confirm that in the first case the effect off j2 on relative poison is about 3.9 km through 10 periods, and the magnitude of charge to mass ratio (q/m) must be -0.256 C/kg to correct about 3.7 km when used magnetic part of Lorentz force only. In addition, the rest of drift 0.2 km has been coerced after the electric part of Lorentz are considered. On the other hand, the drift of the second case for relative position due to J2 is about 2.1 km through 15 periods, and we need a charge to mass ratio + 0.185 C/kg to corrected 1.9, and 0.2 km using magnetic and electric parts of Lorentz force respectively. Finally, the required velocity increment (V) for controlling in both cases charged and uncharged spacecraft are presented.

PSD.1-0022-18 SOLVING THE MAIN PROBLEM IN SATELLITE THEORY THROUGH RECURRENT NEURAL NETWORKS

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Machine learning techniques have turned out to be game-changers in several fields of engineering and applied sciences. However, their potential for the analysis and prediction of dynamical systems is only starting to be expressed. This work takes a decisive step in this direction by investigating the possibility of using Recurrent Neural Networks (RNNs) for the trajectory prediction of an orbiter subject to the gravity field of an oblate Earth (i.e., the main problem in satellite theory).

While previous works have applied static machine learning algorithms such as feedforward neural networks and Support Vector Machines (SVMs) to orbit propagation and prediction tasks, the trajectory evolution may best be represented through algorithms capable of representing sequential time series. RNNs, and, in particular, the specialized architecture called Long ShortTerm Memory (LSTM), model sequential data achieving success in a large variety of domains including natural language processing and genomic analysis. Importantly, LSTM can capture both long range dependencies as well as non-linear dynamics representing an ideal model to capture the behavior of systems with multi-scale dynamical structures. Once trained, the evaluation of a RNN/LSTM output is relatively inexpensive. This makes such algorithms attractive candidates for precise on-board orbit propagation and for large-scale simulations of the RSO catalog, inter alia. Moreover, the parallel programming paradigm can be exploited so as to further decrease the computational time required for training and prediction.

We adopt a supervised learning approach in which a RNN/LSTM is trained on data provided by reference trajectories computed with high-accuracy numerical integrations. The evolution of the trajectory provided by the trained RNN/LSTM is compared to the reference in order to tune its parameters by trial-and-error. Moreover, the correctness of the short-periodic and secular behavior of the RNN/LSTM solution is checked against known firstand second-order analytical approximations. We establish time boundaries in which the RNN solution is under an assigned error threshold, and compare its CPU time with respect to an efficient numerical orbit propagation technique.

PSD.1-0023-18 TWO-LINE ELEMENT ESTIMATION FROM SPACE CATALOG USING DEEP NEURAL NETWORK

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The US Space Catalog includes Two-Line Elements (TLEs) of resident space objects (RSO), and Joint Space Operations Center (JSpOC) publishes publicly available TLEs on its servers. Although TLEs are widely used for space research and space operations, the official estimation scheme of TLEs in the Space Catalog isn't available. The current method for estimating TLE is based on non-linear least squares and finite difference methods VC2008. Because this approach applies differential corrections to the initial conditions to reduce the sums of errors between the orbital data and associated propagation of Simplified General Perturbations #4 (SGP4) propagation to estimate TLEs, it requires good initial estimates of the TLEs to avoid local minima that end up with inaccurate TLEs. Keplerian elements at epoch are used as initial estimates for TLEs in the current method. However, this assumption leads to local minima for most orbits. Therefore, a novel method to estimate TLEs without requiring good initial estimates is needed. Because machine learning methods are basically universal approximation tools, they can be trained to learn to estimate TLEs from Space Catalog. Moreover, the estimations of a machine learning model can be near-real-time (NRT) once it is developed by training with data. Although there is no mathematical tool that can prove a neural network (NN), which is a machine learning method, don't get stuck in local minima, it is highly unlikely that they end up in local minima because the training data are very high-dimensional. In addition, there are empirical techniques to evaluate the performance by monitoring the progress of the search process during training, and improving the model by continuously iterating over training, development test, and test data sets to avoid local minima. For NN to discover the distribution of the information in the data, the data representation is essential. The orbital evolution is represented in osculating elements and mean elements that are corrected for each time step by differential corrections method. Two different NN architecture will be investigated, namely convolutional and fully-connected neural networks. The NN model that can accurately estimate TLEs will be beneficial not only for maintaining space operations but also for promoting space situational awareness by providing a robust tool that doesn't require intensive computations that might be more essential for other tasks.

PSD.1-0024-18 MGEX: STATUS UPDATE ON THE MULTI-GNSS PILOT PROJECT OF THE INTERNATIONAL GNSS SERVICE

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The major task of the Multi-GNSS Pilot Project (MGEX) of the International GNSS Service (IGS) is tracking, collating and analyzing all available GNSS signals. The final goal is the integration of the evolving global and regional satellite navigation systems Galileo, BeiDou, QZSS, and NavIC (IRNSS) into the IGS operational products. The backbone for these activities is a network of multi-GNSS tracking stations available at the IGS data centers. Currently six MGEX analysis centers generate precise multi-GNSS orbit and clock products on an operational basis. Further products include merged navigation data, a dedicated CNAV product for GPS and QZSS, as well as two multi-GNSS differential code bias (DCB) products.

This contribution presents the current status of the multi-GNSS tracking network and the MGEX analysis products. Progress in solar radition pressure modeling is demonstrated and evaluated by satellite laser ranging residuals and orbit comparisons. The GNSS providers of Galileo and QZSS have recently published metadata like antenna offsets, spacecraft mass, and transmit power. The impact of these data on the analysis products will be demonstrated. Furthermore, clock analysis of new satellites not covered by the current MGEX products will be presented, namely for the BeiDou-3 and QZSS geostationary satellites.

PSD.1-0025-18 DETERMINATION OF GALILEO ORBITS AND GEODETIC PARAMETERS BASED ON SLR AND COMBINED SLR-GNSS SOLUTIONS

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Determination of precise satellite orbits of the Galileo constellation constitutes one of the key prerequisites for obtaining high-quality geodetic products, such as station coordinates or Earth rotation parameters. Various external forces, such as direct solar radiation pressure, Earth's albedo and infrared irradiance, perturb Galileo orbits and limit the quality of estimated satellite positions. Galileo satellites are especially vulnerable to non-gravitational accelerations due to their relatively low masses when compared to other GNSS spacecraft. Recently, the European Space Agency published key characteristics and parameters describing surface properties of Galileo In Orbit Validation (IOV) and Full Operational Capability (FOC) satellites, which allow the users to properly account for albedo and Earth infrared irradiance in the process of precise orbit determination. In this study, we evaluate the impact of antenna thrust, albedo and infrared irradiance on Galileo IOV, Galileo FOC, and Galileo FOC launched into incorrect eccentric orbits as a function of the beta angle, the argument of satellite latitude with respect to the Sun position and the height of the satellite above the Earth's surface. We show to what extent the proper orbit modeling reduces the RMS of satellite laser ranging (SLR) residuals and to what extent the neglect of a proper albedo modeling can be absorbed by estimating empirical orbit parameters (ECOM).

All Galileo satellites are equipped today with laser retroreflector arrays dedicated to SLR. Using

SLR data to Galileo allows for estimating global geodetic parameters, such as Earth rotation parameters and geocenter motion. In this study, we evaluate the quality of global geodetic parameters estimated on a basis of SLR tracking of Galileo satellites and other new GNSS constellations. One of the Galileo IOV satellites, E20, has been transmitting the signal solely on one frequency due to a serious batter outage in 2014. Single-frequency signal does not allow for the precise orbit determination when employing ionospheric-free linear combination. Therefore, there are no MGEX orbits available for E20. In this contribution, we use SLR data to determine E20 orbits. The quality of SLR-derived Galileo orbits is then evaluated on the basis of the quality of orbit overlaps and a comparison to E19 which was launched into the same orbital plane as E20. Finally, we show first results from the combined SLR-GNSS solution and advantages of such a combination.

PSD.1-0026-18 AN APPROACH FOR PARAMETER DECORRELATION IN PRECISE DYNAMIC ORBIT DETERMINATION

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Orbits and clocks are two fundmental parameters for the global navigation satellite systems(GNSS). Coventionally, satellite orbits are obtained by the dynamic orbit determination(DOD) technique, which uses satellite's dynamics and perturbations as constrains. Precise GNSS satellite time information is also derived from the DOD technique among the international GNSS community. We find apparent orbit/clock offsets in the most precise estimations among the International GNSS Services(IGS) analysis centers. The offsets include constant and periodical terms.

And the periodical terms of satellite orbits and satellite clocks are highly correlated. These results reveal one problem in the current IGS DOD technique, i.e. the correlation between the orbital radial component and satellite clock. And this problem may limit the accuracy of the GNSS services and its contribution to the definition and maintanance of the International Terrestrial Reference Frame(ITRF). Different from the traditional DOD, we develop a two-step TWTT(Two Way Time Transfer) assisted DOD approach for the decorrelation of satellite orbit and clock parameters. In the first step,the typical technique for precise time transfer TWTT, which is un-affected of satellite orbits error, is used to estimate satellite clocks. Afterwards, the precise clocks are fixed as known in the DOD processing. We test the approach for the BDS precise orbit determination, where TWTT data is retrieved from the ground tracking antennas and the GNSS observations are from around 50 globally-distributed sites. Results show that the new approach improves the precision of orbit determination and orbit prediction by more than 15% and 70%.

PSD.1-0027-18 INTER-SATELLITE LINKS: A VERSATILE TOOL FOR GEODESY AND PLANETARY AND INTERPLANETARY NAVIGATION

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With the use of low-low satellite-to-satellite tracking gravity field recovery made a big step forward. Based on this technique the Gravity Recovery And Climate Experiment (GRACE) mission delivers monthly gravity field with high precision, allowing to measure effects in Earth water storage basins and variations in ice mass in Greenland and Antarctica from space. GRACE is using a Ka-band inter-satellite ranging technique, GRACE Follow-On will in addition test optical ranging. In fundamental physics high-precision optical inter-satellite tracking will be used to detect gravitational waves in space, as a first step LISA Pathfinder was launched recently. Inter-satellite links are not only used for ranging, also data transfer in space is based on such links. ESA's European Data Relay System will be established in up-coming years to collect data from the low orbiting Sentinel satellites and transfer the high data rate to ground. The same link may be used for ranging, data transfer and time transfer, a functionality that is discussed for next generation Galileo satellites. But to exploit this synergy a common concept for all three tasks has to be developed. In this paper we show that with inter-satellite ranging techniques with µm accuracy the limited accuracy of GNSS based orbit determination of low Earth orbiters (LEO), which is due to the limitations of one-way microwave tracking (unsynchronized clocks, phase center variations and offsets of the sending and receiving antennas) can be overcome. In the ESA study GETRIS the following question is answered: How can a highly accurate and precise GEO-based two-way ranging method support GNSS tracking? The reduction of systematic errors in LEO precise orbit determination (POD) by exploiting the synergy between ranging, dataand time-transfer is assessed in a concept consisting of precise two-way GEO-LEO tracking (as used for data transfer) and an ultra-stable oscillator on-board of the geostationary satellite (GEO) synchronized from ground. We now want to get a step further and design a versatile concept for the use of this synergy in a satellite constellation based on existing and future planned ESA infrastructure and highlight the benefits in different disciplines from geodesy to interplanetary ranging, with emphasis on gravity field recovery, where a proposal for the ESA EarthExplorer 10 is based on a minimal constellation for gravity field determination.

PSD.1-0028-18 ORBIT DESIGN OF LUMIO, A LUNAR METEOROID IMPACT OBSERVER

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The Lunar Meteoroid Impact Observer (LUMIO) is a CubeSat mission to observe, quantify, and characterise the meteoroid impacts by detecting their flashes on the lunar farside. This complements the knowledge gathered by Earth-based observations of the lunar nearside, thus synthesising a global information on the lunar meteoroid environment.

The mission implements a sophisticated orbit design: LUMIO is placed on a halo orbit about Earth-Moon L2 where permanent full-disk observation of the lunar farside is made. This prevents having background noise due to Earthshine, and thus permits obtaining high-quality scientific products. Repetitive operations are foreseen, the orbit being in near 2:1 resonance with the Moon orbit. Innovative full-disk optical autonomous navigation is proposed, and its performances are assessed and quantified.

LUMIO is one of the two winner of ESA's LUCE (Lunar CubeSat for Exploration) SysNova competition, and as such it is being considered by ESA for implementation in the near future. In this presentation, emphasis will be put on the orbit design of LUMIO, which has been conducted following a hierarchical trade-off structure. The selected orbit will be described in relation to the scientific objectives of the mission.

Panels (P)

Satellite Dynamics for Earth and Solar System Sciences and Applications (PSD.1)

PSD.1-0029-18 LUNAR FAR SIDE POSITIONING ENABLED BY A DEPLOYED CUBESAT SYSTEM IN AN EARTH-MOON HALO ORBIT

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For the exploration of the far side of the moon, it is necessary to tackle the challenges of navigation and communication as the far side is invisible to the Earth. This paper proposes a mission consisting of four CubeSats in an Earth-moon L2 (EML2) halo orbit to assist the positioning of an asset on the far side of the moon, as EML2 halo orbits are always visible from the Earth and the lunar far side. Being miniature, CubeSats can be carried by a mother spacecraft aimed at the moon and deployed during the mid-course.

On the other hand, CubeSat missions are generally constrained by the very limited communication and propulsion capacity. A previous study has given a low-Δv deployment strategy for forming constellations in halo orbits. To further access the practical feasibility, this paper addresses the mission and system design, the accuracy of positioning related to the configuration of CubeSats, and optimal deployment trajectories in the continuous-thrust full-ephemeris model as well as the propulsion system options.

Key findings include 1) small halo orbits are favorable in terms of far-side coverage and positioning accuracy; 2) a low thrust as small as 0.7 mN can meet the requirement of deployment almost regardless of the reference Julian Date, and 3) the positioning accuracy is 3 km for a maneuvering object and 800 m for a ballistic object.

PSD.1-0030-18 IMPROVING THE GEOMETRY OF KAGUYA EXTENDED MISSION DATA THROUGH REFINED ORBIT DETERMINATION USING LASER ALTIMETRY DATA

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The Japan Aerospace Exploration Agency's (JAXA) SELenological and ENgineering Explorer (SELENE) mission to the Moon was launched in September 2007 and consisted of 3 spacecraft: a main satellite and two sub-satellites. The Kaguya mission, as it was also known, was the first of several late 2000's missions that marked a return to the exploration of the Moon and achieved many firsts. Today, Kaguya data are of fundamental importance and are highly complementary to data acquired by several earlier and later instruments, including of the Apollo Metric and Panoramic Cameras, the Chandrayaan-1 Moon Mineralogy Mapper (M3), and the Lunar Reconnaissance Orbiter's (LRO's) Wide and Narrow Angle Cameras (WAC and NAC). Kaguya's primary mission (PM) lasted from October 20, 2007 until October 31, 2008, and the extended mission (XM) lasted from November 1, 2008 until the controlled impact of the main satellite on the lunar surface on June 10, 2009. The main satellite's average altitude was 100 km during the PM and it was lowered to 50 km during the XM, with some periods having an even lower altitude. As a consequence, Kaguya science products using XM data have an increased spatial resolution. However, the geodetic position quality of these products is much worse than that of those acquired during the PM: radio tracking of Kaguya (necessary for determining the spacecraft's orbit precisely) was reduced after the PM, and the loss of momentum wheels resulted in frequent thrusting to maintain attitude, which further degraded the orbit determination accuracy. As a result, the degraded orbit quality during XM (at a level of several km compared to 10-30 m during PM) severely limits the scientific value of these high-resolution data.

Here, we show how making use of recent advances in lunar knowledge can improve the geometry of the Kaguya XM data. We redetermine the XM orbits for the main satellite by using improved gravity field models of the Moon, derived from data of the Gravity Recovery and Interior Laboratory (GRAIL) mission, and by using a novel data type for orbit determination, based on improved knowledge of the lunar topography from laser altimeter data of the Lunar Orbiter Laser Altimeter (LOLA) onboard LRO. We use the Kaguya Laser Altimeter (LALT) data directly in our orbit determination software GEODYN II, by comparing the LALT ranges to a high-accuracy LOLA topography basemap. As a result, the main satellite's orbit will be geodetically accurate and directly tied to the LOLA/LRO frame. We show that by using the GRAIL models in combination with the LALT data, we can improve the XM orbits from the level of several km to several tens of meters or better. Such improved orbits will greatly enhance the analysis of the entire Kaguya XM data set.

PSD.1-0031-18 IMPROVED NON-GRAVITATIONAL FORCE MODELING FOR MAGELLAN ORBIT DETERMINATION

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One of the main objectives of the Magellan mission to Venus (1990-1994) was to map the Venusian gravity field. The spacecraft was continually tracked at periapsis, during gravity cycles, by using X-band Doppler links from the Deep Space Network. With a near-circular orbit (during phases 5-6, 1993/94) and periapsis altitude as low as 150-220 km, Magellan tracking data still constitute the main source of information to develop high resolution gravity field models for Venus.

Nevertheless, the reference Venusian gravity field model (MGNP180U - Konopliv et al, 1999) is now almost two decades old and shows its limitations when used to constrain increasingly precise geophysical models of Venus' interior and surface processes. This is motivating the development of a new high-resolution gravity field model for Venus, that could be potentially used for planning future missions and to study Venusian geodynamics. A crucial aspect to be considered for the reprocessing of Magellan data is a more accurate modeling of non-gravitational forces acting on the spacecraft, i.e., solar and planetary (albedo and IR) radiation pressure and aerodynamic accelerations. In particular, because of lacking knowledge of Magellan's attitude and material properties, past and ongoing orbit analysis have limited the spacecraft modeling to a simple cannon-ball, eventually corrected by a set of scaling factors.

We will present our advances in the setup of a reliable macro-model for the Magellan spacecraft, constituted of multiple plates. Material properties are based both on the (very limited) available literature and on a detailed analysis of Doppler residuals and resulting orbit quality, e.g., orbit overlaps, for a given set of tests. Moreover, the amplitude of the estimated dynamical and empirical parameters (including scaling factors for each force) shall allow to evaluate the accuracy of the tested setups. Regarding the attitude law, the knowledge of which is also required when using an extended macro-model, we will base our initial analysis on limited information available in the literature and then refine it.

This work shall support ongoing Magellan reprocessing efforts. Moreover, it could constitute a guideline to improve non-gravitational force modeling (and hence, the quality of the recovered orbits) when limited or no information is available on the probe geometrical and optical properties and/or its attitude, which is often the case for (old and sometimes recent) planetary missions.

PSD.1-0032-18 GEODESY, RELATIVITY AND SPACE NAVIGATION WITH THE MORE EXPERIMENT OF THE MISSION BEPICOLOMBO TO MERCURY

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In October 2018 the joint ESA-JAXA mission BepiColombo will start a six year cruise to Mercury, its ultimate destination. With its suite of 16 instruments on two spacecraft (the Mercury Planetary Orbiter, MPO, and Mercury Magnetospheric orbiter, MMO), the mission aims at further extending the already extraordinary results from MESSENGER and answering many open questions on the planet, its formation and interactions with the space environment.

The Mercury Orbiter Radio-science Experiment (MORE) onboard the MPO has been designed to provide an accurate estimation of the spacecraft orbit, the gravity field and rotational state of Mercury, and to carry out classical and new tests of relativistic gravity. The space probe will act as a test mass in near free fall in the gravity field of Mercury and the other solar system bodies. The orbit of the spacecraft will be determined by means of an advanced multifrequency tracking system entailing three separate, coherent, simultaneous, two-way links at X and Ka band (7.2-8-4 GHz, 34-32.5 GHz). This configuration effectively suppresses the noise from the solar corona at nearly all solar elongation angles, providing range-rate accuracies up to 0.003 mm/s at 1000 s integration time. A 24 Mcps pseudo-noise code in the Ka/Ka link enables two-way range measurements with an accuracy of 20 cm after just 1 s integration. The strong non-gravitational accelerations caused by the harsh environment of the inner solar system will be measured and accounted for in the dynamical model by means of a high accuracy accelerometer (ISA), whose sensitivities are about 10-9-10-8 m/s2 in the frequency band 10-4-10-1 Hz. The spacecraft range and range rate observables will be combined with the ISA measurements in the orbit determination process to mimic a drag-free environment in software. This will be the first use of an accelerometer in a planetary geodesy and relativity experiment.

With 12 superior solar conjunctions in the cruise phase, BepiColombo offers the opportunity to carry out excellent determinations of the Post Newtonian parameter γ. The combined accuracy from all conjunctions is expected to improve by about a factor of ten the result obtained by the Cassini mission. In the orbital phase around Mercury, MORE will provide a significant improvement in the hermean gravity field (both static and tidal) and rotational state (obliquity and physical librations in longitude). Thanks to the novel ranging system, the motion of Mercury in the solar system will be determined with unprecedented accuracy, enabling improved tests of general relativity (including the precession of perihelion and the strong equivalence principle), and a direct, dynamical determination of the solar oblateness and mass loss.

PSD.1-0033-18 TRAJECTORIES IN THE NEIGHBORHOOD OF PHOBOS AND DEIMOS AIMING COVERAGE AND APPROACHING

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Due to some interesting physical and orbital characteristics of Phobos and Deimos, satellites of Mars, research involving these moons has grown. These moons have a highly irregular shape and their orbits are close to Mars. In addition, Phobos and Deimos have a high potential to provide important information about the evolution of the Mars system as well as to contribute to a future manned mission to Mars. There have been some attempts to visit Phobos, none of them successfully and, to this day, no mission has been sent to Deimos. This work presents a detailed study of the main perturbations capable of altering the orbit of a spacecraft that orbits Mars, Phobos and Deimos, in order to understand the dynamics of spacecraft movement in the proximity of such bodies and seek cases where it is possible to find stable or near stable orbits around Phobos and Deimos for the maximum possible time. Strategic trajectories are presented that allow the spacecraft to visit both moons on a regular cadence, to approach or to cover the moons. All trajectory simulations are performed using the Spacecraft Trajectory Simulator (STRS). The considered perturbations on the orbital motion of the spacecraft are: the gravitational potential of Mars, expanded in spherical harmonics up to degree and order 80, the gravitational attraction of the Sun, the gravitational potential of Phobos and Deimos and the solar radiation pressure. For the perturbations due to Phobos and Deimos is used a polyhedral model to define the shape and mass distribution of these bodies.

PSD.1-0034-18 CONCEPTUAL DESIGN OF A REVERSED SOLAR SAIL FOR AN ENHANCED PASSIVE PROPULSION

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The science of solar sail is well proven but the technology for utilizing the momentum transfer for the passive propulsion is challenging. Note that if the radiation is totally reflected, the radiation pressure is doubled, which is prudently utilized herein for the conceptual design of a reversed Solar sail with better performance. This paper puts forth the idea of propelling the solar sail towards the source, which is termed herein as a reversed Solar sail. An idealized physical model of a square Solar sail is selected for the parametric analytical studies. The electromagnetic spectrum emitted by the source can hit on the Be/Si/Al multi-layered mirrors. The augmented pressure exerted by the reflected photons on the sail helps in the forward motion of the sail towards the source with high payload capability. In this paper an attempt has been made for the numerical simulation of Sails performance aiming for comparing the system's abilities of both conventional and the reversed Solar sail based on the Scholz's model [2011 COSPAR].

PSD.1-0035-18 ON THE LISSAJOUS AND HALO ORBITS IN THE RESTRICTED THREE BODY PROBLEM WITH OBLATE PRIMARIES

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We compute Lissajous and Halo orbits in the neighbourhood of collinear Lagrangian points L1 and L2 of the spatial circular restricted three body problem under the frame of Sun-Earth system, by using Lindstedt-Poincare method. We consider both the primaries as oblate spheroid. We analyse the effect of oblateness on the orbits (Lissajous and Halo) and it is found that oblateness has a considerable impact on the motion of infinitesimal mass. The results are applicable to extend the study under the influence of perturbation.

Keywords: RTBP; Oblateness; Lissajous Orbit; Halo Orbits; Lindstedt Poincare Method

PSD.1-0036-18 DESIGN AND DEVELOPMENT OF COMPACT VERSIONS OF PERMANENT MAGNET HALL THRUSTERS FOR BRAZILLIAN MICROSATELLITES

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Electric propulsion is, nowadays, a very successful method for primary and secondary propulsion systems. It is essential for station keeping of several existing satellites and for deep space and long term missions within the solar system. Permanent magnet Hall Thrusters (PHALL) have been developed at the Plasma Physics Laboratory at the University of Brasilia since 2004, as part of a space activity program held by the Brazilian Space Agency (AEB). Now, applications of compact versions of Permanent Magnet Hall Thrusters on future Brazilian space missions are needed and foreseen for the coming years, beginning with the use of small Divergent Cusp Field Hall (DCFH) Thrusters on CUBESATS (5-10 kg, 1-5 W) and Microsatellites (50-100 kg, 10-100W). Brazilian (AEB) and German (DLR) space agencies and research centers have been developing new rockets dedicated to small satellite launching known as the VLM - Microsatellite Launch Vehicle.

One of the main advantages of PHALL thrusters is the production of a steady state magnetic field by permanent magnets providing electron trapping and Hall current generation with a significant decreased load on the electric power supply. This advantage turns the PHALL thruster into an especially good option when it comes to space usage for longer and deeper space missions, where solar panels and electric energy storage on batteries is a limiting factor. The development of more compact versions of PHALL can also be very important for the ongoing Brazilian Geostationary Satellite (SBG) program that is being currently developed by an international consortium of Brazilian and foreign space industries.

Electric propulsion is now a key feature for spacecraft exploration of small bodies in the Solar System. It has been done by several countries with increasing frequency in the past twenty years. Since their historical beginning in the sixties, most of the Solar System missions were based on gravity assisted trajectories, which depended heavily on planet orbit positioning relative to the Sun and the Earth. The consequence of such dependence was always the narrowing of the mission launch window. Nowadays, the in situ exploration of icy bodies in the Solar System requires less dependence on gravity assisted maneuvering and needs new high precision and low thrust navigation methods. The main difficulty to reach these minor bodies is related to their specific orbits with high eccentricity and inclination. A good example is the case for sample return missions to NEOs - Near Earth Objects. They are small bodies consisting of primitive leftover building blocks of the Solar System formation. Such missions can be accomplished with the usage of low thrust trajectories with spacecraft's propelled by plasma thrusters.

In this work, we will show the improvements on PHALL II working conditions in a new vacuum facility, and its important contribution to test the development of new design and more compact versions of permanent magnet Hall thrusters. PHALL III is being designed with a DCFH like model and foreseen to be used in future cubesats and on microsatellites, including possible applications in geostationary attitude control systems and on low thrust trajectory missions to the Near Earth Asteroids region. We will show a particular new permanent magnetic field design for PHALL III, together with computer simulations, using a particle-in-cell methodology that predicts thrust performance characteristics and erosion lifetime expectations for these types of thrusters. Based on the successful results that were reached with PHALL II, we believe we will be able to develop a more compact and efficient plasma thruster. This will allow not only its use on microsatellites with small size and limited electric power consumption, but also the necessary performance improvements for future Brazilian spacecrafts on long term space missions.

Ref:Ferreira J. L.; Martins A. A.; Cerda R. M.; Schelin A. B.; Alves L.S.; Costa E.G.; Coelho H.O.; Serra A.C.B.and Nathan F. in "Permanent magnet Hall thruster development for fu- ture Brazilian space missions," Computational and Applied Mathematics, Springer SBMAC, December 2015.

PSD.1-0037-18 PARTICLE IN CELL NUMERICAL SIMULATIONS OF A TWO DIMENSIONAL MODEL OF CYLINDRICAL HALL PLASMA THURSTERS WITH PERMANENT MAGNETS

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The cylindrical Hall thruster (CHT) is a propulsion device that offers high propellant utilization and performance at smaller dimensions and lower power levels than traditional Hall thrusters. In this paper we present first results of a numerical model of a CHT. This model solves particle and field dynamics self-consistently using a particle-in-cell approach. We describe a number of techniques applied to reduce the execution time of the numerical simulations. The specific impulse and thrust computed from our simulations are in agreement with laboratory experiments. This simplified model will allow for a detailed analysis of different thruster operational parameters and obtain an optimal configuration to be implemented at the Plasma Physics Laboratory at the University of Brasília.

PSD.1-0038-18 PARAMETERIZATION AND DATA REDUCTION OF LUNISOLAR EPHEMERIDES

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Ephemerides of natural celestial bodies are needed in space missions, especially in computing the gravitations from the perturbing bodies, among which the Moon and the Sun are of great importance.

To obtain the lunisolar positions, one can use the conventional analytical formulas derived from Celestial Mechanics, which generally has a concise form but is relatively poor in accuracy. Alternatively, numerical ephemeris, such as JPL DE series or the INPOP series, offers highly accurate results. However, these products are always exhaustive for all the major bodies in the Solar System and are ready to be used in the "as is" form. The excess data significantly increases the size of the ephemerides and limits its portability for on-board application even sometimes for ground applications.

The work in this paper is set in the background of orbit propagation (OP) on board the GEO satellite. Every 4 hours, the orbit is updated with solutions from precise orbit determination and onboard OP is responsible to propagate the orbit during the period. The parameters of lunisolar ephemerides are designed to be updated from ground stations every 180 days. Our job is to design proper parameterization for lunisolar ephemerides, which are to be used in onboard OP. The performance is measured by the OP accuracy within 4 hours and the data storage within 180 days.

We use two methods to re-parameterize the lunisolar ephemerides. One method involves spectrum analysis on the lunisolar orbits, which are generated with a reasonable time interval. A full ephemeris spanning approximately 180 years is first analyzed using the conventional Fourier transformation (e.g., FFT). The frequencies are handpicked based on certain rules. These frequencies, once determined, are fixed throughout all 180-day intervals. The amplitudes and phases are fitted for each interval.

The second method is more straightforward, in terms that the raw ephemeris files are directly processed. Excess data are removed from the original files and only the lunisolar parameters are retained. Numerical ephemerides are fitted with Chebyshev polynomials, with carefully designed polynomial order and fitting span. By adjusting these two arguments, we manage to further reduce the parameter size, at the cost of reasonably lower accuracy.

These data reduction strategies are tested individually, regarding fitting accuracy and consistency between different numerical ephemerides. They are also tested in the orbit propagation to find out the impact of the reduced lunisolar ephemerides on the accuracy of the propagated orbits.

PSD.1-0039-18 PRELIMINARY GRAVITY STUDIES FOR A PHOBOS QSO MISSION

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The ambitious MMX mission, lead by JAXA (Japan Aerospace Exploration Agency), aims to study the moons of Mars Phobos and Deimos. One major objective is to return a sample from the surface of Phobos. CNES is involved in some preliminary studies, especially for mission analysis and trajectory design. Phobos has a particular gravity environment, and trajectories around this moon are strongly curved by the proximity of Mars. Therefore, trajectory design is done in a specific rotating frame with the three bodies formalism, which leads to QSO (Quasi Satellite Orbit) for the probe. These results were presented in [R1]. Landing the probe requires accurate knowledge of the gravity. The accuracy one can reach with the different options of trajectory will be presented. The presentation is dedicated to investigate the accuracy of gravity field restitution that can be achieved for 9 candidate orbits (2D or 3D, with various distances to Phobos). A synthetic gravity field deduced from its shape is used in the simulation. Different hypotheses on Doppler (DSN) type and Laser altimetry measurement are tested. The second part of the presentation will propose a strategy for gravity field modeling consistently with a preliminary mission schedule approach. [R1] Elisabet Canalias, Laurence Lorda, and Julien Laurent-Varin. "Design of realistic trajectories for the exploration of Phobos", 2018 Space Flight Mechanics Meeting, AIAA SciTech Forum, (AIAA 2018-0716)

PSD.1-0040-18 ANALYTICAL AND SEMI-ANALYTICAL STUDIES OF DYNAMICAL EVOLUTION OF RETROGRADE GEOSYNCHRONOUS ORBITS

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Although retrograde geosynchronous orbits are not employed for the launched satellites currently, the concept of retrograde geosynchronous orbit is known long ago. It is possible that the retrograde geosynchronous orbits may be employed in some missions in the future. Dynamical evolution of retrograde geosynchronous orbits is studied through theoretical analysis and semi-analytical calculations in this paper. Based on the reasonable and simplified perturbation model, long-term evolution of orbital plane of retrograde geosynchronous orbits is particularly analyzed. The dynamical characteristics of orbital plane evolution are presented, which are markedly different from those of prograde geosynchronous orbits. In accordance with the dynamical characteristic of orbital plane evolution, the theoretical variation range and period of orbital inclination are further derived. Based on the averaged perturbation model, a series of semi-analytical calculations are carried out to discuss the effects of orbital parameters on the long-term dynamical evolution of retrograde geosynchronous orbits, and some conclusions are summarized. The reliability of the results derived from theoretical analysis and semi-analytical calculations is validated by numerical calculations with precise perturbation model finally. Moreover, the subtrack of an object in the retrograde geosynchronous orbit is also plotted through numerical calculation.

PSD.1-0041-18 NONLINEAR FILTERING FOR SEQUENTIAL SPACECRAFT ATTITUDE ESTIMATION WITH REAL DATA: CUBATURE KALMAN FILTER, UNSCENTED KALMAN FILTER AND EXTENDED KALMAN FILTER.

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The purpose of this work is to analyze the performance of the Cubature Kalman Filter, Unscented Kalman Filter and Extended Kalman Filter estimators in the attitude estimation problem when submitted to real attitude sensors data. The Extended Kalman Filter (EKF) is the most used nonlinear filtering algorithm for the attitude estimation in real time. The EKF is the nonlinear version of the Kalman Filter which linearizes about an estimate of the current mean and covariance. However, when the filter is subjected to poor conditions, the linearization of the system may not be efficient and lead to an estimation of low accuracy and divergence of the filter. The Unscented Kalman Filter (UKF) is an algorithm that was developed in order to avoid the linearizations required by the EKF. Basically, the UKF uses a set of points chosen deterministically, called "sigma-points", to capture the probability distribution and generalizes to nonlinear system without the burdensome analytic derivation as in the EKF. More recently, the Cubature Kalman Filter (CKF) was proposed as an alternative estimation algorithm for general nonlinear systems. The CKF, which builds on the numerical-integration perspective of Gaussian filters, employs a third-degree spherical-radical cubature rule to compute Gaussianweighted integrals, derivative-free nonlinear filtering algorithm with improved performance over the UKF in terms of estimation accuracy, numerical stability and computational costs. In this work, the application uses the real measurement data for orbit and attitude of the CBERS-2 (China Brazil Earth Resources Satellite) satellite. The attitude dynamical model is described by nonlinear equations involving the Euler angles. The attitude sensors available are two DSS (Digital Sun Sensors), two IRES (Infra-Red Earth Sensor), and one triad of mechanical gyros. The analyzes are based on the robustness of the filter, in relation to the precision, computational cost and convergence speed in attitude estimation. As the use of real data makes it impossible to compare the estimated results with the real attitude of the satellite, then the results obtained via EKF are taken as reference for comparison with the UKF and CKF. The results in this work show that, for the case studied in this article, the filters are very competitive and present advantages and disadvantages that should be evaluated according to the need of each problem.

PSD.1-0042-18 MULTI-OBJECTIVE TRAJECTORY OPTIMIZATION FOR THE SPACE EXPLORATION VEHICLE

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The research determines temperature-constrained optimal trajectory for the space exploration vehicle by developing an optimal control formulation and solving it using a variable order quadrature collocation method with a Non-Linear Programming (NLP) solver. The vehicle is assumed to be the space reconnaissance aircraft that has specified takeoff/landing locations, specified no-fly zones, and specified targets for sensor data collections.

Vehicle control is accomplished by controlling angle of attack, roll angle, and propellant mass flow rate. This dynamics model is incorporated into an optimal control formulation that includes constraints on both the vehicle and mission parameter, such as avoidance of no-fly zones and exploration of space targets.

In addition, the vehicles models include the environmental models (gravity and atmosphere). How these models are appropriately employed is key to gaining confidence in the results and conclusions of the research. Trajectory optimization techniques have been developed steadily with the advances in optimal control and numerical computations. Optimal trajectories are developed using several performance costs in the optimal control formation, minimum time, minimum time with control penalties, and maximum distance. The resulting analysis demonstrates that optimal trajectories that meet specified mission parameters and constraints can be quickly determined and used for large-scale space exploration.

PSW.1-0001-18 FORECAST VERIFICATION ACTIVITY IN RWC JAPAN

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A need of space weather forecast information is getting bigger and bigger. Many organizations in the world have issued the forecast information. However, the forecast information alone is not enough for users because the users cannot know the accuracy of the forecast. The forecast will be valuable information when issued together with verification information. Therefore, Regional warning center Japan (RWC Japan) have performed forecast verifications for issued forecast with long history. As the RWC Japan's forecasts are deterministic forecasts of various kinds of space weather parameters, we have already performed verification study of deterministic forecast on solar flares and geomagnetic disturbances. Recently, many probabilistic forecast models have developed around the world. As a probabilistic forecast may be more useful for users than deterministic one, a probabilistic forecast is recent trend. Therefore, we have also investigated verification techniques of probabilistic forecast. In this presentation, I will briefly present recent forecast verification activities performed in RWC Japan.

PSW.1-0002-18 VERIFICATION OF MET OFFICE SPACE WEATHER OPERATION CENTRE FORECASTS

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The Met Office Space Weather Operations Centre (MOSWOC) has provided a 24/7 service to a range of government and commercial users in the UK since 2014. Forecasters produce timely alerts and warnings, along with space weather guidance issued at midnight and midday. The space weather forecasts disseminated by MOSWOC include solar flare and geomagnetic storm forecasts out to 4-days ahead. Terrestrial weather verification systems, originally developed for example to verify shipping forecasts, have been adapted to verify solar flare and geomagnetic storm forecasts. An overview of these adapted verification systems and preliminary results will be presented. Adaptation of the flare verification system to verify the NASA CCMC Flare Scoreboard will also be discussed; challenges in implementing the system for non-standardised forecasts will be outlined.

PSW.1-0003-18 SSA SWE NETWORK USER TEST CAMPAIGNS: VALIDATING SSA SPACE WEATHER PROTOTYPE SERVICE PERFORMANCE TOGETHER WITH END USERS

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In this presentation we summarize the preparation, execution, results and conclusions of user test campaigns run by the SSA Space Weather Coordination Centre (SSCC) for validating and improving the products and services of the SSA Space Weather Service Network.

In the frame of the Space Weather (SWE) Segment of its Space Situational Awareness (SSA) programme, the European Space Agency (ESA) is developing the SSA Space Weather Service Network which now provides access to 21 prototype end-user driven services through its SWE Portal (http://swe.ssa.esa.int/). These services are built upon a pool of around 150 products provided to the Network by 40 Expert Groups who themselves are organised into five expert service centres: Solar Weather, Heliospheric Weather, Space Radiation, Ionospheric Weather and Geomagnetic conditions. The Network also includes a Data Centre and the SSA Space Weather Coordination Centre (SSCC) located at the Space Pole in Brussels which provides first line end-user support via the SWE Service Helpdesk and overall service availability monitoring.

The SWE services are distributed over eight different service domains: Spacecraft Design, Spacecraft Operation, Human Space Flight, Trans-ionospheric Radio Link, Space Surveillance Tracking, Non-space System Operation, and General Data Services.

To demonstrate and validate the services and gain further insight into end users' needs, the SSA Space Weather Coordination Centre (SSCC) has run a number of dedicated user test campaigns in

specific high priority domains such as Spacecraft Operations, Aviation and GNSS services. The results of these campaigns are then analysed and the resulting recommendations utilised by ESA in the context of future service improvements.

After a brief description of the context and organisation of the test user campaigns, this presentation will give examples of the resulting tailored SWE bulletins and describe some of the key findings from these campaigns.

PSW.1-0004-18 QUANTIFYING MODEL PERFORMANCE FOR SPACE WEATHER

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Approaches to quantifying model performance vary widely across the space weather domain. Model validation activities can be computationally expensive and need to be targeted at specific model outputs. Any given model may be able to predict multiple quantities of interest to different levels of fidelity, and key performance indicators will be required for each predictand. Accuracy and bias metrics are required for understanding how close the predictions are to observation, while skill metrics are required to describe relative performance and track improvements in model performance. The uncertainty on a prediction is also important and can be challenging to assess. Prediction of continuous quantities brings a different set of challenges than the prediction of discrete events, yet both are required across the space weather domain. We will present a discussion of understanding and quantifying different aspects of model performance, including uncertainty quantification, illustrated by examples using both operational models and models at a lower readiness level.

PSW.1-0005-18 USING SATELLITE IMPACTS TO INFORM SPACE WEATHER SENSOR AND MODEL REQUIREMENTS

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In situ sensors and environment models can provide valuable space weather information to satellite situational awareness and anomaly resolution. We examine how the nature and uncertainty of different kinds of environmental information lead to successful or unsuccessful assessment of the space weather hazard during satellite anomalies. Starting from impacts on high altitude spacecraft, we develop simple statistical models of anomaly hazard as a function of environmental parameters. We then demonstrate how the outputs of those hazard models are affected by nature and uncertainty of the parameters provided by an environmental sensor or model. This allows us to understand the accuracy and performance requirements for space weather sensors and models that provide those environmental parameters.

PSW.1-0006-18 FROM RESEARCH TO OPERATIONS: HOW THE OPERATIONAL COMMUNITY INFLUENCED THE DEVELOPMENT OF THE WSA MODEL

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The Wang-Sheeley-Arge (WSA) model began as basic research model first developed by Yi- Ming Wang and Neil Sheeley at the Naval Research Laboratory back in the late 1980s. In the early 1990s the model became capable of predicting solar wind speed at Earth, and a major push was then made to further develop and operationalize it at NOAA starting in 1996. Fifteen years later the coronal portion of the WSA model was fully coupled to the advanced Enlil solar wind model forming the hybrid WSA-Enlil model. It was transitioned to operations at the National Weather Service's National Centers for Environmental Prediction in 2011. The transformation of the basic Wang-Sheeley research model to today's operational WSA-Enlil model resulted from the frequent interplay between the operational communities and model developers. In this talk I focus on the development of the WSA model and how operational needs and feedback from forecasters helped transform the model into the basic research and applied space weather model it is today.

PSW.1-0007-18 AN OPERATIONAL SOLAR WIND PREDICTION SYSTEM TRANSITIONING FUNDAMENTAL SCIENCE TO OPERATIONS

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An operational solar wind prediction system is presented. The system is an outcome of the collaborative efforts of scientists from the research community and forecasters from a space environmental operation center in China. This system is mainly composed of three modules: (1) a photospheric magnetic field extrapolation module, along with a Wang-Sheeley-Arge (WSA) empirical method, to obtain the background solar wind speed and the magnetic field strength on the source surface, (2) a modified Hakamada-Akasofu-Fry (HAF) kinematic module for simulating the propagation of solar wind structures in the interplanetary space, and (3) a module for coronal mass ejection (CME) detection and parameter derivation using the ice-cream cone model based on coronagraph images. By bridging the gap between fundamental science and operational requirements, this system is finally capable of predicting solar wind conditions near Earth, especially the arrival times of the co-rotating interaction regions (CIRs) and CMEs, which are major triggers for geospace environmental disturbances such as geomagnetic storms. The research to operation (R2O) effort reveals that the capability of operational space weather services can be significantly improved through collaboration between science and operation communities. It is also learned that in the R2O process, sustainable interactions between forecasters and research scientists are needed, to adjust the model parameters and to determine the best running scheme of the system through performance verification.

PSW.1-0008-18 SWIFT-FORECAST: PHYSICS-BASED FORECASTS THE SOLAR WIND IN REAL TIME

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We present a new real-time solar wind forecasting pipeline named SWiFT (Solar Wind FluxTube)-FORECAST developed at IRAP. SWiFT is meant to perform quick and robust simulations (forward modelling) of the whole chain of processes that determine the state of the solar wind from the surface of the Sun to the helipshere. The pipeline couples a series of modules derived from mature research models: determination of the background coronal magnetic field, computation of many individual solar wind acceleration profiles (1 to 30 solar radii), propagation across the heliosphere and formation of CIRs (up to 1 AU or more), estimation of synthetic diagnostics (white-light COR/HI and EUV imaging, in-situ time-series) and comparison to observations and spacecraft measurements. The multiple flux-tube approach allows for very significant gains in computation time in respect to the full 3D MHD problem. SWiFT currently uses a combination of existing surface magnetograms and PFSS extrapolations but the interface is ready to include different combinations of magnotograms sources (WSO, SOLIS, GONG), flux-transport and data assimilation techniques (ADAPT), coronal field reconstruction methods (NLFFF, Solar Models), wind models (MULTI-VP), and heliospheric propagation models (CDPP/AMDA 1D MHD, ENLIL, EUHFORIA). I will discuss an implementation of this modeling chain that is able provide continuously a full set of bulk physical parameters (wind speed, density, temperature, magnetic field, phase speeds) of the solar wind based solely on physical principles up to 6-7 days in advance, and at a time cadence and a forecast compatible with space weather applications. The method benefits from multi-point observations and in-situ measurements and can use several intermediate control points for calibration and forecast validation. This is work is supported by the CNES.

PSW.1-0009-18 PERFORMANCE ANALYSIS OF GEOMAGNETIC STORM FORECASTING SERVICE STORMFOCUS

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Operational forecasting of geomagnetic storms is of great importance for many space weather applications. A new online geomagnetic storm forecasting service StormFocus was implemented in 2011 at SpaceWeather.Ru. StormFocus provides the warnings on the expected geomagnetic storm magnitude for the next several hours on an hourly basis using L1 solar wind and IMF measurements. In this study we present the performance analysis of StormFocus over the years of real-time operation and verification of the prediction algorithm. We also analyze the sources of prediction errors and identify the errors that can be fixed by improving the prediction algorithm and those that cannot be removed in real-time. This source of error is related with the missing data and the calibration-related differences between the real-time and the final data. These latter errors are often not recognized, but actually account for a significant part of the forecast uncertainty. StormFocus provided the successful real-time forecast of 87% storms, while the reanalysis running on final OMNI data predicted successfully 97% of storms. The prediction of the actual final peak Dst using the real-time input was provided successfully for 90% of storms, that proves the practical usefulness of the real-time forecast. These results confirm the general reliability of StormFocus service to provide the advance warnings of geomagnetic storm strength and space weather conditions in the near-Earth environment in real-time.

PSW.1-0010-18 IMPROVEMENT AND VALIDATION OF GEOMAGNETICALLY INDUCED CURRENT MODELLING: NEED FOR CONSIDERATION TO THE TRANSFORMERLEVEL

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During space weather events, geomagnetically induced currents (GIC) can be induced in high voltage transmission networks, damaging individual transformers within substations. One of the risks to power systems is transformer failure, and hence it seems reasonable to consider transformers individually in modelling. However, a common approach to modelling a transmission network has been to assume that every substation can be represented by a single resistance to Earth. We have extended that model by building a transformer-level network representation of New Zealand's South Island transmission network. Our modelling makes use of Transpower

New Zealand provided values of resistances for transmission lines, transformers, and earth ground connections. Using this transformer-level network representation significantly changes the GIC hazard assessment, compared to assessments based on a substation-level assumption. These transformer-level GIC calculations show variation in GIC between transformers within a substation due to transformer characteristics and connections. The transformer-level GIC calculations alter the hazard assessment (in terms of peak GIC amplitude) by up to an order of magnitude at some locations.

New Zealand is unusual, in that we have access to an unusually long and spatially detailed set of Geomagnetically Induced Current (GIC) measurements. Near continuous archived DC current data exist since 2001, starting with 12 different substations, expanding over time to presently include about 20 different substations. There are large numbers of examples where multiple different transformers have been monitored in the same substation. These GIC observations show that different transformers in the same substation can have very different peak GIC during the same geomagnetic storm, confirming the need for this transformer-level detail.

In addition, we will present initial results of validating the modelled GIC against observations for a given geomagnetic storm (St Patricks Day 2015). This validation analysis will include an examination of the sensitivity of the modelled results to different areas of uncertainty, in particular the geomagnetic field changes, ground electrical conductivity and structure, and network properties.

PSW.1-0011-18 FORECAST VERIFICATION IN THE FRAMEWORK OF THE EU FLARECAST PROJECT

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We describe the main practices and results of the comprehensive forecast verification effort undertaken in the framework of the EU FLARECAST project for solar flare prediction. In discussing FLARECAST, we compare between previous verification efforts of solar flare forecasting products or services and the potential advances brought by the FLARECAST project, that served as a uniform platform for testing numerous and diverse flare forecasting meth- ods. Results shown include major skill score values and extensive ranking of flare-predictive parameters. We further advocate for a robust error assessment of the scores and parameters involved in the verification process, that would provide the basis of a much-needed, continuous assessment of solar flare forecasting capabilities. In concluding, we list the discussion areas and recommendations addressed by the COSPAR - ILWS Roadmap, indicating the locations where the FLARECAST project has been contributing and providing feedback, potentially enabling further advances in the verification of forecasting activities of solar and heliospheric weather.

This work has received support by the EU Horizon-2020 FLARECAST project (grant agreement no. 640216).

PSW.1-0012-18 DEFINING METRICS AND TRACKING PROGRESS FOR PREDICTING CME ARRIVAL AND PARAMETERS AT L1: HIGHLIGHTS FROM THE INTERNATIONAL FORUM ON SPACE WEATHER CAPABILITIES ASSESSMENT

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The Coronal Mass Ejection (CME) arrival time and impact working team has made efforts over the past year to decide upon a set of metrics with regard to the modelling and prediction of CMEs in order to quantify and track progress. Both user and science needs are taking into account when defining these metrics. This working team is part of the CCMC-led community-wide international forum for space weather modeling capabilities assessment including a workshop in April 2017. Our team focuses on the assessment of how successfully different models and techniques can predict CME arrival time and impact. After open communication with the scientific and user community, we have established a set of metrics for the quantification of the model performance. Current and future models have and will be tested for their CME arrival time and impact forecasting capabilities, based on these metrics and a selected set of events. The event set consists of a variety of different types such as false alarms, hits, and misses. We present here the current status of the CME arrival time and impact team.

PSW.1-0013-18 DEFINING METRICS AND TRACKING PROGRESS FOR NEAR-EARTH PLASMA AND RADIATION ENVIRONMENT MODELING: HIGHLIGHTS FROM THE INTERNATIONAL FORUM ON SPACE WEATHER CAPABILITIES ASSESSMENT

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The international forum on space weather capabilities assessment aims to quantify scientific progress in the area of space weather. More specifically it aims to deliver a framework for the application of metrics in order to measure performance/progress of space weather modelling and to construct a library of metric and validation techniques which may be used thereby harmonizing comparisons and validations which are made. One of the working groups acting under this umbrella focusses on space plasma and radiation environments and effects.

In this domain there are clearly established standards for defining an environment which spacecraft must survive. Each major agency has its own standards which drive requirements. This is less mature in the domain of commercial aviation. The aim of the working group is to connect the space weather modelling community with experts on environment specification in order to define environmental quantities (scientific predictands) which are representative of the environment driving an effect thus addressing user needs. The effects covered by the working group include surface charging, internal charging, total (ionizing and non-ionizing) dose, single event effects and effects on aircraft. In addition to the scientific (or environmental) predictand an associated effect quantity (and associated timescale) is defined for which tools are readily available to transform quantities from the environment to the effect. Finally, a set of statistical metrics are defined to evaluated the accuracy of model outputs.

The acceptance of quantities will simplify to task of space weather modelers in validating their model and provide an objective comparison between models to show which are more reliable for a given effect over a given timescale. This talk presents the progress of the working group thus far to define concrete quantities which shall constitute space weather metrics in this domain.

PSW.1-0014-18 DEFINING METRICS AND TRACKING PROGRESS FOR GEOMAGNETIC ENVIRONMENT MODELING: HIGHLIGHTS FROM THE INTERNATIONAL FORUM ON SPACE WEATHER CAPABILITIES ASSESSMENT

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The International Forum for Space Weather Capabilities Assessment workshop, held in April of 2017, brought together representatives from across the space modeling community to discuss how to improve systematic validation of our existing models. Working teams formed to focus on specific tasks and regions of interest. Working team members met before, during, and after to Гassess current validation practices, identify needs, and define goals for improving community standards. The ongoing efforts are reported at the Community Coordinated Modeling Center's website and in a special collection in AGU's Space Weather journal.

This talk highlights some of work performed by the International Forum's working teams. Focus is placed on the dB/dt metrics working team, which was tasked with updating standards previously used to select models for transition to operations. Early results from applying new standards on output from the Space Weather Modeling Framework are shown.

PSW.1-0015-18 DEFINING METRICS AND TRACKING PROGRESS FOR IONOSPHERE DISTURBANCES MODELING: HIGHLIGHTS FROM THE INTERNATIONAL FORUM ON SPACE WEATHER CAPABILITIES ASSESSMENT

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The ionospheric prediction models are relevant to a variety of needs. These include the reliable performance of critical engineering systems that operate within or through the ionosphere (e.g. satellite and ground based communication and geolocation applications), as well as scientific challenges in geospace investigations. Since both, the operational needs and our scientific understanding change dynamically with time, the systematic assessment of the performance of new and/or improved models and tracking of progress over time are essential requirements for both the establishment of our knowledge and the effective transition of the scientific achievements to reliable operational services. In this framework, the Ionosphere team was formed within the International Forum Space Weather Modeling Capabilities Assessment (https://ccmc.gsfc.nasa.gov/assessment/) to help the efforts on the assessment of ionospheric prediction capabilities with special emphasis in the ionospheric disturbances. Disturbances into consideration apply to the total electron content (TEC), the F2-layer characteristics (e.g. the peak electron density NmF2 or the critical frequency foF2 and the height of the peak electron density, hmF2), as well as to ionospheric scintillation. The team aims at establishing community agreed metrics that address specific user needs and the evaluation of existing ionospheric modeling capabilities based on the selected metrics in order to provide a benchmark against which new models can be assessed. The work plan is established on experiments performed over of a number of models that assume a wide range of formulations (i.e. empirical, physics-based and data assimilation) and includes the assessment of the uncertainties that accompany datamodel comparison tests (e.g. data quality, sensitivity to models' drivers). This presentation aims to highlight the results of the team's activities as a solid basis for further developments.

PSW.1-0016-18 DEFINING METRICS AND TRACKING PROGRESS FOR THERMOSPHERE DENSITY MODELING: HIGHLIGHTS FROM THE INTERNATIONAL FORUM ON SPACE WEATHER CAPABILITIES ASSESSMENT

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In order to track the progress over time of thermosphere models, both first principle and semi-empirical, appropriate metrics are required. Secondly, neutral density data sets of good qualities and preferably with high-spatial resolution covering long intervals of time (i.e. years, and ideally a complete solar cycle) are needed. The neutral density observations can then be used to verify model accuracy with respect to latitude-longitude-local time variations, and solar and geomagnetic activity levels and seasonal variations, respectively. Data and metrics together allow benchmarking of the models and detailed quantification of the improvement.

In this presentation, the metrics agreed upon at the International Forum on Space Weather Capabilities Assessment will be discussed. The selected data for comparison with the models, and in particular the high-resolution accelerometer-inferred densities from CHAMP-GRACEGOCE, but also daily-mean densities (because that is the unique data source at 700-900 km altitudes), will be presented and shortly reviewed. Both long periods (entire years in order to cover high-medium-low solar activity conditions) as well as short-lived storm events of a few days were selected for the comparisons. Results of semi-empirical model-data comparisons will be shown to illustrate the adopted model performance metric, which is not carved in stone. The same test data and metric will be used by CCMC in the evaluation of selected first principles models.

PSW.1-0017-18 A FRAMEWORK FOR TRACKING PROGRESS TOWARDS USABILITY: APPLICATION USABILITY LEVELS.

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Katherine Garcia-Sage, katherine.garcia-sage@nasa.gov Catholic University of America, Washington, United States Assessment of Understanding and Quantifying Progress

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As our community continues to grow and become more intertwined with industry and other fields, there is a need for a framework that can allow researchers and end users to identify applications for the research, quantify metrics for each specific application, and enable communication between the researchers and end users. To this end, the Assessment of Understanding and Quantifying Progress International Forum for Space Weather Capabilities Assessment working group has developed the Application Usability Level (AUL) framework. The AUL framework was developed by implementing lessons learned from Technology Readiness Levels (TRLs) used by the instrument community and Application Readiness Levels (ARLs) used by the Applied Science program in NASA's Earth Science Division, as well as modifying the levels and their milestones to better suit the needs of the Space Weather and Heliophysics communities. In this talk we will introduce the AUL framework and show examples of how it can be applied to research for the Space Weather and Heliophysics communities. For more information on the AULs and other work being done by the Assessment of Understanding and Quantifying Progress International Forum for Space Weather Capabilities Assessment working group, please see our website at the CCMC https://ccmc.gsfc.nasa.gov/assessment/topics/trackprogress.php

PSW.1-0018-18 TOWARDS COMMON VALIDATION AND VERIFICATION PROCEDURES IN THE ONGOING SSA SPACE WEATHER SERVICE NETWORK

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In the framework of the Space Situational Awareness Programme (SSA) of the European Space Agency (ESA), the Space WEather (SWE) segment aims to help end-users in a wide range of SWE affected sectors to mitigate the effects on their systems, reducing costs and improving reliability. In the SWE segment, five Expert Service Centres (ESCs), the SSA Space Weather Coordination Centre (SSCC) and the SSA Space Weather Data Centre (SWE-DC) form the SSA SWE network. This network is providing SWE services to users dependent on space weather conditions. The SWE services are composed of an extensive number of products provided by numerous contributing expert groups. Each product is delivered to the SSA SWE network with a full package of documentation and user guidance. This includes results of validation and verification procedures helping the end-user to identify the appropriate products for each application. The currently diverse procedures for product validation and verification hamper the comparison and evaluation of different products. Therefore, the SWE network aims to harmonize these procedures. Here, an overview of the ESCs product validation assessment and planning for the current activity will be given, including examples of best practice and approaches for common validation and verification procedures.

PSW.1-0019-18 TERRESTRIAL WEATHER FORECAST VERIFICATION: METHODS AND TOOLS RELEVANT FOR SPACE WEATHER

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Verification and validation activities are critical for the success of modelling and prediction efforts at organizations around the world, including the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA) in the U.S., the European Center for Medium Range Weather Forecasts (ECMWF), the Met Office in the United Kingdom, and others across the globe. Over many decades, methods have been developed, tested and applied to evaluate terrestrial forecasts and to track their performance over time. Because different methods are required for different types of forecasts, and users have different requirements for verification information, the methods cover a broad spectrum of tools and approaches. For example, categorical methods are used to evaluate event-based forecasts and probabilistic methods are used for ensemble and probability forecasts. A wide variety of display and summary approaches - including line graphs, box plots, reliability diagrams, performance diagrams, and score cards - are used to track and compare performance across time, model, and region. Advanced spatial methods developed and applied in recent years provide enhanced information about forecast performance beyond point-by-point comparisons.

More recently, comprehensive community tools have been developed and applied to provide consistent evaluations and to track terrestrial forecast performance. In particular, the Model Evaluation Tools (MET) developed at NCAR is being applied under the auspices of the U.S.'s Next Generation Global Prediction System (NGGPS) program to create an advanced unified terrestrial verification system (MET+). The MET+ system consists of several components, including a C++/Fortran code-base (MET), for the computation of verification statistics based on gridded forecasts and either a gridded analysis or point-based observations. The system also incorporates a database and display system (METViewer) for aggregating statistics and plotting graphical results. These tools are designed to be highly flexible to allow

for quick adaption to meet additional evaluation and diagnostic needs. A suite of python wrappers have been implemented to facilitate a quick set-up and implementation of the system, and to enhance the pre-existing plotting capabilities.

It is envisioned that this effort will expand to development of a unified verification system that will encompass a variety of spatial scales and provide a basis for evaluation of individual earth system component models (including atmosphere, atmospheric composition, land, ocean, ice and waves) and of the entire earth system model including coupling among system components and the evaluation of critical space weather fields and forecast products. This presentation will provide an overview of the current state-of-the-art in terrestrial forecast verification and the MET+ unified verification system, and will highlight how the system might be used within the space weather community. Some of the challenges associated with realizing this ambitious goal will also be considered.

PSW.1-0020-18 PSW1 DISCUSSION: COORDINATED SPACE WEATHER VALIDATION AND VERIFICATION ACTIVITIES: PROGRESS AND NEXT STEPS

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The COSPAR-ILWS Roadmap made several recommendations in the area of verification and validation. These were framed in terms of teaming different communities active in space weather towards ensuring a coordinated collaborative environment leading to improved capability. Specific recommendations included the development of standard data and product metrics, ensuring harmonised access to data and model archives for the purposes of validation and definition of datasets needed to test models and forecast systems. This discussion will address progress made in these areas since the publication of the roadmap and consider what next steps could be supported within the framework of COSPAR's Panel on Space Weather. This discussion slot will build on the presentations given earlier in the event. All PSW1 presenters and interested panel participants are encouraged to participate in the discussion. The results of this discussion will be summarised and presented as part of PSW5: Space Weather Initiatives and Coordinated International Efforts to Implement the COSPAR-ILWS Roadmap Recommendations.

PSW.1-0021-18 PSW1 DISCUSSION: COORDINATED SPACE WEATHER VALIDATION AND VERIFICATION ACTIVITIES: PROGRESS AND NEXT STEPS

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The COSPAR-ILWS Roadmap made several recommendations in the area of verification and validation. These were framed in terms of teaming different communities active in space weather towards ensuring a coordinated collaborative environment leading to improved capability. Specific recommendations included the development of standard data and product metrics, ensuring harmonised access to data and model archives for the purposes of validation and definition of datasets needed to test models and forecast systems. This discussion will address progress made in these areas since the publication of the roadmap and consider what next steps could be supported within the framework of COSPAR's Panel on Space Weather. This discussion slot will build on the presentations given earlier in the event. All PSW1 presenters and interested panel participants are encouraged to participate in the discussion. The results of this discussion will be summarised and presented as part of PSW5: Space Weather Initiatives and Coordinated International Efforts to Implement the COSPAR-ILWS Roadmap Recommendations.

PSW.1-0022-18 STATISTIC OF SOLAR PARTICLE EVENT FLUENCES, PEAK FLUXES, DURATIONS, TIME INTERVALS BETWEEN EVENTS, AND TIMES TO PEAK FLUXES

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The high-energy protons from solar energetic particle (SEP) events present hazard to space systems: damage to science instruments/electronics/materials or to astronauts. A reliable estimate of the high-energy proton environment is critical to assure the mission success. Important characteristics of an SEP event are fluence, peak flux, energy spectrum, and time to reach the peak flux after an event starts. All of these characteristics are important to understand in order to design space missions properly whether it is a robotic mission or a human mission. For example, an estimate of the mission fluence spectrum from SEPs is needed to design the spacecraft shielding to ensure that the system survives the total mission fluence environment; the peak flux information is used to estimate single event effects to electronics devices. Another example may be that the knowledge of the time to reach the peak

flux could be used to provide an advanced warning to astronauts during an extravehicular activity (EVA) to take a shelter from an incoming SEP event. Because of unpredictable and sporadic nature of SPEs, statistical models are often used to represent the SEP parameters described above. For example, Feynman and her colleagues (Feynman et al., 1993; Feynman et al., 2002) used a log-normal distribution and Xapsos (Xapsos et al., 2000) used a truncated power laws to describe the statistics of the historical SEP event fluences. In a previous study, the statistics of event fluences, durations, and time intervals between events were investigated using the then-available historical SEP dataset obtained from the instruments onboard the IMP-8 spacecraft (Jun et al., 2007). It was found that (1) the event fluences can be approximately fit to a log-normal distribution and (2) the distributions of event durations and time intervals between the events can be represented by Poisson distributions. Since then, more comprehensive SEP dataset called Reference Data Set Version 2.1 (RDSv2.1) has become available covering the SEP events up to Year 2015 under a framework of the European Space Agency's (ESA's) Solar Energetic Particle Environment Modelling (SEPEM) project (Jiggens et al., 2017). The main objectives of this paper are twofold: First, the statistics of event fluences, durations, and time intervals will be re-visited by using the RDSv2.1; Second, the statistical analyses of peak fluxes and times to reach the peak fluxes will be performed using the same dataset RDSv2.1. The results of this study will address the statistical properties of all key parameters for designing a spacecraft or a mission where the SEP environment is an important consideration.

PSW.1-0023-18 VALIDATING SPACE ENVIRONMENT MODELS USING BOTH SCIENCE AND APPLICATION METRICS: A CASE WITH SURFACE CHARGING

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To make space science and space weather models useful for application purposes, it is important to validate them using proper metrics. Working with the community, the Community Coordinated Modeling Center (CCMC) has initiated the International Forum for Space Weather Modeling Capability Assessment. The space plasma and radiation effects group stemmed from this effort has discussed and come up with a set of science and engineering metrics for several types of effects that are relevant to spacecraft and/or other space assets (https://ccmc.gsfc.nasa.gov/assessment/topics/radiation-all.php). In this presentation, initial validation results of a few models in producing surface charging effect during two events/intervals (Event 1: from 16 March to 20 March 2013; Event 2: from 31 May to 2 June 2013) will be shown. The goal of such validation effort is to be able to track model performance over time and at the same time to provide feedback and stimulate improvement of models. The two events occurred during geomagnetic time periods where the former was due to a CME and the latter was likely caused by the flank impact of a slow CME followed by a high speed stream. Therefore, different solar drivers' influence on the near-Earth region and on surface charging can be analyzed as well.

PSW.1-0024-18 ANALYTICAL REPRESENTATIONS FOR CHARACTERIZING THE GLOBAL AVIATION RADIATION ENVIRONMENT BASED ON MODEL AND MEASUREMENT DATABASES

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Two major sources of radiation hazards at commercial aviation altitudes have been known for decades and those are galactic cosmic rays (GCRs) as well as solar energetic particles (SEPs). GCRs are produced outside the solar system in high-energy explosive events and consist mostly of energetic protons slowly modulated by the strength of the Sun's interplanetary magnetic field (IMF). SEPs come from either solar coronal mass ejections (CMEs) related to flaring events or from IMF shocks. In the latter case fast CMEs plow through a slower solar wind creating a shock front to produce energetic protons. Recently, a third radiation source has been identified that originates from relativistic electron precipitation (REP) associated with the Van Allen radiation belts and have been called radiation clouds although a physical perspective is likely to be flight through a -ray beam. This ensemble radiation field creates safety concerns for aviation. In human tissues, radiation can cause atoms and molecules to become ionized, dissociated, or excited. Cell death can result from higher doses and at extremely high doses, an organ's cell population can drop so rapidly that cells cannot be replaced quickly enough resulting in the tissue failing to function normally. Epidemiological studies in occupational groups have been conducted for several decades, usually with a focus on radiation-associated cancer, and there continues to be a broad discussion in this field of study. Because of this safety hazard, a broad community is seeking to i) define the requirements for real-time monitoring of the charged particle radiation environment to protect the health and safety of crew and passengers during space weather events; ii) define the scope and requirements for a real-time reporting system that conveys situational awareness of the radiation environment to orbital, suborbital, and commercial aviation users during space weather events; and iii) develop or improve models for the real-time assessment of radiation levels at commercial flight altitudes. While benchmarks for ionizing radiation related to aviation have included characterizing an occurrence frequency of 1 in 100 years and an intensity level at the theoretical maximum for radiation events, it is also important to develop a baseline radiation environment for GCRs, SEPs, and REPs against which events can be compared. We describe functional, analytical baselines for describing the ionizing radiation environment for commercial aviation based on observations and modeling as part of the NAIRAS, ARMAS, and RADIAN programs.

PSW.1-0025-18 IMPROVEMENTS TO THE NOWCAST OF ATMOSPHERIC IONIZING RADIATION FOR AVIATION SAFETY (NAIRAS) MODEL AND COMPARISONS WITH MEASUREMENTS FROM THE RADIATION DOSIMETRY EXPERIMENT (RAD-X) FLIGHT CAMPAIGN

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The NASA Nowcast of Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS) model is a real-time, global, physics-based model for predicting exposure to cosmic radiation to air travelers from both galactic and solar sources. Tabular and graphical data products from the prototype operational NAIRAS model are available via its public web site. The transport of cosmic radiation through the atmosphere is modeled in NAIRAS using the High Charge (Z) and Energy Transport (HZETRN) code. The transport procedures in NAIRAS have been recently updated by transitioning from HZETRN version 2010 to version 2015. The most important update in HZETRN2015 for the application of the NAIRAS model is the inclusion of pion-initiated electromagnetic cascade processes. The improvements to the NAIRAS model predictions, as a result of updating to the HZETRN2015 code, are quantified by comparing to the measurements obtained from the Radiation Dosimetry Experiment (RaD-X) flight campaign. The RaD-X campaign provided high-precision measurements of dosimetric quantities at seven altitudes ranging from the lower altitudes of commercial aircraft flight levels to altitudes above the Pfotzer maximum where the contributions from cosmic ray primaries are discernable in the dosimetric quantities. These comparisons between the NARIAS model predictions and the RaD-X measurements are shown for the first time.

PSW.1-0026-18 CROSS-VALIDATION OF TEC MAP PRODUCTS FROM IGS AND ESA SWE DURING QUIET AND DISTURBED CONDITIONS

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TEC map products and their forecasts are increasingly used for assessing space weather impacts on infrastructures in our society and in decisions, where GNSS positioning and timing are an integrated element. Within communication, aviation, maritime safety, and leisure, precise knowledge of space weather impacts plays a growing importance. This cross-validation study addresses a comparison of the ESA ESC-I TEC map products with similar IGS data products for the European sector and the globe as well. Two monthly test periods were identified from 1995, describing the evolution of geophysical phenomena for quiet and disturbed conditions. The latter where dominated by CMEs (Coronal Mass Ejections) and HHS (High Speed Streams) originating from coronal holes hitting the magnetosphere of the Earth. The exact periods for the validations are: 1) March 1st - March 31st, 2015 (primarily dominated by disturbed conditions), and 2) October 15th - November 15th, 2015 (a quiet period with shorter lived disturbance periods). The metrics of the cross-validation was based on establishing statistical values of correlation, mean, mean model error, standard deviation, bias, and skill score for TEC cell values in the ESA and IGS data products. To resolve the spatial and temporal resolution issues in the two data products (ESA and IGS), all global data were transformed into similar grid-cell resolution in latitude and longitude, using a time resolution of one hour. The longitude and latitude resolution were 5.0 x 2.5 degrees, respectively. The ESA TEC maps over Europe had a smaller grid cell-size (2 x 2 degrees) than the datasets from IGS and CODE (5 x 2.5). To reduce truncation errors and unrealistic geophysical TEC gradients, mapping the products to a uniform resolution, a 2D-surface polynomial interpolation scheme (in longitude and latitude) was applied. The ESA now-casting products had a grid cell resolution of 1 x 1 degrees. In the cross-validation the above-mentioned interpolation scheme was applied here too. Spatial resolutions were obtained through a 7th order polynomial spline to the one-hour calculated standard deviations. Results were compared to a cubic spline during periods of data gaps. Only distribution functions, representing the hourly developments in the standard deviation for each separate period (March and October/November), showing a functional relation similar to a normal distribution, were considered in the estimates. The cross-validation gave for the global data set a mean and standard deviation averaged estimate for disturbed conditions of 4.3 and 3.4 TECU, respectively. Around 2 -2.5 TECU was related to differences in background models and mapping functions, giving rise to model-driven TEC gradients. During the main phase of the observed geomagnetic storms the mean of TEC differences shows a sudden positive bias, however during calm periods this bias tends to be slightly negative. For the quiet time period the mean squared error difference amounted to 3.4 TECU with a mean squared deviation of 3.1 TECU. For the European sector the number became for the same unbiased mean squared error estimator 5.3 (disturbed) and 4.7 (quiet) TECU with smaller standard deviations (from 0.7 to 1.0 TECU). Further insight into these differences and a discussion of the causes will be given in the presentation.

PSW.1-0027-18 ASSESSING AN APPROACH TO IONOSPHERIC TOTAL ELECTRON CONTENT FORECASTING USING PHYSICS-BASED MODELS

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A goal of space weather forecasting is to predict conditions in the upper atmosphere (ionosphere and thermosphere) based on forecasted solar wind conditions, that might be available with a few day's lead time. To explore the forecast capabilities of state-of-the-art ionospheric and thermospheric models, we conduct ionospheric simulations with three first-principles models for multiple geomagnetic storms via the Community Coordinated Modeling Center (CCMC). The models we consider are the Coupled Thermosphere Ionosphere Plasmasphere Electrodynamics Model (CTIPe), the Global Ionosphere-Thermosphere Model (GITM), and the Thermosphere Ionosphere Electrodynamics General Circulation Model (TIE-GCM). The simulations are set up such that they are driven exclusively by quantities that could be forecasted, such as solar wind parameters, as might be available from a solar wind forecast. Specifically, we drive the models with a forecasted F10.7 solar flux index based on time series regression, and calculated hemispheric power indices based on empirical relationships with solar wind data. Observed interplanetary conditions are used to drive the models, in effect assessing the models as if a perfect solar wind forecast were available. These "forecast-mode" simulations are conducted for approximately 40 representative storm events, including storms caused by high-speed solar wind streams and coronal mass ejections, storms occurring at different phases of the solar cycle, and storms with various intensities. The simulated ionospheric total electron content (TEC) is analyzed with a metric that quantifies the global and local TEC responses during storms. By comparing to the TEC responses derived from Global Positioning System observations, we assess the potential of the three ionospheric models CTIPe, GITM, and TIE-GCM to forecast upper atmosphere conditions. Our research provides insights into the model capabilities in forecasting ionospheric space weather.

PSW.1-0028-18 PREDICTION OF THE EQUATORIAL PLASMA BUBBLE USING THE LINEAR GROWTH RATE OF THE RAYLEIGH-TAYLOR INSTABILITY OBTAINED WITH GAIA

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In recent years, the prediction of the equatorial plasma bubble (EPB) has been one of the most important issues in space weather forecasting. Previous observational and theoretical stud- ies have indicated that EPBs can be generated through the Rayleigh-Taylor (R-T) instability in the ionosphere. To investigate the possibility of the EPB occurrence prediction using the R-T instability analysis, we evaluated the linear growth rates of R-T instability in the ionosphere using a whole atmosphere-ionosphere coupled model GAIA (Ground-to-topside model of Atmosphere and Ionosphere for Aeronomy). The effects of thermospheric dynamics driven by atmospheric waves propagating from below on the R-T growth rate were included in the model by incorporating meteorological reanalysis data in the region below 30 km altitude. The daily maximum R-T growth rates for the period of 2011-2013 were compared with the observed occurrence days of EPB determined by the Equatorial Atmosphere Radar (EAR) and Global Positioning System (GPS) in West Sumatra, Indonesia. We found that a high R-T growth rate tends to correspond to the actual EPB occurrence. Based on this result, we will discuss the predictability of EPB occurrences using GAIA.

PSW.1-0029-18 OPERATIONAL ANALYSIS OF THE EARTH'S RADIATION ENVIRONMENT DURING FEBRUARY 14 - MARCH 5, 2014

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Internet-based system of Space Monitoring Data Center (SMDC) of Moscow State University has been developed to predict and analyze radiation conditions in the near-Earth's space. This system consists of satellite databases and operational models devoted to collect, store and process in the near-real time monitoring data. SMDC operational services acquire data from ACE, SDO, GOES, Electro-L, Meteor-M satellites and use them for forecasting, now-casting and post-casting of the radiation and geomagnetic conditions in the near-Earth's space. Period of high level solar and geomagnetic activity on 14 February - 5 March, 2014 has been considered to test and validate SMDC operational services. Solar sources of interplanetary space disturbances and their influence on geomagnetic and radiation state of the Earth's magnetosphere are described based on the data obtained from SMDC Web-based applications. Validation of the operational models developed at SMDC was performed based on the quality of description of the physical conditions in the near-Earth's space during series of events on 14 February - 5 March, 2014.

PSW.1-0030-18 WI SKILL SCORES FOR SOLAR ENERGETIC PARTICLE EVENT FORECASTS

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Some solar energetic particle (SEP) event forecasting tools yield binary (yes-no) forecasts of event occurrences based on defined SEP peak intensity thresholds. These tools typically take solar flare parameters and flare longitudes and latitudes as inputs and calculate SEP event parameters, such as peak intensities and onset and maximum times. When the calculated peak intensities exceed a target threshold, a SEP event is forecast; if not, no event forecast or warning is issued. The quality of the tool is evaluated using one of several skill scores, which require four kinds of predicted versus observed outcomes: (1) yes - yes (a hit), (2) yes - no (a false alarm), (3) no - yes (a missed event), and (4) no - no (a correct null). In cases (2) and (3) no account is taken of the disparity between the forecast and observed SEP intensities. Thus, for a 10 pfu (proton flux unit) at $E > 10$ MeV threshold, a forecast of 11 pfu with an event observation of 8 pfu is treated the same as a forecast of 1100 pfu with an observation of 0.8 pfu: both are false alarms and weighted the same in the skill score calculations. We introduce an alternative approach to skill scores (called WI skill scores) accounting for false alarms with observed events just below the threshold and for missed events with observed events just above the threshold. A recent data set of SEP forecasts is used to illustrate the technique.

PSW.2-0001-18 SPACE WEATHER AT MERCURY: ICME EFFECTS ON MERCURY'S MAGNETOSPHERIC BOUNDARIES AND NORTHERN CUSP REGION

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Using observations from the MESSENGER spacecraft in orbit around Mercury, we conduct statistical analyses and detailed case studies of the large-scale processes in Mercury's magnetosphere during interplanetary coronal mass ejections (ICMEs). The dynamic nature of Mercury's small magnetosphere is pushed to its extremes during times of ICMEs. We study the motion of the bow shock and magnetopause boundaries, erosion of the dayside magnetosphere, the size, extent, and plasma pressure of the northern cusp region, and the plasma precipitation to the surface during extreme events. Our statistical ICME study gives us a glimpse of Mercury's average response to extreme forcing, while the case studies reveal the large variability in both the magnetospheric response and in the nature of the forcing. We find that the magnetopause is substantially compressed due to an increase in solar wind ram pressure at these times. On average during ICMEs, the subsolar stand-off distance from the center of the planet is reduced by 15% as compared with the value during nominal solar wind conditions, and the magnetopause reaches the surface of the planet 30% of the time. On the other hand, the bow shock under these conditions is located farther from the planet than for nominal solar wind conditions, because of a decrease in Alfvén Mach number during the ICME passage. The cusp is observed to extend ~10° further equatorward and 2 h wider in local time. In addition, the average plasma pressure in the cusp is more than double that determined under nominal conditions. For the most extreme cases, the particle precipitation to the surface is an order of magnitude higher than average. The solar wind ram

pressure is found to be the dominant factor controlling these cusp characteristics, with the IMF BZ direction playing a small, but likely non-negligible role.

PSW.2-0002-18 SPACE WEATHER ON THE SURFACE OF MARS

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The surface of Mars, unlike Earth, is directly exposed to Space Weather as a result of it's lack of a global magnetic field and thin atmosphere. The Radiation Assessment Detector (RAD) on the Mars Science Laboratory(MSL) has been characterizing the Space Weather environment on the surface of Mars since landing in 2012 by providing measurements of the energetic particle radiation environment due to solar flares, coronal mass ejections (CMEs), and galactic cosmic rays (GCRs).

The synoptic measurements of the energetic particle environment provided by RAD will aid heliospheric modeling of space weather over solar cycle. These observations of SEP fluxes are contributing to a solar energetic particle (SEP) event database at Mars and the Martian surface to aid prediction of Solar Particle Events (SPEs), including onset times and size predictions.

This presentation will provide an overview of the RAD investigation and present measurements of the solar flare, GCR and radiation environment on the surface of Mars, and discuss the importance of providing broad heliospheric coverage for situational awareness of space weather as we plan to send humans out into deep space and to Mars.

RAD is supported by NASA (HEOMD) under JPL subcontract 1273039 to SwRI, and by DLR in Germany under contract with Christian-Albrechts-Universitat (CAU).

PSW.2-0003-18 ACCURATE PREDICTION AND TESTING OF CME ARRIVAL AND PROPERTIES FROM SUN TO EARTH

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Most major space weather events are due to fast CMEs and their shocks interacting with Earth's magnetosphere. Accurate prediction of CME arrival, propagation, and properties is thus vital for prediction of space weather at Earth as well as elsewhere in the solar system. In particular, it is important to accurately predict the CME velocity, shape, and evolution as functions of position and time, as well as the flow velocity and magnetic field vector in the coronal and solar wind plasma, downstream of the CME shock, and inside the CME. We report the results of simulating 4 separate CMEs from the Sun to 1 AU with the Space Weather Modelling Framework (SWMF; 2015 and 2016 versions). The simulations are set up carefully using Wilcox photospheric magnetogram data and coronagraph images and height-time data below 10 solar radii from coronagraphs. Outstanding agreement between the observations and simulations is found for the CME on 29 November 2013 that was directed primarily towards STEREO A. In particular, the CME's arrival at STEREO A, deceleration of the CME in agreement with the Gopalswamy et al. [2011] model, and the time-varying plasma and field (including Bz) agree extremely well. from upstream of the CME shock to within the CME. Similarly, the results of the simulations to the Earth-directed CMEs of 4, 6, and 7 September 2017 range from excellent to very good for the arrival time and for the 1-hour averaged density, radial speed, Bz, and magnetic field strength from the shock to well into the CME. These results provide strong evidence that we have the capability with the Space Weather Modeling Framework, when sufficiently carefully initialized, to accurately predict the properties and

evolution of CMEs and the interplanetary magnetic field and plasma from the Sun to 1 AU. This suggests that we are very close to being able to accurately predict the triggers for CME-driven space weather at Earth.

PSW.2-0004-18 PREDICTIVE REANALYSIS-DRIVEN OPERATIONAL AND VERSATILE ELECTRON RADIATION BELT MODEL

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The Earth's radiation-belt environment is a dynamic region of harmful radiation driven by a complicated competition between external and internal drivers. Understanding the recent state, and predicting the changes in the radiation environment has seen increased societal interest due to the ever increasing reliance on space-based assets for navigation, communication, and surveillance. Numerous past models have been developed to forecast fluxes at and inside of geosynchronous orbit, however they typically rely on observed particle fluence or flux observations, often integrated or averaged over a daily period. Such models, although useful, can not accurately reproduce flux observations globally, and thus are not able to provide spacecraft operators what they really require, fluence on a given trajectory, whether that be at low-Earth orbit, mid-Earth orbit, geosynchronous orbit, or a transfer between orbits, where radiation belt electrons may damage or destroy components that are not sufficiently radiation hardened.

Presented is an operational, data-assimilative, physics-based radiation belt forecast model capable of producing a recent 8-day hindcast and 2-day forecast of inner magnetospheric electron fluxes, globally, and at 1-hour temporal resolution from 100's of keV to several MeV. The model has been running in real time since February 2015. With the presented model, comes the ability to estimate daily fluence for any inner-magnetospheric satellite trajectory, and thus a significant step towards providing a monitor for safe access to space. The presentation includes a review of model performance over the past 2 years of operation, including an analysis of future directions to improve accuracy and reliability.

PSW.2-0005-18 MAGNETOPAUSE LOCATION BASED ON ACE AND DSCOVR DATA

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Solar wind propagation from L1 point to the Earth orbit has been realized in terms of simple convection model taking data from DSCOVR and ACE as input. Data from the two spacecraft were processed since 1st of March, 2017 and solar wind parameters measured by spacecrafts at L1 point were compared. Solar wind parameters calculated at the Earth orbit were compared to that collected in OMNI database.Subsolar distance has been calculated using Shue, Suvorov-Kuznetsova, Sibeck, Petrinek-Russel, Kalegaev-Lutov models of the magnetopause. The obtained results were compared for several quiet and disturbed periods.

PSW.2-0006-18 SYSTEMATIC ANALYSIS OF MACHINE LEARNING TECHNIQUES FOR KP PREDICTION IN THE FRAMEWORK OF THE H2020 PROJECT 'SWAMI'

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The Kp index is a global measure of geomagnetic activity and it represents short-term magnetic variations driven by solar particle dissipation into near Earth's space. The Kp index is used as the most important indicator for space weather alerts and serves as input to various models, such as for the thermosphere and the radiation belts. It is therefore crucial to predict the Kp index accurately. Previous works in this area have mostly employed artificial neural networks to nowcast Kp and based their inferences on the recent history of Kp and solar wind data. In this study, we systematically test how other machine learning techniques apart from neural networks perform on the task of nowcasting and forecasting Kp for longer prediction horizons up to 72 hours. Additionally, we investigate the longer time history inclusion into the models and the influence of the 27-day recurrency and persistence on the predictive performance during disturbed and quiet times. We also test performance with solar wind predictions from WSAEnlil model. Finally, we evaluate and report the optimal combinations of machine learning models with the 27-day recurrency and persistence for different levels of geomagnetic activity.

PSW.2-0008-18 SPACE WEATHER FORECASTING: A DATA-DRIVEN AND PHYSICS-BASED CHALLENGE

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Predicting is not the same as understanding. We can understand in depth the physics behind a process but without data on the state of the system we can't make predictions. We know perfectly well the laws of physics regulating fluid dynamics, yet we can't predict whether it will rain in one week. Unless, like us, you live in Belgium and then it will surely rain. And we can say that because weather forecast is data-driven. We know that statistically in Belgium it rains almost every day. So much so that we go to Scotland for a break of sunshine. For space we do not have the same level of knowledge of statistics of past event nor a wealth of information from the current conditions. Predicting space weather than means making the best use of the coarse, partial and limited availability of data and using the incomplete understanding of the physical mechanisms behind it. To this end we need to develop methods that are best suited to work on small amounts of data. If we like to understand in depth a CME we need to use highly resolved simulations that include all physics processes. But that does not help us much in predicting if what is happening right now on the sun is leading to a Carrington-type event. For that we need a quicker simpler model that can be run many times using data assimilation to constrain the outcome as best as possible. We present a new approach, part of the AISA H2020 project and based on tools developed via funding by the US AirForce. The new tools are a Lagrangian MHD model of the solar wind plasma and its embedded disturbances and a statistical technique based on the representer technique to identify the best strategy for data assimilation.

PSW.2-0009-18 INVESTIGATION OF EXCEPTIONAL SOLAR ACTIVITY IN SEPTEMBER 2017: G4 GEOMAGNETIC STORM (07-08.09) AND GLE72 (10.09) IN MINIMUM OF SOLAR CYCLE 24

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The exceptional solar activity in early September 2017 at minimum of solar cycle 24 is analised. The beginning of the intensive solar-terrestrial disturbances was the Active Region AR2673, which produced four powerful eruptions class X, including the strongest flare X9.3 of Solar Cycle 24 on September 6, 2017, after which began G4 - Severe geomagnetic storm on 07-08.09.2017 with Ap = 106, and also - the second strongest flare 8.2 of Solar Cycle 24 on September 10, 2017, which generated instantly the Ground Level Enhancement (GLE) of cosmic rays. This is GLE72 with increase of solar cosmic ray flux 6% in Oulu Station (Finland) (effective vertical geomagnetic cutoff rigidity: 0.8 GV), and increase 9% in DOMC Antartica and 14% in DOMB Antartica (in the latter case - lead free neutron monitors with effective vertical cutoff rigidity

<0.01 GV). h GLE72 develops under the conditions of a deep Forbush decrease (around 15%) in South Pole cusp caused by September 7th Coronal Mass Ejection. The three space regions of impact are investigated and analised in the present work: 1) Sun - photosphere and solar corona; 2) Interplanetary space with solar wind and its basic parameters - velocity V, density (or concentration N), temperature Tp and intensity of the magnetic field B; 3) Earth and its magnetosphere. Calculations of the solar wind parameters from measurments by SOHO and DSCOVR space probes in the point of Lagrange are made: the kinetic (dynamic) energy density Ek, thermal energy density Et and magnetic energy density Em during the investigated period September 2-15, 2017. We found two interesting phenomena in the investigated period: 1) tunnel effect in the Earth's environment, and 2) specific distribution of the solar wind energy density during and after the series of Coronal Mass Ejections. It is likely that both kinetic and magnetic energies can be used as predictors of strong geomagnetic storms. Besides

the investigation of GLE72 as second GLE in the current solar cycle 24 (after GLE71 on 17 May 2012 during the solar maximum) represents special interest.

PSW.2-0010-18 SOLAR WINDSOCKS - A SERVICE TO DERIVE ESTIMATES OF SOLAR WIND SPEEDS FROM COMETS' ION TAILS

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Comets' ion tails show material being carried away from cometary nuclei by the solar wind. As we know where each comet is, how fast it's moving, and in what direction, we can use the orientation of the tail to estimate the solar wind speed at the comet. Solar Windsocks is based on the assumption that the solar wind flow is radial, i.e. that it flows directly away from the Sun. This is known to not quite be true, with the solar wind often deviating a few degrees from the radial direction, but this assumption is necessary in order to derive solar wind speed estimates from comet images. The service takes a user's image, and projects it onto the comet's orbital plane. The position of the ion tail is then identified manually in the image, and the solar wind speed corresponding to each marked position in the tail is calculated. Using this technique, several solar wind speed estimates can be provided from each image. It is hoped that amateur and professional comet observers will donate their images and the resultant solar wind speed estimates to the project, to build up a database of point measurements of the flow speed in the inner heliosphere. The Solar Windsocks project is only possible through the financial support of the Europlanet-2020 Research Infrastructure, funded by the European Commission. Solar Windsocks is part of the Europlanet Planetary and Space Weather Services activity.

PANELS (P)

FROM IONOSPHERIC INDICES TOWARDS STANDARDISED ACTIVITY SCALES FOR SPACE WEATHER SERVICES (PSW.3)

PSW.3-0001-18 AN OPERATIONS PERSPECTIVE ON AN IONOSPHERIC INDEX

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Forecasters at the National Oceanic and Atmospheric Administration's (NOAA) Space Weather Prediction Center (SWPC) are charged with

. assessing the current and forecast space weather situation, including devising and formulating all necessary warning and forecast products . with emphasis on meeting the needs of the users.

In order to meet the needs of the GNSS community, consideration is given to the establishment of an ionospheric index to augment the existing NOAA scales: (R)adio blackout, (S)pace radiation storm, and (G)eomagnetic storm. The latitudinal stratification of ionospheric disturbances suggests an approach to developing an index. The concept will be explored from the perspectives of user needs, operational implementation and the associated complexities, including the need for consistency between existing and proposed scales. The adequacy of current operational ionospheric monitoring and modeling to support watch, warning, and alert capabilities will also be discussed.

PSW.3-0002-18 A REPORT ON DISCUSSIONS AT PAST SPACE WEATHER WORKSHOPS REGARDING THE NEED FOR AN IONOSPHERIC SCALE

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This is a report of the discussions at previous side meetings held during the Space Weather Workshop in Boulder over the past 3 years. We began by addressing basic questions such as: Do we need an ionospheric scale? What customer base is currently not served well by existing NOAA Space Weather Scale G, R, and S? What form should the scale take? What real-time data stream should drive it? Do we need both regional and global scales? Is more than one scale needed to address different customer sectors impacted by the ionosphere? At previous meetings the group was tending towards using the GNSS L1 and L2 phase data sometimes referred to as Along the Arc TEC Rate (AATR); e.g., hourly RMSE of 30 sec weighted TEC data. The target user group was GNSS because of the huge market, and since the existing scales already partially addressed the needs of some of the other user groups, such as HF propagation. The thought was to quantify the variability of AATR in different longitude and latitude sectors, and correlate with things like geomagnetic storms, Kp, solar flares, sudden stratospheric warnings, TIDs, MSTIDs, or other geophysical events. Assemble data over one solar cycle and multiple latitude and longitude sectors. The plan was to develop both regional and global "indices" or Scales. Other questions raised: Can it be forecast? What level of disturbance in AATR affects GNSS signals and has impact on users? How many stations would we need to monitor to define a global 1 to 5 scale? What is the relationship of AATR with S4 and sigma phi scintillation indices, and ROTI. What temporal cadence is needed? What is the impact of cycle slips? This paper will review some of this discussion and conclusions reached.

PSW.3-0003-18 SYNERGY BETWEEN THE DEVELOPMENT OF IONOSPHERIC DISTURBANCE INDICES AND MEDIUM-RANGE IONOSPHERIC FORECASTING

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At this time, there does not exist a widely used index that describes the magnitude of ionospheric space weather disturbances, despite the potential for significant user impacts. Yet, geomagnetic activity indices compiled over decades have had enormous scientific and practical value in characterizing the geomagnetic storm environment. Related to geomagnetic indices are the space weather scales (e.g. G1-G5) defined by NOAA's Space Weather Prediction Center, which are used both for space weather characterization and in medium-range forecasts (forecasts with a few days lead time). We are currently engaged in research on medium-range ionospheric forecasting, with the goal of predicting ionospheric conditions arising from both coronal mass ejections and high speed solar wind streams. Such upper atmosphere forecasts are based on forecasted solar wind values at 1AU that could be available a few days in advance. We consider both first-principles and data-driven approaches to forecasting, and place emphasis on improved scientific understanding that can arise from forecast-centric research. Due to the inherent complexity of the upper atmosphere response to space weather,

we are finding it advantageous to define metrics that characterize space weather conditions over large regions or globally. Such metrics could have a high degree of overlap with ionospheric disturbance indices, which are the focus of this session. We will describe ionospheric disturbance metrics relevant to forecasting that could also inform on the development of ionospheric indices. Initial forecast experiments using the Space Weather Forecast Testbed (SWFT) tool will be shown.

PSW.3-0004-18 THE DERIVATION AND VERIFICATION OF A REGIONAL IONOSPHERIC TEC DISTURBANCE INDEX

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A regional ionospheric disturbance index (RIDI) derived from the regional TEC map was introduced in this paper. The RIDI index can give a clear description for the disturbed phase (positive or negative) and strength of the ionospheric perturbation. The comparison between indices and the regional TEC disturbance suggested RIDI can represent the regional TEC well. Further verification using the multidimensional scaling suggested the RIDI is more correlated with TEC disturbance. The RIDI index can be used in global coverage. In addition, a Ns index was used to describe the disturbance range and it had a good relationship with Dst index. The RIDI and Ns can be used in space weather operational services to give the disturbance strength and influence range, which is convenient for users to know about ionospheric current conditions.

PSW.3-0005-18 ABOUT NEW IONOSPHERIC INDICES FOR SPACE WEATHER SERVICES

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Strong and, as a rule, sudden perturbations in the near-Earth space (magnetosphere and ionosphere of the Earth) cause numerous disruptions in the operation of systems of radio navigation and telecommunications, global information networks, tracking and warning devices on the Earth, can lead to malfunctions in the operation of powerful energy systems. As a rule, information on the characteristics of ionospheric disturbances is based on geomagnetic data, such as Kp, Ap, Dst, calculated from ground-based observations. It is known that solar radiation affects the parameters of the ionosphere and the ionization processes in it, and an indicator of the level of ionized particles can be a relatively easily recorded critical frequency of the reflection of a radio signal during ionospheric sounding f0F2. The study of the influence of the total level of solar activity on the state of the ionosphere can be reduced to a study of the characteristic deviations Δf0F2 in the behavior of regular ionogram parameters over a large interval of observations. Assuming that the observed deviations are a consequence of other characteristic phenomena in quasiregular processes on the Sun, we are looking for possible cross-correlation relations and primary parameters that ensure the maximum correlation coefficients between the processes. For example, the data measured on satellites in geostationary orbits is considered: particle fluxes, X-ray radiation (GOES-13, 15). At the same time, a joint analysis of the characteristics of solar activity recorded in the immediate vicinity of the Sun, for example, on the ACE device located in the front libration point, and the frequency deviations

Δf0F2 showed the existence of correlation links between the parameters of high-speed solar wind flows and the response of ionospheric characteristics. Thus, according to the results of measurements of the solar wind velocity, magnetic field, plasma concentration, the information on the origin and degree of ionospheric disturbance can be obtained much earlier than the data of events near the Earth are used. The report presents the results of a joint analysis of the behavior of the parameter of the mid-latitude ionosphere of the Earth at the F2 layer heights

(Δf0F2) and its relation to the characteristics of coronal mass ejections and high-speed solar wind fluxes in various phases of solar activity to determine prognostic probabilistic relationships between the parameters of the indicated solar phenomena and variations in the parameters of the mid-latitude ionosphere.

PSW.3-0006-18 THE RATE OF TEC INDEX AND GLOBAL IONOSPHERIC IRREGULARITY MAP

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The rate of total electron content (TEC) index (ROTI) [Pi et al., 1997] characterizes random fluctuations of ionospheric TEC, which occur when the radio signals traverse ionospheric irregularities. The index can be derived from dual-frequency carrier phase data of Global Navigation Satellite System (GNSS) signals tracked using geodetic-type GNSS receivers. Compared to the traditional ionospheric scintillation measurements, major characteristics of ROTI include: (1) measurements of integrated ionospheric irregularities; (2) not susceptible to receiver local oscillator error; (3) applicable to detection of irregularity-induced phase fluctuations at different carriers; (4) applicable to GNSS-based systems to mitigate the effects of ionospheric scintillation. ROTI data can be obtained from thousands of existing geodetic survey stations. ROTI measurements have been applied to the assessment of GNSS positioning degradation due to scintillation effects [Pi et al., 2017]. Using ROTI, global ionospheric irregularity maps (GIIMs) can be generated at 5-minute cadence. GIIMs capture global and regional activities of ionospheric irregularities under nominal geophysical conditions and during space weather storms. Prototype systems for global and regional nowcast of ionospheric irregularities using ROTI and GIIM have been developed and tested with real-time GNSS networks. This presentation will give an overview of ROTI and GIIM, discuss pros and cons of the ROTI vs. the traditional ionospheric scintillation measurements, and report the development of prototype nowcast systems. Highlights of science investigations and technology applications using ROTI and GIIM will also be presented.

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PSW.3-0007-18 AATR AN IONOSPHERIC ACTIVITY INDICATOR SPECIFICALLY BASED ON GNSS MEASUREMENTS AND TAILORED FOR GNSS USERS

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This work reviews an ionospheric activity indicator useful for identifying disturbed periods affecting the performance of Global Navigation Satellite System (GNSS). This indicator is based in the Along Arc TEC Rate (AATR) and can be easily computed from dual-frequency GNSS measurements.

The AATR indicator has been assessed over more than one Solar Cycle (2002-2017) involving about 140 receivers distributed world-wide. Results show that it is well correlated with the ionospheric activity and, unlike other global indicators linked to the geomagnetic activity (i.e. DST or Ap), it is sensitive to the regional behaviour of the ionosphere and identifies specific effects on GNSS users.

Moreover, from a devoted analysis of different Satellite Based Augmentation System (SBAS) performances in different ionospheric conditions, it follows that the AATR indicator is a very suitable mean to reveal whether SBAS service availability anomalies are linked to the ionosphere. On this account, the AATR indicator has been selected as the metric to characterise the ionosphere operational conditions in the frame of the European Space Agency (ESA) activities on the European Geostationary Navigation Overlay System (EGNOS). The AATR index has been adopted as a standard tool by the International Civil Aviation Organization (ICAO) for joint ionospheric studies in SBAS.

In this contribution, we explain how the AATR is computed, paying special attention to the cycle slip detection, which is one of the key issues in the AATR computation, not fully addressed in other indicators such as the Rate Of change of the TEC Index (ROTI). Furthermore, we present the advances towards the real-time implementation of the AATR index. These improvements focus on the timely monitoring and warning of Space Weather events. The main conclusions about the ionospheric activity that extracted from the AATR values during the above mentioned long-term study are: (a) the different spatial correlation related with the MOdified DIP (MODIP) which allows to clearly separate high, mid and low latitude regions, (b) the large spatial correlation in mid latitude regions which allows to define a planetary index, similar to the geomagnetic ones, (c) the seasonal dependency which is related with the longitude and (d) the variation of the AATR value at different time scales (hourly, daily, seasonal, among others) which confirms most of the well-known time dependences of the ionospheric events, and finally,

(e) the relationship with the space weather events.

PSW.3-0008-18 ESTIMATING THE DEGREE OF IONOSPHERIC PERTURBATIONS USING AN IONOSPHERIC INDEX

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Space weather can strongly influence trans-ionospheric radio signals depending on the frequency used. To assess the intensity of a space weather event from its origin at the sun to its influence on the ionosphere, there is a number of physical quantities which must be derived from scientific measurements, such as the solar flux density F10.7, interplanetary magnetic field and geomagnetic indices. In combination with additional classification systems, all these parameters provide orientation in a physically complex environment. Therefore, indices are used for a brief communication of simplified but adequate situation awareness to users. Space weather driven ionospheric phenomena can heavily affect customers in the communication and navigation domain, but they are still served inadequately by the existing indices. We present a new robust index, based on ground based real time GNSS measurement data from several GNSS reference networks,that is able to properly characterize temporal and spatial ionospheric variations on small to medium scales. The proposed ionospheric disturbance index can overcome several drawbacks of other ionospheric measures and might be a suitable candidate as potential driver for an ionospheric space weather scale.

PSW.3-0009-18 ON THE IONOSPHERIC SCALES BASED ON TEC DATA

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The present work shows the preliminary results from the analysis for developing the ionospheric scales based on Disturbance Ionospheric Index (DIX). This index aims to target all the different user groups affected by ionospheric disturbances, e.g. the navigation, positioning and satellite communication users, in a simple and straightforward approach. Therefore, we used the Vertical TEC (VTEC) over South America to calculate the Total Electron Content Maps covering latitudes from 60°S to 20°N and longitudes from 90°W to 30°W, with 5 x 5 degrees resolution. Afterwards, the DIX Maps are obtained to reveal the variation of the TEC over an average quiet ionosphere background. Among the results, we have different methodology for achieving the average quiet ionosphere background and disturbances in the DIX at different latitudinal sector.

PSW.3-0010-18 AN ANALYSIS OF IONOSPHERIC SCINTILLATION INDICES

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This paper will review the ionospheric indices used to quantify the ionosphere scintillation levels. It will start with a review of observations both at low and high latitudes. The low latitudes observations will include years of major solar activity, this being the main driver of the equatorial scintillation activity. The high latitudes scintillation data set will include an analysis of the major magnetic storms which occurred in the last two years.

In both cases, low and high latitudes, the main indices and the algorithms to derive them will be analysed. This concerns in particular the phase and scintillation indices, the signal correlation characteristics and the spectra parameters.

The ability of a scintillation model to reproduce these scintillations will be investigated in the two cases.

PSW.3-0011-18 NEW CAPABILITIES FOR PREDICTION OF HIGH-LATITUDE IONOSPHERIC SCINTILLATION: A NOVEL APPROACH WITH MACHINE LEARNING

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Space weather has a wide-reaching impact on technological systems. Among the critical affected technologies are those dependent on radio signals propagating through the complex, variable ionosphere, especially those from Global Navigation Satellite Systems (GNSS). Complexity and multi-scale variability (in both time and space) characterize the ionosphere and threaten the integrity of GNSS signals. However, these signals also provide better spatial coverage at a higher cadence than any single ionospheric data set. We present a new data-driven approach to the prediction of ionospheric disturbances to GNSS signals, specifically scintillation, by taking advantage of years of GNSS scintillation data. These data are used to train a supervised machine learning classification model known as a support vector machine (SVM) [1]. We focus for the first time on high-latitudes, where space weather effects are most direct and no prediction capability currently exists. We show through robust quantitative metrics (i.e., beyond the conventional visual assessment) that this method produces a high degree of accuracy in predicting high-latitude scintillation with one-hour lead times based on the current state of the ionosphere, geomagnetic environment, and solar wind.

We discuss the use of this new predictive capability as a predictive benchmark and a much more robust means of characterizing ionospheric effects on radio signals than global indices, thereby fulfilling the role of an ionospheric index. This work embodies the future of space weather as outlined by the COSPAR roadmap [2], placing focus on prediction, taking a data-driven approach, and leveraging state-of-the-art techniques that can evolve traditional approaches in lieu of the growing and complex space weather observational system.

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PSW.3-0012-18 FORECASTING GNSS SCINTILLATION USING A NEW PROXY SCINTILLATION INDEX (ROBI) DERIVED FROM ALL SKY IMAGERS

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Global Navigation Satellite System (GNSS) signals propagating through structured ionosphere such as aurora may be scintillated causing observation and possibly positioning errors. It is advantageous to determine the magnitude of GNSS signal scintillation associated with a given level of auroral brightness observed around the signal's ionospheric pierce point (IPP). Such information would enable the exploitation of auroral image observations in space weather monitoring and impact assessment. Many previous studies have observed a general correlation between auroral luminosity and GPS phase scintillation but not a defined one-to-one relationship. Consistent with such findings, in this study a relatively low correlation coefficient of 0.38 is observed between the phase scintillation and the level of brightness around the GPS signal's ray path for a dataset of 292 events in the Canadian sector. Alternatively, a new pseudoscintillation index, Rate of change of Brightness Index (ROBI), is introduced in this study which is derived from the changing auroral brightness around the satellite's IPP. This ROBI is highly positively correlated (correlation coefficient: 0.77) with GPS phase scintillation (σϕ). Forecasting scintillation in GNSS signals when these signals pass through auroral arcs is also an important capability to have for high precision positioning and navigation applications in the auroral regions. In this study we also demonstrate the capability of artificial neural networks to forecast scintillation due to auroral using ROBI from an ASI and σϕ for that satellite obtained from a GPS receiver as inputs. This study demonstrates that neural network forecasted phase scintillation (σϕ) clearly follows the σϕ index reported by the receiver with a correlation of 75%

PSW.3-0013-18 THE USE OF REAL-TIME POLAR CAP (PC) INDICES FOR SPACE WEATHER MONITORING

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The Polar Cap (PC) indices, PCN (North) and PCS (South), reflect the transpolar plasma convection driven by the interaction of the solar wind with the magnetosphere. The standard PC indices based on geomagnetic observations at Qaanaaq (Thule) and Vostok, respectively, have been used in a variety of solar-terrestrial investigations relating to magnetic storm and substorm conditions. In their real-time versions, the indices could be useful for power grid protection by enabling warning an hour or more (Stauning, 2013) ahead of violent events of geomagnetically induced currents (GIC) that may threaten high-voltage power grids in the vicinity of the auroral zones. The PC indices, furthermore, might help the forecast of auroral substorms with their colourful and impressive display of vivid auroras for the benefit, among other, of polar winter tourism. The presentation shall consider such applications and shall also discuss the available methods to derive real-time PC index values as well as the quality of presently provided indices (Stauning, 2015, 2018). Furthermore, the potential use of alternative locations in the northern and southern polar caps to provide data for PC indices (Stauning, 2018) shall be considered.

PSW.3-0014-18 PLANETARY DISTRIBUTION OF IONOSPHERE IONIZATION RATE BY GALACTIC COSMIC RAYS (GCR): HOW IT CHANGED WITH TIME FROM 1950 UP

TO EXPECTED AT 2050 DUE TO VARIATIONS OF CR PENUMBRA FUNCTIONS AND CUTOFF RIGIDITIES WITH TAKING INTO ACCOUNT TIME VARIATIONS OF GCR SPECTRUM?

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We use results on the trajectory calculations of planetary distribution CR penumbra function (equal to 1 for allowed CR trajectories and 0 for forbidden trajectories) and calculations of corresponding variations of CR effective cutoff rigidities Rc for each 5 years during 1950 - 2050 (1950, 1955, and so on, up to 2050) with taking into account changes of primary rigidity GCR spectrum due to modulation in the Heliosphere. Based on these results we determine how changed the flux of GCR and corresponding ionization rate in low ionosphere (where GCR is the one of main sources of ionization) due to time variations of Rc for the same each 5 years during 1950 - 2050 in dependence of latitude and longitude. Obtained results are important for more exact determining influence of GCR on ionosphere and radio-wave propagation in 1950

2015 and forecasting of expected influence up to 2050. For solar CR events (with different primary energetic spectrums) obtained results give possibility to calculate and forecast more exactly their influence on ionosphere and radio-wave propagation finally caused by processes on the Sun, by Space Weather effects, and by processes deep inside the Earth.

PSW.3-0015-18 IONOSPHERIC DISTURBANCE SCALES TO SUPPORT AERONAUTICAL COMMUNICATIONS, NAVIGATION, AND SURVEILLANCE SYSTEMS

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In the civil aviation, different communications, navigation and surveillance (CNS) systems are used to support aircraft operations and air traffic control. Radio waves from HF to L-band radio waves are for communications between ground and air and between air and air. In navigation, conventional ground navigation aids such as VOR (VHF Ommnidirectional Range) or ILS (Instrument Landing System) use VHF. Recently Global Navigation Satellite Sytem (GNSS) using L-band is getting more widely used. In surveillance to monitor the airplanes, ADS-B (Automatic Dependent Surveillance - Broadcast) where airplanes broadcast their information such as position or direction is getting widely used. The source of the position is the GNSS. These systems use radio waves and are often influenced by ionospheric activities. However, since the frequencies are different, ionospheric phenomena that have impacts on each system is different.

Considering the increasing air traffic and importance of space weather effects, International Civil Aviation Organization (ICAO) is standardizing the space weather information service for aeronautical operations. As the information provided for aeronautical operations, they have to be simple and concise. Therefore, physical quantities have to be interpreted into scales that is related to the relevant operations.

In this study, GNSS is taken as one of the examples. Currently, GPS and GLONASS signals at the L1 frequency are standardized and available for aviational use. Therefore, ionospheric delay variations associated with ionospheric disturbances are serious error sources and their impact needs mitigated. However, ionospheric disturbances have different scale sizes corresponding to different physical mechanisms behind them. This study discusses the contents of the relevant information and their necessary spatial granularity. In the next generation GNSS, more constellations and a second frequency (L5) will be available. For this multi-constellation and multi-frequency (MC-MF) GNSS, ionospheric delay (or equivalently total electron content) effects will almost disappear. However, effects of scintillations will become more important. Instead, frequency dependent information will be necessary. Thus, space weather information necessary for the next generation MC-MF GNSS will also be discussed in this study.

PSW.3-0016-18 APPLICATION-ORIENTED INDICES FOR DESCRIBING TEMPORAL AND SPATIAL VARIATIONS OF THE IONOSPHERIC IONIZATION

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Ionosphere can adversely affect accuracy, continuity, availability, and integrity of modern Global Navigation Satellite Systems (GNSS) in different ways. Hence, reliable information on key parameters describing the perturbation degree of the ionosphere is helpful for estimating the potential degradation of the performance of these systems. So, to guarantee the required safety level in aviation, Ground Based Augmentation Systems (GBAS) and Satellite Based Augmentation Systems (SBAS) have to detect and mitigate ionospheric threats in particular due to ionospheric gradients. In this talk we investigate two approaches for estimating temporal and spatial gradients of the Total Electron Content (TEC) in near real time. The approaches allow estimating the current perturbation degree of the ionosphere with high temporal resolution. The capabilities and accuracy of the approaches are demonstrated by a simulation study using a 3D electron density model of the ionosphere and plasmasphere in conjunction with realistic GNSS constellations. The potential of these approaches to serve as objective ionospheric indices for scaling horizontal TEC gradients and rapid solar flare effects has been investigated. The results are presented focusing on their use in precise dual frequency GNSS applications.

PSW.3-0017-18 IONOSPHERIC STORM EFFECTS ON GNSS PRECISE POSITIONING

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Dynamic changes in ionospheric electron content and structure, commonly referred to as ionospheric space weather, have the potential to affect the performance and availability of GNSSbased positioning applications. Further, the impact is largely dependent on how the positioning algorithm mitigates the effects of GNSS signal delay through the ionosphere. This varies considerably across positioning platforms. Developing a simple index that adequately captures the impact of ionospheric space weather on all GNSS positioning platforms is therefore a challenging task. We evaluate the impact of an ionospheric storm on a number of positioning algorithms, including both PPP-AR and PPP-RTK. Multiple performance metrics are used to relate GNSS-based positioning performance to ionospheric space weather conditions.

PSW.3-0018-18 AN ASSESSMENT OF THE IONOSPHERE RESPONSE TO FIVE THE MOST INTENSE GEOMAGNETIC SUPERSTORMS DURING 60 RECENT YEARS

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An assessment of the ionosphere perturbations can be made through the construction of the global instantaneous maps of the foF2 critical frequency (GIM-foF2) and the ionospheric weather index maps GIM-Wf(foF2). These maps can offer a potentially useful tool to provide users with the prevailing tracking conditions over a certain area and also be used to help mitigate the effects of the disturbances on HF communication and GNSS positioning. This paper presents results of reconstruction of the ionospheric weather during five the most intense superstorms observed since IGY (1957, 1958, 1959, 1989, 2003) with the instantaneous global maps of the F2 layer critical frequency, GIM-foF2, and the ionospheric weather index maps, GIM-Wf. The intensity of the ionospheric superstorm is characterized by the planetary Wfp index derived from GIM-Wf maps. Model relationship is established between mean Wfp profile and geomagnetic superstorm profiles demonstrating saturation of the ionospheric storm activity towards the peak of geomagnetic storm. Superposed epoch analysis of five events has shown delay of the ionospheric superstorms regarding the geomagnetic superstorms. Time lag of Wfpmax is found equal to 9 h after AEmax, 6 h after apmax and aamax, 2 h after Dstmin which allows model forecast of the ionospheric superstorm when geomagnetic superstorm is captured with one or more of geomagnetic indices.

PSW.3-0019-18 THE RELATIONS OF POLAR CAP (PC) INDICES TO SOLAR WIND PARAMETERS AND GEOSPACE MAGNETIC DISTURBANCES

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The Polar Cap (PC) indices are based on geomagnetic observations at Qaanaaq (Thule) and Vostok, respectively. To derive index values, the geomagnetic variations are projected to the direction considered to be perpendicular to the noon-midnight transpolar plasma convection and scaled with respect to the solar wind merging electric field. The PC indices measure the transport of plasma and magnetic fields from the front of the magnetosphere to the tail region and are considered to represent the input of energy from the solar wind to the Earth's magnetosphere. With appropriate time shifts and integration of samples, PC indices could be used to predict auroral (AL), mid-latitude (Kp) and ring current (SYM, ASYM, Dst) geomagnetic disturbance indices (e.g., Stauning, 2012). In addition to their inherent relations to the solar wind electric fields and thereby to the solar wind velocity and the transverse components of the interplanetary magnetic fields, the PC indices respond to density changes related to impulsive variations in the solar wind dynamical pressure (Stauning, 2008). The general solar wind density level, however, has little effect on the PC index values. The presentation shall discuss the relations of PC indices to further disturbance parameters and provide insight in PC index dependencies of importance for the proper interpretation of index variations at space weather monitoring applications.

PSW.3-0020-18 POLAR CAP (PC) INDICES BASED ON MULTIPLE SOURCES ENSURING CREDIBILITY AND OPERATIONAL RELIABILITY

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To establish reliable Space Weather forecasts based on Polar Cap (PC) indices, and also to ensure credibility of their use for scientific analyses of solar wind-magnetosphere interactions, additional sources of data for the PC indices have been considered (Stauning, 2018). In the search for alternative index sources, objective quality criteria were established to be used for the selection among potential candidates and also for control of the quality of PC index series in current use. In the Canadian region, the data from Resolute Bay magnetometer, as will be shown, may provide alternative PCN indices of adequate quality. In Antarctica, the data from Concordia Dome-C observatory are shown to provide an alternative basis for qualified PCS indices. Examples to be presented shall document the usefulness of these alternative index sources. Thus, PCN indices in a real-time version based on magnetometer data from Resolute Bay could have given 6 hours of early warning, of which the last 2 hours were "red alert", up to the onset of the strong substorm event on 13 March 1989 that caused power outage in Quebec. The alternative PCS indices based on data from Dome-C have helped to disclose that presently available Vostok-based PCS index values are corrupted throughout most of 2011

PSW.3-0021-18 SPACE-TIME DISTRIBUTION OF IONOSPHERE IONIZATION RATE DURING GLE AND SEP EVENTS BY SOLAR COSMIC RAYS (SCR): THEIR CHANGING FROM 1950 UP TO EXPECTED AT 2050 DUE TO VARIATIONS OF CR PENUMBRA FUNCTIONS AND CUTOFF RIGIDITIES WITH TAKING INTO ACCOUNT TIME VARIATIONS OF SCR SPECTRUM DURING GLE AND SEP EVENTS.

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The effective cutoff rigidity is determined not only by the penumbra function (equal to 1 for allowed CR trajectories and 0 for forbidden trajectories), but also by rigidity/energy spectrum of SCR, which changed with time during GLE and SEP events (caused by dependence of propagation parameters from rigidity/energy of SCR). We use results on the trajectory calculations of planetary distribution CR penumbra functions for each 5 years during 1950 - 2050 (1950, 1955, and so on, up to 2050). Based on these results we determine how changed the flux of SCR and corresponding ionization rate in low ionosphere (where SCR and GCR are main sources of ionization) due to time variations of Rc for the same each 5 years during 1950 - 2050 in dependence of latitude and longitude. For solar GLE and SEP events (with different primary rigidity/energy spectrums) obtained results give possibility to calculate and forecast more exactly their influence on ionosphere and radio-wave propagation finally caused by processes on the Sun (generation SCR and ejection from solar corona into solar wind), by Space Weather effects during SCR propagation from the Sun to the Earth), and by processes deep inside the Earth (changing the main magnetic field).

PANELS (P)

INTEROPERABILITY OF SPACE WEATHER DATA MODELS, DATA HOLDINGS AND DATA ACCESS TOOLS (PSW.4)

PSW.4-0001-18 THE SPASE METADATA MODEL FOR HELIOPHYSICS DATA AND MODELS

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The Space Physics Archive Search and Extract (SPASE) Metadata standard is a communitydeveloped standard that is being supported and used by the NASA-funded space and solar physics community. It is also in use by the international community and by other U.S. agencies (NOAA). SPASE metadata has long been used to describe experimental data, software, documents and more. The most recent additions to the SPASE information model are extensions to support describing a simulation or model and the results generated from a run. These extensions are based on the work done by the EU's Framework 7 Integrated Medium for Planetary Exploration (IMPEx) project. In addition to IMPEx, these extensions have been adopted by the multi-agency Coordinated Community Modeling Center (CCMC) to describe supported models and run results. These extensions, along with the core SPASE metadata, enable the discovery of related observational and theoretical data resources through search portals such as NASA's Heliophysics Data Portal. In addition, SPASE provides a variety of tools and services related to generating and validating resource descriptions. One new service is that SPASE now provides support for issuing Digital Object Identifiers (DOI) for resources that are described with SPASE. The SPASE Metadata Working Team (SMWT) will work with data producers who lack other avenues for producing DOI so that their registered data may be referenced in publications. SPASE also provides generated landing pages based on the content of SPASE resource descriptions which can be used for any DOI. Overall SPASE metadata is capable of providing the infrastructure to connect data, documents, people, software, services and published works. And when SPASE metadata is harvested by a portal an ability to have rich discoverability.

PSW.4-0002-18 THE SMWT: A CONCERTED EFFORT TO PRODUCE SPASE-BASED METADATA FOR HELIOPHYSICS AND SPACE WEATHER DATA TO ENABLE UNIFORM ACCESSIBILITY

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Heliophysics measurements have been made over the years by both space-based and groundbased instruments, which are typically supported or funded by various international and national agencies. As a result, data repositories are globally distributed across geopolitical and agency boundaries. The data themselves have also been obtained by a large variety of observing platforms and instrument types, thus the resulting measurement types, data types and data attributes are diverse and the heliophysics data environment is fundamentally heterogeneous. As such, users of heliophysics data have to become accustomed to and utilize different pathways and tools to access, search, and use the data they need to analyze. While discipline-specific data services and tools have so far served the heliophysics research community adequately, the recognition of the importance and emphasis in recent years on heliophysics systems science and space weather research, however, have brought new requirements for data services to serve interdisciplinary and diverse user communities. This presentation will describe a concerted undertaking by the SPASE Metadata Working Team (SMWT) in identifying all electronically accessible heliophysics data products (space-based and ground-based) and describing them by using the same metadata model, SPASE, so that they can be uniformly accessed and searched by a common protocol, e.g. the Heliophysics Applications Programming Interface (HAPI). The SMWT undertaking will help implement the recommendations from international bodies, such as the COSPAR-ILWS Space Weather Roadmap and the International Space Weather Initiative (ISWI), so that effective international data coordination can foster successful space weather research.

PSW.4-0003-18 METADATA EFFORT AT THE COMMUNITY COORDINATED MODELING CENTER (CCMC)

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The Community Coordinated Modeling Center (CCMC) at NASA GSFC is home to one of the largest and an ever-growing collections of space weather models, simulation runs, and simulation results. Members of the Space Science community regularly rely on these unique collections of data for space weather forecasting, validation efforts, space science research, and education purposes. Starting in 2016, as part of the Information Architecture for Interactive Archives (IAIA) working team, the CCMC began implementing a new metadata system for models, model runs, and model outputs that is compliant with the SPASE metadata standard. This metadata system will be an important component in our Comprehensive Assessment of Models and Events Based on Library tool (CAMEL) framework, which is currently under development. It will also be the major backbone of the Runs-On-Request Next Gen system. By adding metadata to CCMC hosted models and data, it will allow CCMC to develop sophisticated search functionality to aid in harvesting our unique collections of data. To support data accessibility and interoperability, the CCMC plans to implement application programming interfaces (APIs) following the Heliophysics Application Programmer's Interface (HAPI) protocol whenever possible starting with the integrated Space Weather Analysis (iSWA) system time series API. Allowing the space science community to take full advantage of our unique collections of data is one of the primary goals at the CCMC.

PSW.4-0004-18 THE HELIOPHYSICS APPLICATION PROGRAMMER'S INTERFACE (HAPI) SPECIFICATION FOR SHARING AND ACCESSING TIME SERIES DATA

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The Heliophysics Application Programmer's Interface (HAPI) is a new interface specification that both large and small data centers can use to expose time series data holdings in a standard way. It is a REpresentational State Transfer (REST) or RESTful web service that provides a method to stream digital time series information from data providers to data users. The HAPI concept relies on data products that have been organized in consistently formatted files with increasing, though not necessarily uniformly increasing, time tags. The data product files must be uniform in terms of parameter content but may have any number of parameters and the individual parameters may be any assorted collection of scalars, vectors, tensors, or generalized arrays.

HAPI requires four endpoints to allow clients to evaluate and provide access to the contents of a data server. The four endpoints all specify the HAPI server version number and the HAPI server response status. The set of endpoints that the HAPI server requires are: 1) Capability - defines the output stream format, either comma-separated values, binary, JSON, or custom, 2) Catalog - a list of the available datasets, 3) Info - a data header in JSON format that provides at least the minimum required information to automate streaming of the data; this endpoint may include information for data set attributes and parameter attributes, and 4) Data - specifies the time range, parameter selection, and format for the data streaming request.

The HAPI specification is available at Github, where projects are also underway to develop reference implementation servers that data providers can adapt and use at their own sites. Also in the works are data analysis clients in multiple languages (IDL, Python, Matlab, Javascript and Java). Institutions which have agreed to adopt HAPI include Goddard (CDAWeb for data and CCMC for models), LASP at the University of Colorado Boulder, the Planetary Plasma Interactions node of the Planetary Data System (PPI/PDS) at UCLA, the Plasma Wave Group at the University of Iowa, the Space Sector at the Johns Hopkins Applied Physics Lab (APL), and the timeseries.org site maintained at George Mason University. Over the next year, the adoption of a uniform way to access time series data is expected to significantly enhance interoperability within the Heliophysics data environment.

PSW.4-0005-18 SPACE WEATHER JHELIOVIEWER IN A HETEROGENEOUS WORLD

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The Space Weather JHelioviewer project aims to augment the freely available services of the Helioviewer project with space weather relevant capabilities. As such, it merges the output of several networked software services by combining the display of 1D data (timelines), 2D data (solar images and spectrograms), 3D data (multispacecraft imaging, magnetic field lines modelling), solar event detections (e.g., HEK), and space weather alerts. This talk will highlight the experiences gathered while incorporating this system with several diverse datasets and services.

PSW.4-0006-18 SDDS - YET ANOTHER DATA WAREHOUSE SYSTEM FOR SPACE EXPERIMENTS

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This work introduces the Satellite Data Downloading System (SDDS) developed at SINP MSU in 2016. SDDS is a fully automatic, flexible, and scalable data warehouse system that accumulates data from Russian and foreign space crafts, and also ground stations in near real-time. SDDS monitors all its components and visualizes their activities in real-time. If an error occurs, the monitoring system will immediately deliver the error description to satellite operators using the Telegram messenger service. For data acquisition, SDDS provides a user-friendly web interface, a Python library, and a REST API. Using the built-in Python library, one can easily compose data from available in SDDS space experiments into a dataset (NumPy arrays, Pandas data frames) and use it in different machine learning models. The web interface provides the possibility to retrieve data and save them to a local computer in text format. It also supports creating customizable plots on the fly with retrieved data and saving the results as images.

PSW.4-0007-18 ENHANCED INTEROPERABILITY THROUGH AUTOMATED DATA ARCHIVE PRODUCT TRACKING, ADAPT, OF SPACE WEATHER DATA PRODUCTS

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The Automated Data Archive Product Tracking, ADAPT, effort is a project that addresses the need to enable seamless discovery and access of Heliophysics data products. ADAPT consists of a collection of software composed mainly of BASH shell scripts and IDL routines, that automate the production of SPASE metadata files. SPASE, which is an ontological XML schema, has been designed by Heliophysics researchers to generate metadata documents that describe data products down to the parameter level. And, SPASE is the NASA accepted standard for the description of heliophysics and space weather data products. Once SPASE data product descriptions are generated, they are ingested into metadata GIT registries, which are then leveraged by the Heliophysics Virtual Observatories, VxOs, for data product search and download with interoperability across many data servers that are distributed worldwide. It is important to recognize that the heliophysics and space weather data environment is highly dynamic with thousands of data products involved. Access to data is clearly facilitated via the VxOs but routine access is possible only if the VxO SPASE metadata registries contain accurate and up to date information. The track record until now has clearly demonstrated that the ADAPT method is a highly prolific means of producing SPASE metadata descriptions in a timely, uniform fashion and with a high degree of quality control. As of January 2018, nearly half of all SPASE data product descriptors that are registered in the Heliophysics VxO GITs have been produced by various versions of the ADAPT tool set. Currently, ADAPT has been used primarily to describe data products that are stored on the NASA GSFC CDAWeb data server by using the Common Data Format, CDF. Over 1,000 such data product descriptors have been generated via ADAPT and submitted for VxO registration. An early version of the ADAPT, then called the SPASEnator, was used to generate data product descriptions for World Data Center ground magnetic field and other data sets. ADAPT is not limited in terms its ability to skim metadata out of variously formatted self-describing data products. It has been constructed in a modular fashion that allows the harvesting such metadata by substitution of a single routine. And, another valuable aspect of ADAPT is its ability to provide detailed data parameter attribute information. The parameter information is crucial to enable value-added services that rely on leveraging the SPASE metadata information. Finally, well-documented SPASE descriptions can also be used to ease the archiving of space weather data products.

PSW.4-0008-18 VOEVENT FOR SUN-EARTH AND PLANETARY SPACE WEATHER

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With its Planetary Space Weather Service (PSWS), the Europlanet-H2020 Research Insfrastructure (EPN2020RI) project is proposing a compelling set of databases and tools to that provides Space Weather forecasting throughout the Solar System. We present here the selected event transfer system (VOEvent). We describe the user requirements, develop the way to implement event alerts, and chain those to the 1) planetary event and 2) planetary space weather predictions. The service of alerts is developed with the objective to facilitate discovery or prediction announcements within the PSWS user community in order to watch or warn against specific events. The ultimate objective is to set up dedicated amateur and/or professional observation campaigns, diffuse contextual information for science data analysis, and enable safety operations of planet-orbiting spacecraft against the risks of impacts from meteors or solar wind disturbances.

The Europlanet H2020 Research Infrastructure project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654208.

PSW.4-0009-18 THE ESA VIRTUAL SPACE WEATHER MODELLING CENTRE - PART 2

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VSWMC

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The goal of the ESA ITT project AO-1-8384-15-1-NB VSWMC-Part 2 is to further develop the Virtual Space Weather Modelling Centre (VSWMC), building on the Phase 1 prototype system and focusing on the interaction with the ESA SSA SWE system. The objective and scopes of this project include:

The efficient integration of new models and new model couplings, including a first demonstration of an end-to-end simulation capability.

The further development and wider use of the coupling toolkit and the front-end GUI which will be designed to be accessible via the SWE Portal.

Availability of more accessible input and output data on the system and development of integrated visualization tool modules.

The consortium that took up this challenge involves: 1) the Katholieke Universiteit Leuven (Prime Contractor, coordinator: Prof. S. Poedts); 2) the Belgian Institute for Space Aeronomy (BIRA-IASB); 3) the Royal Observatory of Belgium (ROB); 4) the Von Karman Institute (VKI); 5) DH Consultancy (DHC); 6) Space Applications Services (SAS); 7) British Antarctic Survey (BAS).

The VSWMC-Part 2 project started in February 2016. At the time of the meeting, the project will be finished, which means that all the models (EUHFORIA, CTIM, CTAN2, BAS-RBM, COOLFluiD, GUMICS, etc.) and all the model couplings will be installed and operational in the VSWMC. Hence, after a short description of what and how, several models and model couplings will be demonstrated, including a full Sun-to-Earth scenario simulation of a CME evolution and impact at Earth.

The VSWMC system is being developed under ESA's Space Situational Awareness (SSA) Programme and is intended to become an operational system as part of the ESA SSA SWE system.

PSW.4-0010-18 DEVELOPING GUIDELINES FOR TRANSPARENT DATA DISCOVERY, ACCESS AND DISTRIBUTION

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The panel event will conclude with a half hour round table discussion, with the aim of identifying guidelines for improving access to data holdings and querying of existing metadata standards. Participants are invited contribute to the discussion and to prepare questions and (very) short presentations beforehand.

PSW.4-0011-18 OPERATIVE PRODUCTS OFFERED BY LAMP (LABORATORIO ARGENTINO DE METEOROLOGíA DEL ESPACIO) IN ARGENTINA

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The number of countries developing operative Space Weather (SWx) activities has significantly increased during the last years. Several international institutions, as for instance the World Meteorological Organization (WMO), the International Civil Aviation Organization (ICAO), the United Nations Office for Outer Space Affairs (UNOOSA), have began to develop programs and activities on Space Weather, some of them with the aim of having answers to the negative effects of extreme SWx events. At the beginning of 2016, our laboratory on SWx in Argentina (LAMP: Laboratorio Argentino de Meteorología del esPacio) started to develop activities on operative SWx. These activities are being developed by four institutions: Departamento de Ciencias de la Atmósfera y los Océanos at Universidad de Buenos Aires (DCAO-UBA), Instituto de Astronomía y Física del Espacio (IAFE), Instituto Antartico Argentino (IAA), and Servicio Meteorológico Nacional (SMN). These SWx activities started in 2014 with a programme of courses on operative SWx. In 2015, a website at DCAO started to offer the first operative products in Space Weather (spaceweather.at.fcen.uba.ar), offering information about the current conditions of the energetic proton flux arriving to the terrestrial environment, online information about the flux of radiation at two X-rays bands near Earth (GOES), and also information of the Kp index. A forecasting service of SWx is also provided. Since 2016, we started to develop a daily monitoring of real-time information on the SWx conditions, in particular, the conditions of the Sun, the interplanetary medium, the magnetosphere, and the ionosphere. The information is analyzed by each participant and discussed later on, during monthly briefings. A weekly report is done as a resume of the space weather activity and it is posted on the website. Also from a collaboration between DCAO and EMBRACE-INPE, a product showing the total electron content in the Argentine ionosphere is also include in the portal. We present here an example of the activities on operative Space Weather developed in Argentina and a summary of the products we develop in the LAMP group.

PSW.4-0012-18 FACILITATING ADVANCEMENTS IN SPACE WEATHER DATA AVAILABILITY THROUGH A SPACE WEATHER TESTBED AND DATA PORTAL

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Society has grown reliant on complex and highly interconnected technological systems, which makes us increasingly vulnerable to the effects of space weather events. An extreme space weather event today could conceivably impact many of the crucial systems we rely on, including disrupting operating earth-orbiting satellites, potential collapse of electrical grids, and impairing navigation, communication, and remote sensing capabilities. Thus, it is imperative that the scientific community address the question of just how severe events might become and to ensure stakeholders have access to the essential data needed for research and decision making. Stakeholders include policy makers and public safety officials who need to be informed by the facts on what might happen during extreme conditions. This requires essentially extremely timely up-to-the-minute alerts, warnings, and also forecasts of severe space weather events, which in turn demands measurements, models, and associated data products to be available via the most effective data discovery and access methods possible.

Similarly, advancement in the fundamental scientific understanding of space weather processes is also vital, requiring that researchers have convenient and effective access to a wide variety of data sets and models from multiple sources. The space weather research community, as with many scientific communities, must access data from dispersed and often uncoordinated data repositories to acquire the data necessary for the analysis and modeling efforts that advance our understanding of solar influences and space

physics on the Earth's environment. The University of Colorado (CU) is a leading institution in both producing data products and advancing the state of scientific understanding of space weather processes, is well positioned to address many of these issues. CU is inaugurating a dedicated Space Weather Technology, Research, and Education Center (SWx TREC) that will serve many of these needs, including implementation of an interoperable data portal intended to more effectively serve the needs of the Space Weather research community, as well as facilitating the advancement of models into production/operational use. In this presentation, we will outline the motivating factors for effective space weather data access and present plans and methods for meeting model testing/incubation needs, as well as the data management and access needs of the disparate communities who require space weather data and information.

PSW.4-0013-18 OPEN SOURCE DATAHUBSYSTEM: FROM SENTINELS DATA ACCESS TO AN AGNOSTIC DATA DISTRIBUTION TOOL

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Keywords: Open Source Data Hub System (OS DHuS), data access, dissemination, Sentinels, Copernicus, Earth Observation, European Space Agency (ESA), Landsat-8, Cosmo-Skymed, Pleiades.

Today we are assisting to an increasing amount of heterogeneous and distributed Earth Observation data. These data allow to investigate better our Earth from different perspectives and to monitor and observe its environment and security. In this challenging context, the European Union's Earth Observation Programme Copernicus [1], plays an important role looking at our planet promoting free and open access policy to data, creating new services and benefits for all users (e.g. data scientists, researchers, service providers and decision policy makers). This work describes the Data Hub System, an open source software developed by a European consortium (lead by Serco-Gael companies) to guarantee ESA Copernicus data access. The OS DHuS is used to disseminate all Sentinels data products via two different access mechanisms: Graphical user interface (GUI) and Application Program interface API. [2].The DHuS, being open source is online in GitHub public repositories [3]. This paper will show in particular how OS DHuS modularity allows to create plug-in components dedicated to the management of heterogeneous set of data (e.g. EO data, maps, etc.). We'll illustrate the developed modules, called add-ons, to handle also non-sentinel missions. Landsat-8, Cosmo-Skymed, and Pleaides add-ons represent some of these examples available in our public GitHub repositories [4]. This approach demonstrates how the OS DHuS can be considered an agnostic Earth Observation and geospatial information data access and dissemination tool. The software can be easily extended and enriched with new modules, to manage dispersed datasets from heterogeneous fields like in situ data

(i.e. ground stations, airborne sensors and sea-borne sensors). [1] http://www.copernicus.eu/

[2] https://scihub.copernicus.eu/dhus/ [3] http://sentineldatahub.github.io/DataHubSystem/

[4] https://github.com/SentinelDataHub?tab=repositories

PSW.4-0014-18 NGSAT - A FRAMEWORK FOR SPACE EXPERIMENT DATA WAREHOUSE

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This work introduces the NgSat framework developed at SINP MSU in 2016. NgSat provides tools, libraries, and routines that significantly ease the process of developing automatic systems for space experiment data downloading, processing, storage, and distribution. NgSat automates the whole satellite data processing cycle which consists of the following steps: connecting to satellite data sources, downloading new data, extracting scientific data from the downloaded data, inserting processed data into a database, and moving data to a storage. The approach proposed in NgSat was evaluated through real-world scenarios and addressed the challenges related to space experiment data warehouse. NgSat can potentially be adapted to a wide range of data warehousing scenarios in other fields of physics.

PSW.4-0015-18 INTEGRATED SYSTEM TO HANDLE AND VISUALIZE AURORAL OVAL DATA

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Space Weather is an integrated science, encompassing the full cause and effect chain of physical processes from Sun to Earth surface. Data handling and access tools available now usually concentrate on some specific data type,like solar images or time-sequences of spacecraft plasma data. Our prime interest is Earth auroral region, described with a very wide variety of heterogeneous data, including auroral spacecraft and ground imaging, magnetic and electric current vector maps, radars, etc. Currently a tool able to integrate, visualize and process the whole variety of available data is absent. We are developing such a system for auroral data storage, access, visualization and analysis. It is based on a Geo-information Web-based System, used in IKI for remote sensing data, and currently handling more than 2 PB data online, including data computations. This system driver is now updated to include geomagnetic coordinate transformations, real-time solar wind data, geomagnetic indices, etc. Currently the system includes DMSP UV data, auroral oval models, and is rapidly filled with other sources. The bonus of using standard remote sensing GIS is availability of real-time weather data for any location. Having in mind huge data volumes typical to remote sensing data, this auroral system is capable to handle almost unlimited amounts of any existing auroral data. The Web-site will be shown at poster.

PSW.5-0001-18 ACTIVITIES AT THE NATIONAL SCIENCE FOUNDATION IN SUPPORT OF SPACE WEATHER RESEARCH

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NSF's primary role in developing space weather readiness for the nation is in the support of basic research that advances fundamental understanding of space weather and related processes. This includes the generation of solar storms, their propagation through the interplanetary medium, and their impact on the near-Earth space environment. NSF-supported community members draw upon that research in the development of models for these space weather processes. These models often utilize observations from NSF's persistent ground-based observational platforms, among others, to test and further refine our community's understanding of space weather. Among the goals of these NSF-funded research activities are to benefit society and contribute to the achievement of specific desired societal outcomes, such as improving space weather predictive capabilities.

PSW.5-0002-18 ESA SSA SPACE WEATHER ACTIVITIES AND COSPAR-ILWS ROADMAP

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One of the objectives of the ESA Space Situational Awareness (SSA) Programme is to develop a European Space Weather (SWE) System that can provide operational space weather services to support protection of European space and ground based assets against adverse effects from space weather. Service provision in the system is based on a federated network of Expert Groups (EGs) within ESA Member States grouped into five thematic Expert Service Centres (ESCs). EGs are responsible for the processing of the space weather measurement data into products. These products are combined into services to the end users by the SSA SWE Coordination Centre (SSCC).

The Programme is currently in its third phase focussing on strategic objectives that have been defined together with stakeholders and the ESA member states. Current ESA SSA space weather activities are focussing on verification and validation of the available precursor services and targeted developments of new service capabilities. These development activities are addressing for example developments of physics based space weather models and enhanced services targeting critical user domains including satellite operations, ground based power system operations and aviation.

ESA SSA Programme's main objective is to develop operational space weather service capability. This means that many of the activities within the programme are related to Researchto-Operations (R2O) developments based on European scientific expertise. COSPAR-ILWS Roadmap provides a reference that supports the dialogue between the Programme and the scientific community about research that is needed for new building blocks for operational space weather services. ESA SSA Programme is continuously collecting feedback from the end users to improve the understanding of the user needs and to enhance the already available space weather services. COSPAR-ILWS Roadmap offers a global framework for this Operations-toResearch (O2R) discussion. ESA is also actively participating coordination of space weather activities in many international forums including UN COPUOUS, WMO, CGMS, ISES and

COSPAR PSW.

This presentation will address the status and prospects of the Space Weather System in ESA's SSA Programme, the international collaboration framework and how ESA SSA Programme is approaching international space weather coordination within Europe and at global level.

PSW.5-0003-18 SUPPORTING SPACE WEATHER OPERATIONS-TO-RESEARCH ACTIVITIES

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The COSPAR/ILWS Space Weather Roadmap recommends actions to advance international preparedness to space weather. This involves identifying the highest priority research areas to address space weather service needs. In the United States, the National Space Weather Action Plan addresses the need to improve the understanding of, forecasting of, and preparedness for space weather events. In response to the need to advance and coordinate space weather research and operations capabilities, NASA, NOAA, and NSF are supporting research to promote space weather operations-to-research (O2R) activities. O2R activities can broadly be defined as the joint pursuit of improvements of operational capabilities and advancements in related fundamental research. The focus of an initial pilot research opportunity is the improvement of forecasts of the background solar wind, solar wind structures, and coronal mass ejections. This presentation will describe the multi-agency effort to promote operations-to-research and research-to-operation activities and discuss future goals, including the possibility of internationally coordinated efforts.

PSW.5-0004-18 ISAS/JAXA HELIOPHYSICS PROGRAM

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There has been multiple Heliophysics missions by ISAS/JAXA that served the world-wide scientific community by providing it with high-quality data. The good examples for large missions are Geotail (launch in 1992, still operative) and Hinode (launch in 2006, still operative). Two small missions launched by the Epsilon rocket, Hisaki in 2013 and ERG/Arase in 2016, are good examples showing that small missions of this class can be useful to Heliophysics research. That is, there are multiple platforms that ISAS can offer to the world-wide community to deepen the space weather research. What mechanism is missing in order to make a necessary international collaboration utilizing an ISAS platform to happen? I would like to disclose the dialogue I have been having with the community members and discuss what should be the next step in this line.

PSW.5-0005-18 CHINA ACTIONS TO THE SPACE WEATHER ROADMAP

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In response to the COPSAR/ILWS Roadmap recommendations, China has recently approved several projects aiming at enhance the abilities of understanding and monitoring space weather. The major projects are: ASO-S (Advanced Space-borne Solar Observatory), MIT (Magnetosphere - IonosphereThermosphere Coupling Exploration), and the ESA-China joint space weather science mission SMILE (Solar wind - Magnetosphere - Ionosphere Link Explore), a new mission to image the magnetosphere. Compared to satellites, ground-based monitors are cheap, convenient, and provide continuous real-time data. The new projects on the ground are: Chinese Meridian Project II (CMP-II), a ground-based program fully utilizing the geographic location of the Chinese landmass to monitor the geo-space environment, the International Meridian Circle Program (IMCP) for space weather hopes to connect chains of ground-based monitors at the longitudinal meridians 120 deg E and 60 deg W. In these short presentation, all the above will be mentioned briefly.

PSW.5-0006-18 SPACE WEATHER IN THE UK

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The UK Government's inclusion of severe space weather on the National Risk Register (NRR) of Civil Emergencies in recent years has led to a somewhat co-ordinated, yet wide-ranging set of activities that is attempting to tackle space weather threats at the national level, but incorporating active engagement on the international scene. Two immediate responses to the Government's decision in managing the space weather risk are: (a) the setting up of a UK space weather forecasting centre at the Met Office, in Exeter (UK) - which is only one of two civil forecasting centres world-wide that are manned 24 hours a day, 7 days a week; and (b) the formation of the Space Environment Impacts Expert Group (SEIEG), chaired by Prof. Mike Hapgood from STFC RAL Space, that advises the UK Cabinet Office and the Government Department of Business, Energy and Industrial Strategy. These activities have come about from active partnerships between agencies, industrial groups, and the science community to ensure that the wide range of issues involved are fully covered. In parallel, the UK Space Agency (UKSA), in responding to these activities and engaging with key institutes such as the STFC Rutherford Appleton Laboratory (RAL) and the Met Office, has become a major supporter of the emerging ESA Space Situational Awareness (SSA) space weather programme, which ultimately ensured that the UK has taken leadership roles in the instrument development activities for the planned Lagrange L5 space weather mission as well as in service activities such as the Heliospheric Expert Service Centre. All of these activities, and more, have come about because of extensive dialogue between the academic community, the industrial community, the relevant agencies, and Government in the UK, as well as with international groups such as ESA and NOAA. The strategic approach in the UK has been particularly successful and continues to evolve. Of particular interest in the coming years is the development of the role of the UN COPUOS and COSPAR, with which the UK will be fully engaged.

PSW.5-0007-18 UNOOSA VIEW ON COSPAR/ILWS ROADMAP AND GLOBAL COORDINATION FOR SPACE WEATHER

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Space weather monitoring, prediction and research have become essential pillars of the global response to advance space weather science, thereby advancing the development of improved operational space weather services and improving resilience against adverse space weather effects and impacts.

There are many instruments to be included in coordination efforts. Among the most important is providing decisionand policy-makers with relevant information by awareness-raising about hazards and risks related to space weather. When risks are identified, the steps to mitigate them could be taken more effectively. Improving resiliency to address them is a process in which coordination and communication of best possible designs and engineering could lead to improved mitigation or complete avoidance of adverse effects. When infrastructure is better protected, data can be gathered more reliably and through increased coordination, open-data sharing and real-time data accessibility the stakeholders can avoid duplication of efforts and help each other in forecasting hazardous events.

There is a need to monitor progress in field of space weather, a task that could be delivered by already established relevant stakeholders, including UNOOSA, COSPAR, ICAO, WMO, ISES, IAU, or SCOSTEP to name a few.

PSW.5-0008-18 WMO'S INITIATIVE FOR PROMOTING SPACE WEATHER IN OPERATION

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The space weather observations include the following domains: the Sun, interplanetary space, near-Earth space, magnetosphere, ionosphere, thermosphere, geomagnetic field. The required space weather data are obtained by a numerous types of instruments, both in space and on Earth. These platforms are operated by different organizations, in many cases not associated with meteorological services.

In May 2015, the World Meteorological Congress (Cg-17) agreed that WMO should undertake international coordination of operational space weather monitoring and forecasting with a view to support the protection of life, property and critical infrastructures and the impacted economic activities in an optimized overall effort. In June 2016, the Executive Council (EC-68) approved the Four-year Plan for WMO activities related to Space Weather in 2016-2019, and requested to establish Interprogramme Team on Space Weather Information, System and Services (IPT-SWeISS) who will pursue the work and achievement of the former expert team on Space Weather, the Interprogramme Coordination Team on Space Weather (ICTSW) with 23 WMO Member Countries and 6 UN and Intergovernmental Organizations as of 10 January 2018.

Ad hoc Task Team on Aviation (TT-AVI) was established in IPT-SWeISS to assist WMO in the conducting of site assessments and audits of prospective space weather information at the request of the International Civil Aviation Organization (ICAO). Consistent with the working arrangements between the two Organizations, ICAO has officially requested WMO to undertake such site assessments and audits between October 2017 and February 2018 in view of ICAO's intention to introduce an operational space weather information service for international air navigation by November 2018.

In this talk, the present status of WMO's initiative for promoting space weather will be presented with its difficulties and problems.

PSW.5-0009-18 SCOSTEP EFFORTS IN THE GLOBAL COORDINATION FOR SPACE WEATHER SCIENCE

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The scientific committee on solar terrestrial physics (SCOSTEP) is an interdisciplinary body of the International Council for Science (ICSU) collaborating with five scientific unions unions (IAMAS, IAU, IUGG/IAGA, IUPAP, URSI) and three interdisciplinary bodies (COSPAR, SCAR, and WDS). SCOSTEP is actively involved in the science, capacity building, and public outreach activities related to solar terrestrial physics. By design, space weather is a significant part of solar terrestrial physics dealing with the short-term variability of the Sun and how it affects Earth's space environment. The space weather activities of SCOSTEP are conducted via the scientific programs such as the current VarSITI (variability of the Sun and Its Terrestrial Impact). Of particular interest for space weather is the ISEST (International Study of Earthaffecting Solar Transients) project directly deals with the two sources of space weather at Earth, viz., coronal mass ejections and high speed solar wind and their consequences (geomagnetic storms and solar energetic particle events). As part of this project, daily alerts are issued whenever a space-weather causing feature such as a filament or a coronal hole appears near the disk center of the Sun. SCOSTEP also collaborates with COSPAR, URSI, and the International Space Weather Initiative (ISWI) to run Space Science Schools for PhD students and young postdocs. These capacity building activities enhances space weather literacy among researchers in developing countries. SCOSTEP also runs a visiting scholar program that provides shortterm (1-3 months) training in solar terrestrial relationship in advanced laboratories for students from developing counties.

PSW.5-0010-18 GLOBALLY COORDINATED SPACE WEATHER EDUCATION AND OUTREACH INITIATIVE: UNOOSA SCHOOLS AND OUTLOOK ON COORDINATED EDUCATIONAL AND OUTREACH OPPORTUNITIES

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The Office for Outer Space Affairs, in its central role of fostering capacity-building in the use of space science and technology and their applications for the benefit of all countries, in particular developing countries, has organized several hundred training courses, workshops, seminars and meetings for the benefit of Member States, including in the area of space weather.

The International Space Weather Initiative (ISWI), which grew out of the International Heliophysical Year 2007 (IHY), is an international cooperation programme to advance space weather science by combining the deployment of instruments with the analysis and interpretation of space weather data obtained from those instruments in conjunction with space data, and to advance education and capacity-building in space weather science and communicate the results to the public.

IHY and ISWI have contributed to the development of space science schools that encourage students to consider a career in space science. In that context, the Office for Outer Space Affairs is organizing discussion forums to educate the public and policy-makers about space weather phenomena, as well as training courses and seminars for students and professionals in space weather data analysis and prediction. Those activities bring together a large number of experts every year, including experts from developing nations.

PSW.5-0011-18 COMMUNITY COORDINATED MODELING CENTER: BRINGING SPACE WEATHER AWARENESS TO THE NEXT GENERATION

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Maria Kuznetsova, Sarabjit Bakshi, Justin Boblitt, Darren De Zeeuw, Peter Macneice, Leila Mays, Michelle Mendoza, Richard Mullinix, Kiran Patel, Asher Pembroke, Lutz Rastaetter, Ja Soon Shim, Aleksandre Taktakishvili, Tina Tsui, Yari Collado-Vega, Chiu Wiegand, Yihua Zheng

Community Coordinated Modeling Center (CCMC) is a multi-agency partnership aimed at enabling, supporting and performing research and development for next-generation space science and space weather models. Additionally, over the past decade we have become an international hub for raising generations of young space scientists and engineers by providing multifaceted opportunities for hands-on learning, supporting graduate education and research, and spreading space weather awareness worldwide. CCMC hosts an expanding collection of models developed by the international Heliophysics community and has built web-based tools, including interfaces for model execution and analysis of simulation results, an online space weather awareness system (iSWA), a database of space weather phenomena and multiple space weather learning and analysis tools.

These unique assets and services stand ready to support graduate summer schools worldwide, including ones in remote locations. CCMC's portable computer systems have enabled student interactive learning during schools as far as India and Siberia. Our hands-on exercises and tailored simulation modules are a staple of Heliophysics summer schools. We are always happy to develop new materials on your request!

Our more recent educational effort is focused on the firstand second year college undergraduates (including students from two year colleges) and could possibly become a component of the new millennium core education. The CCMC has developed a hands-on space weather forecaster training package, Space Weather Bootcamp, aimed at igniting young people's enthusiasm for space physics by involving them in an active, real life project. The training provides space environment awareness, an understanding of the fundamentals of the Sun-Earth system and of the impacts of space weather on humans and technological systems. Our undergraduate experimental research forecasters get an exciting opportunity to work with the CCMC team engaged in prototyping the latest state-of-the-art space weather forecasting capabilities and to actively contribute to the NASA missions through real time analysis and forecasting. The Bootcamps are also open to graduate students, mission operators, interested researchers and educators.

Our experience shows that to build space weather capacity we can start promoting space weather awareness to students in their very first year in college, in a way that helps recruit and retain young people in science. We can reach wider audiences by building more interactive tools for space weather learning (including citizen science applications) and by organizing training for teachers and college educators. At the moment, the CCMC is the sole hub for this kind of space weather awareness training. With international help, multiple forecaster training hubs can be established at different locations over the world, with students from different countries in different time zones collaborating on round-the-clock, real time space weather forecasting.

PSW.5-0012-18 SPACE WEATHER WITHIN THE FRAMEWORK OF COSPAR'S PANEL ON CAPACITY BUILDING

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Through its Panel on Capacity Building, COSPAR organises a series of capacity building workshops with various partners. The workshops aim to convey practical knowledge in areas addressed by COSPAR's Commissions and Panels and build lasting bridges between scientists. The typical workshop aims to provide practical training based on currently operating missions and extensive online data archives. In 2016 and 2017 3 and 4 workshops were organised respectively, covering a range of areas including Space Weather.

The first COSPAR Capacity Building Workshop focusing on Space Weather took place in 2016 in Kamchatka, Russia led by IKIR RAS and the second will take place later in 2018 in Sao Jose dos Campos, Brazil led by INPE's Embrace Programme. Space Weather is by definition a highly cross-disciplinary topic and the COSPAR framework provides an excellent opportunity to develop a training format which combines scientific excellence with operational awareness and practices. Current experience will be presented along with possible future directions.

PSW.5-0013-18 INPUTS AND OUTLOOK ON ROADMAP AND I-SWAT FROM PSW.1,4 EVENTS:

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Updates from PSW.1: Metrics and validation needs for space weather models and services (Alexi Glover) - Updates from PSW.4: Coordinated Information dissemination and interoperability (Daniel Heynderickx)

PSW.5-0014-18 INPUTS AND OUTLOOK ON ROADMAP AND I-SWAT FROM PSW.2-3 EVENTS:

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Updates from PSW.3 Towards standardized ionospheric activity scales (N. Jakowski) - Updates from PSW.2: Space weather in solar system and beyond (M. Grande)

PSW.5-0015-18 INPUTS TO AMBIENT SOLAR WIND MODELING: PLANS FOR INTERNATIONAL SPACE WEATHER ACTION TEAMS

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As part of the COSPAR Space Weather Roadmap study (Schrijver et al. 2015), several observational, computational, and theoretical needs were identified, which in turn require improvements to our understanding in specific areas. One such area is the ambient corona and solar wind, which form the backdrop for eruptive events like coronal mass ejections. A key input is the solar magnetic field, which structures the corona and solar wind; a related input is coronal heating, which is strongly correlated with the magnetic field and is also important for solar irradiance. The roadmap also identifies the challenge of transforming the cohort of spaceweather researchers into an effectively functioning global research community. In this talk, I will briefly outline how the concept of International Space Weather Action Teams (ISWAT) may be brought to bear in improving space-weather related capabilities for understanding and modeling the ambient corona and solar wind.

PSW.5-0016-18 IDEAS AND PLANS FOR ISWAT CLUSTERS FOCUSED ON PROPAGATION OF TRANSIENTS THROUGH EVOLVING AMBIENT HELIOSPHERE AND INPUT TO GEOSPACE

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Space Weather is an important issue of global matter, but needs coordinated efforts. Many international groups perform research on the propagation of transients and based on that develop Space Weather forecasting services. In order to avoid duplication and to efficiently improve the performance of currently available models, they need to become better visible and to undergo scientific peer-review qualification. iSWAT is an international, community driven effort and provides the required platform to challenge propagation models and to exchange experience with peers. iSWAT is also a network that fosters collaboration among interdisciplinary group members, like from geospace, that are potential users of propagation models. Coordinated international cooperation will offer new perspectives and will make models more efficient and progress them efficiently towards operational tools. Operational tools are not only meant to be used by (industrial) end-users, but particularly by peers in order to get a more complete understanding of the physical processes underlying CME propagation.

PSW.5-0017-18 IDEAS AND PLANS FOR ISWAT CLUSTERS FOCUSED ON SOLAR ENERGETIC PARTICLES THROUGHOUT THE HELIOSPHERE

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Different from photons or energetic neutral atoms, charged solar energetic particles are tied to the local magnetic field which governs their transport throughout the heliosphere. In the last decade, measurements of energetic particles accelerated at the Sun have shown us that these particles can be observed to regions of the heliosphere which are not believed to be magnetically connected to the acceleration site. These humbling observations underline the need for coordinated efforts in the following areas: 1) determination of the global solar and heliospheric magnetic field, 2) measurements of the turbulent properties of the inner heliosphere,

3) multi-point measurements of energetic particles throughout the heliosphere, 4) modeling of particle acceleration and transport through this background. These efforts are not as difficult as they may seem. We stand at the eve of a "Golden Age" for in-situ investigations of the inner heliosphere with a concurrent international fleet of spacecraft distributed in many regions of space. Ensuring free exchange of scientific and other data from these missions will allow us to understand particle acceleration and transport and to use solar energetic particles as a tool to probe the magnetic structure of the inner heliosphere.

PSW.5-0018-18 IDEAS AND PLANS FOR THE DEVELOPMENT OF I-SWAT CLUSTERS FOR NEAR-EARTH RADIATION AND PLASMA ENVIRONMENT AND IMPACTS ON (AERO)SPACE ASSETS

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The COSPAR-ILWS Roadmap (2015-25) "Understanding space weather to shield society" identified three impact pathways, including "Pathway II: Dynamic radiation belt modeling". To address Pathway II, and "to understand the particle environments of (aero)space assets leading to improved environmental specification and near-real-time conditions", the Roadmap recommends that community should "Combine spaceand ground-based observations of solar wind, particle populations within the magnetosphere, and ground-based magnetometer and ionospheric networks into radiation-belt models." Towards this goal, this talk will provide an initial overview of elements of the activities of International Space Weather Action Teams (I-SWAT) and clusters relating to the near-Earth space radiation and plasma environment, focussing on applications for understanding their impacts on (aero)space assets. Such I-SWAT activities include modelling efforts to advance our understanding of the fundamental processes responsible for space radiation dynamics, and improving our understanding of the linkages and between the highly coupled elements of the solar wind-magnetosphere-plasmasphere-ionosphere system. Such activities are essential to address one of the highest priority COSPAR-ILWS research areas to improve space weather information and forecasting to: "Understand the radiation belts through dynamic observation-based modeling".

PSW.5-0019-18 ATMOSPHERIC VARIABILITY AND SATELLITE DRAG

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The global COSPAR-ILWS roadmap for 2015-2025 mentions satellite drag, but user needs, research (ongoing and opportunities), and recommendations are not discussed in the paper. The first task of the "Neutral Density and Orbit Determination at LEO" cluster is therefore consolidating a list of user needs for satellite drag forecasting capability in order to evaluate which items require improvement. This concerns not only the obvious candidate, the thermosphere model, but also the solar and geomagnetic drivers (often proxies) and the quality of their forecast, as well as the satellite model (shape, mass, material, etc).

To track progress of a thermosphere model appropriate metrics are required, as well as highquality and high-resolution data over many years. The 2017 International Forum on Space Weather Capabilities Assessment produced both metrics and test data, and models are currently being evaluated with help from CCMC. Pure model performance, i.e. using observed solar and geomagnetic input, is not constant but a function of time scale (solar cycle to minutes), solar and geomagnetic activity levels, and location. When forecasting density, thermosphere model errors increase due to the error in the forecast of the drivers. Forecast horizons vary from a few days to months, to years, to complete solar cycles in mission design. It is essential that solar and geomagnetic activity forecast models and thermosphere models are improved in concert, and this is foreseen in the present I-SWAT cluster design. Scoreboards for thermosphere models, solar and geomagnetic activity forecast models will be created.

The third component, satellite model, is the most problematic one. Standard models, such as CIRA for the atmosphere, do not exist. Our ultimate goal is satellite drag forecasting; improvement can be quantified too by means of precise orbit determination, i.e. scorecards can be produced. However, computation of satellite shape and aerodynamic coefficients must be harmonized first, either through applying identical models, or for example through scaling.

PSW.5-0020-18 IDEAS AND PLANS FOR ISWAT CLUSTERS FOCUSED ON IONOSPHERE VARIABILITY AND IMPACT ON COMMUNICATIONS AND NAVIGATION

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The ionospheric variability is the result of major processes that occur within the coupled atmosphere-ionosphere-magnetosphere system. Short-wavelength solar radiation, magnetospheric energetic particles, and magnetospheric convection are the key drivers that trigger enhancement of the ionospheric conductance at high latitudes and modify the electrical currents that flow between the ionosphere and magnetosphere. These injections of energy drive a global thermospheric circulation, exciting a spectrum of waves that redistribute energy both locally and globally. Planetary waves, tides, and gravity waves from the lower atmosphere propagate upwards, deposit momentum into the mean circulation, and generate electric fields via the dynamo mechanism in the lower ionosphere. Neutral winds and electric fields from these combined sources redistribute plasma over local, regional, and global scales and sometimes create conditions for instability and production of smaller-scale structures in neutral and plasma components of the system. The resulting large scale ionospheric effects, travelling ionospheric disturbances, scintillations and bubbles constitute a threat for operational systems using predictable ionospheric characteristics, such as GNSS, SBAS, HF communications, geolocation systems and for scientific observations such as the radio astronomy. Because of the strong local time and latitudinal character of the perturbations, the development of a global monitoring and prediction system for all scales of ionospheric disturbances is extremely challenging. This requires, at first, continuous improvements in the models' prediction capability to match users' requirements. Another major challenge is the users' awareness. This must be primarily addressed through the setup of a Research-to-Operations (R2O) validation framework which is the main mission of the CCMC at NASA and it is also attempted in the framework of the ESA SSA SWE programme for the European assets. Another important activity, which is implemented for the needs of the EC H2020 TechTIDE project, is the specification of the impacts with one-to-one correspondence between the type of ionospheric phenomena and the imposed perturbations in each affected system. This is attempted through the establishment of an open dialogue with the users that can lead to a database of effects, and through joint actions between scientists and users for the developments of mitigation technologies. The talk reviews ongoing efforts worldwide and provide recommendations for teaming and collaboration activities.

PSW.5-0021-18 ADDRESSING LONG-TERM SOLAR VARIABILITY AND CLIMATE CONSEQUENCES THROUGH THE ISWAT INITIATIVE

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.Abstract: In this talk, I will briefly summarize the current state of understanding of the solar magnetic cycle and its long-term variability. In the context of the international space weather roadmap, I will highlight outstanding issues in translating our understanding to forecasting of long-term solar activity and its space weather and climate consequences. We will discuss coordinated action plans under the umbrella of the International Space Weather Action Teams to address these challenges.

PSW.5-0022-18 TOWARDS A GLOBAL SPACE WEATHER COMMUNITY HUB AND A NETWORK OF INTERNATIONAL SPACE WEATHER ACTION TEAMS (ISWAT) AIMING TO ADVANCE SPACE WEATHER CAPABILITIES AND TO FACILITATE GLOBAL SPACE WEATHER ROADMAP UPDATES

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Panel discussion: Outlook on Roadmap and Sun-to-Impact I-SWAT Clusters

PSW.5-0023-18 LOFAR NETWORK, NEW TOOL FOR SPACE WEATHER PROGRAM IN THE FRAME OF H2020 ACTION LOFAR4SW

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The LOFAR for Space Weather (LOFAR4SW) is an international project the aim of which is to deliver the full conceptual and technical design for creating a new leading-edge European research facility for space weather science. The project will engage with stakeholders to prepare a facility which produces unique research data with key impact on advance predictions of space weather events affecting crucial technological infrastructures of today's society.

The objective of LOFAR4SW is to prepare for a large scale high-end research facility in which completely simultaneous, independent observing modes and signal paths provide continuous access to two research communities: radio astronomy and space weather research.

Space weather science aims, through observation, monitoring, analysis and modelling, at understanding and ultimately predicting the complex state of the solar wind - magnetosphere - ionosphere - thermosphere system, and the potential impact on biological and technological systems on Earth. Increased fundamental knowledge, coupled to large-scale monitoring programs, is needed for much more advanced predictions of the impact of space weather events on Earth.

A fully-implemented LOFAR4SW system will enable a wide range of solar and space weather research topics to be tackled and have unique strengths in several high-impact science areas: tracing the initial launch of a CME; detailed tracking of the solar wind and CMEs through interplanetary space; in-depth studies of micro-structure in the Earth's ionosphere. This facility will uniquely provide the missing link of measurements of the interplanetary magnetic field on global scales - a key parameter in forecasting the severity of geomagnetic storm on Earth. The LOFAR4SW will allow scientists to to answer many important questions with regard to the solar corona, the heliosphere, and Earth's ionosphere.

The action was started on December 2017 and the aim of this presentation is to show the main goals of the project and the initiated activities

PSW.5-0024-18 THE CONTRIBUTION OF THE IONOSPHERE PREDICTION SERVICE PROJECT IN SUPPORTING THE MITIGATION OF THE IONOSPHERIC EFFECTS ON GNSS

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The Ionosphere Prediction Service (IPS) is an on-going project funded by the EC (project 434/PP/GRO/RCH/15/8381; 2016-2018). IPS is led by TELESPAZIO (IT) in collaboration with the Istituto Nazionale di Geofisica e Vulcanolgia (INGV-IT), the University of Nottingham (UNOTT-UK), the University of Tor Vergata (UTOV-IT), the Nottingham Scientific Ltd (NSL,- UK) and TELESPAZIO VEGA (DE). The scope of this project is to design and develop a service prototype capable of providing different products to GNSS users and service providers that can assist with early warnings and predictions on the state of the ionosphere. Such products are fine-tuned to match the needs of the different communities (aviation, mass market, critical infrastructures monitoring etc.) to which the service is targeted. The core scientific contribution of the project is represented by the research activities carried out by the project's research collaborators (i.e., INGV, UNOTT and UTOV) with the aim to go beyond the state of the art in understanding the impact of significant ionospheric-related geophysical events on today's technology-based society. The outputs of the research activities are nowcasting and forecasting tools, dealing with different topics that can be divided into three blocks: "Solar and Space-Weather Monitoring" (UTOV), "Ionosphere weather monitoring and forecasting" (INGV) and "Receiver and user positioning performance" (UNOTT). TELESPAZIO is in charge of integrating all the products into a Central Processing and Storage Facility (CPSF) as a chain of processors. These are capable of describing the Space-Weather phenomena from the sun Sun to the ionosphere affecting the GNSS service provider and user community. This paper presents the nowcasting and forecasting algorithms developed in the frame of the research activities, their validation as well as the web portal in which the user can setup customized alerts and warnings.

PSW.5-0025-18 SPACE WEATHER SERVICE IN MEXICO. GROUND BASE INSTRUMENTAL NETWORK, WARNING SYSTEM AND SCIENTIFIC STUDIES.

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The Mexican Space Weather Service (www.sciesmex.unam.mx) was created in 2014 in response of changes in the Civil Protection Law in Mexico. These modifications included space hazards and space weather events as national risks. The SCiESMEX comprises several products including a warning system, and weekly and special reports. SCiESMEX became a Regional Warning System of the International Space Environment Services (ISES) in June 2015. The SCiESMEX instrumental network includes real time data from a radio telescope to perform interplanetary scintillation (IPS) observations of solar wind conditions, two CALLISTO systems, cosmic rays observatory, a total magnetometer, and maps of the total electron content (TEC) using data from local networks of GPS receivers. This year we are deploying a network of five ionosondes, and a network of five magnetometers. The data from these instrumental networks will allow us to perform studies in Mexico to evaluate the regional responses to different space weather events. The SCiESMEX is also collaborating with National Civil Protection authorities to develop protocols to react to intense or extreme space weather events. These efforts in Mexico are also in agreement with COSPAR and United Nations recommendations to impulse international collaboration in space weather studies.

PSW.5-0026-18 GLOBALLY COORDINATED SPACE WEATHER EDUCATION AND OUTREACH INITIATIVE

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Description: This panel discussion will bring together diverse organizations involved in space weather education and outreach activities, provide brief summaries of ongoing activities and discuss a new initiative of the COSPAR Space Weather Panel towards global coordination in space weather awareness, education and outreach.

Plan: I plan to kick this off with a brief introduction highlighting the importance of global coordination in developing a framework for space weather education and outreach and COSPAR's Space Weather Panel's role in enabling this. Subsequently, speakers would be asked to present the activities of their organizations (5 minutes each, with slides if necessary).

PSW.5-0027-18 NATIONAL/REGIONAL AGENCIES VIEW ON COSPAR/ILWS ROADMAP AND GLOBAL COORDINATION FOR SPACE WEATHER.

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Questions to be addressed by the panelists: - How roadmap guidelines are correlated with national/regional/international programs, action plans and policies? - Are there any focused space weather programs and upcoming missions run by the agencies that will aid in understanding the origin of space weather, its assessment and forecasting? - What are major challenges in global coordination on space weather? How we should address those challenges? - What should be the role of COSPAR PSW in global coordination efforts and how the Roadmap should be updated to enable/facilitate this role?

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SPECIAL (S)

CSES PRELIMINARY RESULTS ON IONOSPHERIC VARIABILITY AND ITS CONNECTION WITH SEISMIC ACTIVITY AND SOLAR FORCING (S.1)

S.1-0001-18 THE 1ST CHINA SEISMO-ELECTROMAGNETIC SATELLITE MISSION

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The 1st China Seismo-Electromgnetic Satellite (CSES) launched at Feb.2, 2018 after 15 year's research and developing and currently it sounds good status onboard. CSES mission was proposed to be the first satellite of space-based geophysical fields observation system in China with a lot of application prospect in earthquake science, geophysics, space sciences and so on. And coincide with the mission objective, the satellite decides to use the Circular Sun Synchronous Orbit with altitude about 500km and descending node time at 14:00LT. The payload assemble includes 8 instruments, Search-Coil Magnetometer, Electric Field Detector, High precision Magnetometer, GNSS occupation Receiver, Plasma Analyzer, Langmuir Probe, Energetic Particle Detector, and Three-frequency Transmitter, in which, we have an effective cooperation with Italian Space Agency on Energetic Particle Detector and Austrian Institute of Space on High precision Magnetometer. At this moment, the satellite and the launching vehicle shipped to and have passed different test in the launching site. Before their shipment, CSES have done a series of test and calibration both in China and Italy, most of the test results accord with the designing requirement and is due to very useful for the coming scientific application. According to the schedule, CSES will have its life time of 5years with the first six months for commission test and then deliver to CEA for regular operation. The CSES data will open for global scientists with few class of authorization. And at this moment, we may expect that CSES primary result will be issued during the conference.

S.1-0002-18 GEOMAGNETIC EXPLORATION IN CHINA SEISMO-ELECTROMAGNETIC SATELLITE (CSES) MISSION

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With the exploration of the near Earth magnetic field, the internal structure of Earth, the Earth geomagnetic distribution and spatial environment can be studied. CSES will be the first Chinese satellite of this kind in a near Earth orbit. Its scientific goal is the real-time monitoring of electromagnetic changes by studying the Earth system, especially the ionosphere and other spheres' mutual actions. The magnetic field is one of the most important physical parameters for monitoring the ionosphere. And the High Precision Magnetometer (HPM) will be responsible for the accurate measurement of magnetic field vector components from DC to 15Hz in orbit. Considered the magnetic environment of the spacecraft and the vector value accuracy requirement for magnetic field detection. The HPM consists of two fluxgate sensors and a CDSM scalar sensor. The fluxgate sensors will provide the vector components of the magnetic field but with limited accuracy and long-term stability. The CDSM sensor measures the scalar of the magnetic field with high accuracy and stability and will be therefore used to calibrate the vector data. With the help of two fluxgate sensors, the satellite remanence magnetic interference can be reduced. Several ground data processing methods used to get the real accuracy vector magnetic field data have been considered, include the physical calibration of the single sensor, the absolutely vector correction algorithm, the remanence magnetic interference elimination and coordination conversion method. And several ground calibration tests have been operated to get the real excellent performances of each sensor. The CSES will be launched in early 2018, after several month's in orbit operation, it will be a good opportunities to show the geomagnetic data get by CSES-HPM to all attendants during the COSPAR.

S.1-0003-18 THE HIGH ENERGY PARTICLE DETECTOR (HEPD) ON-BOARD CSES

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CSES (China Seismo-Electromagnetic Satellite) is a scientific program developed in the framework of a collaboration between the China National Space Administration (CNSA) and the Italian Space Agency (ASI). The CSES satellite mission is developed by China Earthquake Administration (CEA), together with several Chinese institutes, in collaboration with Italian universities and research institutes lead by the National Institute for Nuclear Physics (INFN). CSES is the first satellite of a space monitoring system proposed in order to investigate the topside ionosphere and designed in order to gather world-wide data of the near-Earth electromagnetic environment.

The main objectives of the mission are to investigate the near-Earth electromagnetic, plasma and particle environment and for studying the seismo-associated disturbances in the ionospheremagnetosphere transition zone, the anthropogenic electromagnetic noise as well as the natural non-seismic electromagnetic emissions, mainly due to tropospheric activity. In particular, the mission aims at confirming the existence of possible temporal correlations between the occurrence of earthquakes for medium and strong magnitude and the observation in space of electromagnetic perturbations, plasma variations and precipitation of bursts of high-energy charged particles from the inner Van Allen belt.

In this framework, the High Energy Particle Detector (HEPD) of the CSES mission has been developed by the Italian Limadou Collaboration. HEPD comprises a double-sided microstrip silicon tracker, a layer of plastic scintillators for trigger and a calorimeter, made of a tower of plastic scintillators and a matrix of inorganic crystals, surrounded by plastic scintillator veto planes. The detector is capable to provide good energy and angular resolution and a wide angular acceptance, for electrons of 3 - 100 MeV, protons of 30 - 200 MeV and light nuclei up to the oxygen.

The CSES satellite, launched on February 2nd 2018 from the Jiuquan Satellite Launch Center (China), was placed in a sun-synchronous orbit at an altitude around 500 km.

S.1-0004-18 HIGH-ENERGY PARTICLE DETECTOR ONBOARD CSES: THE DESCRIPTION AND FIRST RESULTS

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This paper gives a description and the first results of the high-energy particle detector(HEPP) placed onboard the CSES satellite. This detector include three independent detectors namely HEPP-H, HEPP-L and HEPP-X. The HEPP-H and HEPP-L are aimed to measure energetic particle fluxes in the energy range from 100keV to about 50MeV for electron and 2Mev to about 200MeV for proton in order to provide information on the energetic particles which can interaction with the low frequency waves. The energy resolution, better than 10keV, and the 256 energy channels allow to obtain insights on the radiation belt structure. The HEPP-X can provides information of the Solar X ray in the energy range from 1keV to about 35keV which can bu used to evaluate the effects of solar activity to the Earth. The satellite was launched on Feb 2 of 2018. The data received during orbit test show for the first time that the detector work well and the detector data can be used to study the variation of the energetic particles during the magnetic storm and substorm and also the relationship between the earthquake and the energetic particles at the lower ionosphere.

S.1-0005-18 IDEAS AND SOLUTIONS FOR A NEXT GENERATION HIGH ENERGY PARTICLE DETECTOR FOR THE CSES MISSION

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The High Energy Particle Detector is one of the instruments on board the China Seismic Electromagnetic Satellite, designed, constructed and operated by the Italian Limadou collaboration. The HEPD is sensitive to 10-100 MeV electrons, as well as 30-300 MeV/n nuclei, to be detected in the latitude range 65°. Observing MeV electron precipitations to study seismic phenomena is newer and less consolidated than traditional approaches, focused on measuring electric and magnetic field variability, as well as plasma features in the ionosphere. The Limadou collaboration took advantage of the experience gained from currently-flying CSES mission to improve the design of a new 1-100 MeV particle detector, lowering the energy threshold, distinguishing electrons and nuclei already at trigger level and tracking particle trajectories online. Ideas for an upgraded HEPD are discussed and details are given about technical solutions envisaged to put them into effect.

S.1-0006-18 A HIGH-PERFORMANCE ELECTRIC FIELD DETECTOR FOR SPACE-BORNE MEASUREMENTS

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In the framework of the CSES-Limadou collaboration a prototype of a new Electric Field Detector (EFD) for space applications has been developed. The instrument has been conceived for space-borne measurements to investigate electromagnetic phenomena in the ionosphere in order to improve the knowledge of lithosphere-ionosphere coupling. The proposed instrument can measure electric field as a potential difference between probes pairs. The instrument measures electric field in a wide band of frequencies extending from quasi-DC up to about 4 MHz. The resolution in the ULF band is better than 1 µV /m with a dynamic range of 120 dB. With this bandwidth and precision, the described electric field detector represents a very performing and updated device for electric field measurements in space. The detector consists of four spherical probes to be installed on four booms deployed from the 3-axes stabilized satellite. Ranges of expected probe potentials have been obtained by studying the various currents collected by the sensors along a simulated orbit. Plasma data of Demeter mission measurements have been analyzed to evaluate the proper bias current to be injected. Cross-calibration with Langmuir probe data of CSES will be performed for better comprehension of the EFD measurements.

S.1-0007-18 PRELIMINARY RESULTS OF EFD ON CSES

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On February 2, Chinese first geophysical satellite, China Seismo-Electromagnetic Satellite, was launched successfully. Following the DEMETER, this satellite is a new satellite with the main aim to look for the earthquake-related ionosphere precursor. On CSES, there are 8 payloads, including Electric Field Detector (EFD), High Precise Magnetometer (HPM), Search Coil Magnetometer (SCM), Plasma Analyzer Package (PAP), Langmuir Probe (LAP), High Energetic Particle Package (HEP), GNSS Occultation Receiver (GOR) and Tri-Band Beacon (TBB). The EFD payloads, including the Probe, pole and electrician, will detect the electricity with the frequency DC-3.5MHz, which is divided into 4 bands, ULF (DC-16Hz), ELF (6Hz2KHz), VLF (1.8kHz-20Khz) and HF (18Khz-3.5MHz). For ULF and ELF, the waveform series are produced. For VLF, it is produced in waveform with burst mode and in spectrum with survey mode. For HF, it is produced in spectrum. Here some results are shown to see variation around the magnetic storm, earthquakes and Hiss.

S.1-0008-18 ACTUAL AND VIRTUAL CONSTELLATIONS FOR PROBING THE IONOSPHERE AND MIT COUPLING - THE CASE OF SWARM

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The European Space Agency's three-satellite Swarm constellation was launched in November 2013 to carry out absolutely calibrated multipoint observations using a multiple payload philosophy. Its suite of instruments include dual magnetometers, a thermal ion imager, Langmuir probes, accelerometers and state-of-the-art GNSS receivers, all of which contribute to measurements of both the electromagnetic and neutral environment. Four years later the mission has become a catalyser for the interaction between the geophysical and space science communities, for one. But even more importantly, the constellation has proven to provide conclusive, high temporal and spatial resolution information on energy transport, current and turbulence in the MIT system, worldwide and in all sorts of geomagnetic conditions.

This paper describes the role of the Swarm mission in the context of geospace research, specifically targeting the MIT system, and including plans for the future. Moreover, in 2015 a strategic collaboration initiative between the European Space Agency and the Chinese National Space Administration regarding the joint exploitation of the CSES and Swarm missions, supported by the successful launch of CSES-01 on 2 February 2018, now offers the possibility to address common research objectives in a virtual constellation approach. This pertains to the MIT system, but also to calibration and validation of the payload suites as well as our common research objectives in terms of ionospheric earthquake precursor detection.

S.1-0009-18 GEOMAGNETIC FIELD DATA IN SUPPORT OF THE ELECTRIC FIELD DETECTORS ANALYSIS ON CSES.

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The measurement of ionospheric static electric fields on board CSES will require exact knowledge of various contributions due to ambient and instrumental effects. An order of magnitude evaluation of several such effects has been performed, including vxB, in order to model corrections to sensor readings which may significantly improve the identification of geophysical parameters. It is shown that very precise measurements of flight and ambient parameters and detailed modeling of the configuration of probes and satellite, will be necessary for the appropriate inference of external geophysical electric field and its dynamics. Data from the DEMETER mission are used to simulate the environment around CSES.

S.1-0010-18 IONOSPHERIC ELECTRIC FIELD MEASUREMENTS ON CSES FOR VARIOUS PLASMA CONDITIONS.

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The precise measurement of ambient DC electric fields in the ionosphere with the technique of double probes requires the removal of several effects from the floating potentials measured by the sensors, in relation with the ambient plasma parameters, the geometrical configuration of the probes and boom system and the flight parameters. In addition, the plasma parameters will have to include measurements from the plasma motion instrument. Detailed analysis of the influence of such external parameters on the final measurement of the DC ambient electric field is provided, and requirements on the precision of intercalibration from other CSES instruments are assessed. Data from the DEMETER and Swarm missions are used to simulate the environment around CSES.

S.1-0011-18 MINIATURIZED FUV IONOSPHERIC PHOTOMETER

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As a space-based optical remote sensing method, Miniaturized FUV Ionospheric PhotoMeter with small size, low power consumption, high sensitivity is an important means to detect physical parameters of the ionosphere. Using the Miniaturized FUV Ionospheric PhotoMeter to detect the ionospheric 135.6nm night airglow can obtain the ionospheric TEC, F layer peak electronic density(NmF2), which can be used to study ionospheric space environment change information, the impact of the ionosphere on the radio communications, etc.; The ionospheric 135.6nm day airglow and the LBH radiation radiance can be used to obtain the ionospheric O / N2 ratio information, which can be used to study the space weather events and monitor the electromagnetic environment changes in the Earth's space. The FY3-D Ionospheric PhotoMeter(IPM), launched on November 15, 2017, has a detection sensitivity which is greater than 150 counts / s / Rayleigh and a spatial field of view of 1.6×3.6 ° with high horizontal spatial resolution that helps to achieve more accurate ionospheric exploration.This report will introduce several features of the FY3-D IPM. Key Word:FUV,ionosphere,photometer,135.6nm airglow,LBH radiation radiance

S.1-0012-18 LOOKING FOR SEISMO-INDUCED PERTURBATIONS OF THE INNER VAN ALLEN BELTS WITH THE LIMADOU-HEPD PARTICLE DETECTOR OF THE CSES MISSION

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CSES mission will investigate the structure and the dynamics of the topside ionosphere, the coupling mechanisms between upper atmosphere, ionosphere and magnetosphere and the temporal variations of the geomagnetic field, in quiet and disturbed conditions. Data collected by the mission will also allow to studying solar-terrestrial interactions and phenomena of solar physics, namely coronal mass ejections, solar flares and cosmic ray solar modulation. Anyway, the main objective of the mission is to study the existence of possible (temporal and spatial) correlations between the occurrence of earthquakes (EQs) and the observation of iono-magnetospheric perturbations with a particular focus on the precipitation of particle bursts (PBs) from the inner Van Allen belts. The claimed PBs-EQs correlations ask for a confirmation based on a careful rejection of the large background of the natural non-seismic geomagnetic perturbations due to solar activity, tropospheric e.m. emissions and artificial emitters. We present: i) the details of the High-Energy Particle Detector (HEPD) of the CSES mission, conceived for optimizing detection of energetic charged particles precipitating from the inner Van Allen belts and built by the italian LIMADOU Collaboration; ii) the general method for investigating such a PBs-EQs correlations that has been developed by analyzing data from the SAMPEX mission and that will be extended to study HEPD data.

S.1-0013-18 THE DEFINITION OF INSTRUMENTAL AND ENVIRONMENTAL BACKGROUNDS IN THE ELECTROMAGNETIC EMISSIONS ABOVE SEISMIC REGIONS.

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To define a background for the electromagnetic emissions above seismic regions, it is necessary to consider the statistical distribution of wave energy in absence of seismic activity. N˘emec et al. [2008], built a map of electromagnetic emissions containing the statistical description of the intensity of electromagnetic waves obtained from the entire DEMETER satellite data set. Then, they estimated the frequency of occurrence of a signal during a seismic event with a different intensity then the background level defined by the map. In this work, we applied a completely new method to determine both the environmental and instrumental background. Our technique is based on a new data analysis tool called ALIF (Adaptive Local Iterative Filtering, [Cicone et al. 2016 and 2017; Piersanti et al. 2017]); through a time-frequency analysis, this method can identify and quantify the variations across different scales for nonstationary signals due to the complexity and non–linearity of the system that generated them. To evaluate the instrumental noise, we applied the SMT method (Standardized Mean Test) proposed by Alberti and Piersanti (2016) and we performed a multiscale statistical analysis (MSA). The MSA calculated the variance σ, the skewness S, the kurtosis excess Kex = K 3,

the relative energy rel and the Shannon Information Entropy I for each ALIF mode (IMF). To evaluate the environmental noise, a background map of 1° 1° latitude/longitude cells, showing the averaged Erel (Er¯el), has been constructed; the geomagnetic activity, the presence of seismic activity and the local time sector were used as a parameters. Any signal exceeding by a certain threshold both the instrumental and environmental backgrounds will be considered as a case event to be investigated. Here we show the results obtained for the entire DEMETER satellite data set (2004 - 2011) for both the electric and magnetic field instruments. The same analysis is ongoing with the recently collected CSES data.

S.1-0014-18 LITHOSPHERE-ATMOSPHEREIONOSPHERE COUPLING STATISTICAL VALIDATION BY MEANS OF 3.5 YEARS OF SWARM SATELLITE ELECTROMAGNETIC DATA ANALYSIS

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SAFE ("Swarm for Earthquake study") project (funded by ESA in the framework of "STSE Swarm+Innovation") deals with the integrated analysis of more physical parameters whose abnormal variations have been found to be possibly associated with impending earthquakes. These observations are mainly: electromagnetic variations, total electron content and the electron density in the ionosphere, measured both from Swarm satellites and ground-based observatories. We show here the results of a systematic analysis of around 3.5 years of magnetic and electron density satellite anomalies in the whole space-time interval of interest, avoiding high magnetic latitudes (1 Jan 2014-31 Aug. 2017, |geomagnetic latitude|50o) which are correlated with earthquakes by means of a superimposed epoch approach. Both data analyses show that the anomaly concentrations are superior with respect to random anomaly distributions by more than 2.5, supporting the hypothesis for a lithosphere-atmosphere-ionosphere coupling in the preparation phase of earthquakes. The recent launched CSES satellite mission with dedicated scientific payload for pre-earthquake anomaly detection will let us available more electromagnetic data for applying the same techniques for searching precursors of future earthquakes.

This work is partly funded by the European Space Agency under "SAFE" Project and by the Italian Space Agency under "Limadou-Science" Project.

S.1-0015-18 CHANGES IN IONOSPHERE DUE LARGE EARTHQUAKES AFFECT: A PERSPECTIVE

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Abstract: In the present study a detailed study has been done and observes, it is somehow that great and major earthquakes affect the ionospheric current. And from the some research it is found that the anomalies occurred near the epicentres take place before two or one days which will be help in short term prediction. This study highlight the use of Ionospheric changes in the atmosphere will help to predict the earthquake and how big data analysis present a better scenario in study the relation between the earthquake and ionosphere changes. Foreshocks also generate the anomalies in the region of epicentre as foreshocks are indicator of major shocks, so anomalies due to fore shocks can be used in the prediction of earthquake to save the casualties. In the present work from all the study it is concluded that using the ionospheric changes give a advancement in prediction of the earthquake. For example the study of Nepal earthquake also reveals that there is changes in the ionospheric current before the main shock and foreshock. Using the observations of Global positioning system (GPS) and movement of the crustal plate and global ionosphere map (GIM) given by the centre for orbit determination (CODE) in Europe, it is found that major earthquake occurred in Nepal of magnitude 7.9 (Mw) has been affected the ionospheric changes including its before and after shocks. There are more researcher suggest that gravity wave at ionosphere causes anomaly Hayakawa (1999).

S.1-0016-18 EARTHQUAKESPREDICTION TO PRECURSOR

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Earthquake is one of the deadliest occurrences on earth that is destroying the entire human societies. There were many studies that took place from predictions until the precursor, but still scientists do not have a precise scientific theory about earthquakes. Through this research, efforts have been made to explain the changes in the environment before the earthquake and what's the principle behind that changes. Present study also provides possible explanation about how to get the earthquakes waves in the atmosphere and affect the ionosphere layers.

S.1-0017-18 AN INTERACTIVE STUDY OF LITHOSPHERIC - IONOSPHERIC - MAGNETOSPHERIC COUPLING THROUGH POES SATELLITE ENERGETIC PARTICLE BURST DURING AND PRIOR TO NEPAL EARTHQUAKE

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Ionospheric Magnetospheric transition region and the time correlation of particle rate fluctuation and earthquake is a subject of interest for various authors for last few decades. Van Allen Radiation Belt is a zone of energetic charged particle originated from solar wind that is captured by earth's magnetic field line. Van Allen radiation belt is consisted of two part outer belt and inner belt. Outer Van Allen radiation belts variation depends on solar cycle variation, semi-annual variation and solar rotational variation. Inner Van Allen radiation belts variation depends on solar cycle only. There are several low earth orbital satellite to observe count rate of energetic particle in Van Allen Radiation Belt. In our study we use Medium Energy Proton and Electron Detector (MEPED) instrument data which is on-board in NOAA 15 satellite to study particle flux and burst correlated with earthquake. MEPED consisted of 6 proton channel collecting data for 30-80 keV, 80-240 keV, 240-800 keV, 800-2500 keV, 2500-6900 keV, >6900 keV respectively and 3 electron channel collecting data for >30 keV, >100 keV,

>300 keV respectively. These 6 proton channels and 3 electron channels also collect data in 0 degree and 90 degree direction simultaneously. MEPED on-board NOAA 15 satellites collects particle count rate on its orbital path and then it can be interpolated over global circumstance. We present the electron count rate data collected by MEPED on its path and the interpolated result of the data showing particle burst associated with Nepal earthquake on May 12, 2015. As the upcoming Chinese Seismic-Electromagnetic Satellite (CSES) deals with the similar study of deposition of energetic charge particle in the radiation belt due to seismic activities, it will be an unique opportunity to corroborate our previous findings during Nepal earthquake with newly coming outputs for other future earthquake. This comparison will also provide sufficient scope to understand the physical process behind LAIC mechanism.

S.1-0018-18 ELECTROMAGNETIC FIELD OBSERVATIONS BY THE DEMETER SATELLITE IN CONNECTION WITH THE 2009 L'AQUILA EARTHQUAKE.

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On April 6, 2009, at 01:33 UT, a 6.2 Mw earthquake stroke the city of L'Aquila (=42,21;

=13,23). An intense preseismic activity (3<M<5) had been observed for several months. The DEMETER satellite was operational and flew within 1 hour in local time (LT) over L'Aquila twice a day (10 LT and 22 LT). Electromagnetic field data from DEMETER, experiments ICE and IMSC, have been analyzed during periods in which waveform data collection was available to retrieve possible signals, connected with the earthquake and possible precursor activity. The data analysis was performed based on a new technique (ALIF, Cicone et al. 2016 and Piersanti et al. 2017). The statistical background was evaluated over four months (January - April) in 2009 and 2010 when geomagnetic activity was very low (0<Kp2; Sq). On April 4, 2009, when DEMETER flew exactly over L'Aquila at UT=20:29, an intense signal was observed at 333 Hz, whose characteristics seem to be related to a rotation of the electromagnetic field, giving rise to a different ionospheric plasma circulation.

S.1-0019-18 MAGNETIC FIELD FLUCTUATIONS FEATURES IN THE IONOSPHERE

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Ionosphere-Magnetosphere system is recognized as a complex and active element of space weather and as a region where important science questions can be answered. In this framework, a high priority has the understanding how local, regional, and global-scale phenomena couple to produce observed responses across scales. Turbulence provides one pathway by which energy moves across scale sizes from large to small where energy can be dissipated in the form of heating. Swarm mission, which is a true multi-point and multi-purpose constellation, represents a unique opportunity for address some of these science questions. In detail, it gives us a chance of investigating the nature and the scaling features of magnetic field fluctuations for different geomagnetic activity levels and of unveiling the role played by turbulence on ionospheric plasma medium. In particular, using the magnetic field data recorded on board of Swarm, the local scaling indices of the 1st and 2nd order structure functions of the external field fluctuations are evaluated, showing its capability both to give new insights about the ionosphere-magnetosphere coupling and to provide information of the ionospheric turbulence. The results presented are an example of the capability of the Swarm data to generate new insights on the ionospheremagnetosphere coupling and, at the same time, to develop new applications where the changes in scaling features can be used as a local indicator of the magnetosphere conditions. This information can also give new key clues for the development of more actual physical models and could be relevant also for similar studies with data from CSES mission.

S.1-0021-18 FEATURES OF MAGNETIC FIELD AND PLASMA PARAMETER FLUCTUATIONS IN THE MID-LOW LATITUDE IONOSPHERE

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The dynamics of the Earth's ionosphere is strongly influenced by the changes of the current systems flowing in the Earth's magnetosphere. Although this is particularly true in the case of high latitude and polar regions, the increase of the equatorial ring current systems causes some dynamical changes in the status of the ionospheric plasma and field conditions. Here, using data collected by the ESA-Swarm constellation, we investigate the features of the magnetic field and plasma parameter (electron density and temperature) fluctuations in the ionosphere at middle and low latitudes, as well. In particular, we investigate the spectral/ scaling features of these fluctuations and their changes with the geomagnetic activity, as monitored by AE and Sym-H indices. A close view of the features of these fluctuations along the CSES trajectory is also presented.

This work is partly funded by the Italian Space Agency under grant ASI-INFN "Limadou Scienza".

S.1-0022-18 ESTIMATION OF GEOMAGNETIC CUTOFF RIGIDITIES FOR EARTH-ORBITING SPACECRAFT

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Geomagnetic cutoff rigidities are a quantitative measure of the shielding provided by the Earth's magnetic field. Their estimation allows to predict the energetic charged particle transmission through the magnetosphere to a specific location as a function of direction. The tracing-particle method has been applied to determine the particle trajectories and asymptotic directions by assuming the Tsyganenko 1989 model for the geomagnetic field. Different states of the magnetosphere corresponding to different levels of geomagnetic activity have been considered. Finally, grids of cutoff rigidities distributed over the Earth have been computed at the altitudes of the CSES orbit in order to characterize the penetration through the geomagnetic field of both galactic cosmic rays and large solar energetic particle events.

This work is partly funded by the Italian Space Agency under grant ASI-INFN "Limadou Scienza".

S.1-0023-18 IONOSPHERIC AND GEOMAGNETIC BACKGROUND CHARACTERIZATION FROM GROUND-BASED AND SPACE-BORNE MEASUREMENTS: PRELIMINARY RESULTS FROM LIMADOU-SCIENCE PROJECT ACTIVITIES

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Definition of an ionospheric and geomagnetic background is essential to catch anomalies possibly related to lithosphere-atmosphere-ionosphere coupling (LAIC) but a universally accepted method to define "quiet" ionosphere and magnetic field is not established at present time. Ground-based (ionosonde and GNSS) instruments provide large datasets that can be used to define a background ionosphere and magnetic field under different conditions. On other hands, space-borne measurements by Langmuir probe and vector magnetometer installed on board of CHAMP and Swarm satellites need models to define a reference background. In this paper, a first attempt to highlight anomalies in ionospheric electron density and magnetic field components under different solar conditions is presented to support future study that will be performed by using measurements from CSES mission. Results suggest that IGRF-12 describes very well the magnetic field in the considered period (2014-2017) while IRI-2016 overestimates electron density at the altitude of the CHAMP satellite (about 350 km) during the solar minimum (2007-2009). Some possible alternative solutions are proposed in order to mitigate the latter problem.

S.1-0024-18 DISCRIMINATION BETWEEN INTERNAL AND EXTERNAL ORIGIN CONTRIBUTIONS FROM LEO SATELLITE MAGNETIC FIELD DATA.

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The evaluation of the external origin contribution (BEXT and EEXT) in geomagnetic field satellite observations in the near Earth location (1.2 RE<R<1.5 RE; RE being the Earth radius) during active magnetic conditions is one of the key problem in the Space Weather context. We propose an innovative algorithm able to discriminate the external from the internal origin (BINT) contributions in immediate post-processing of the one time series under exam. Differently from the currently implemented procedure, which relies on models based on statistics of several months of data, the proposed algorithm will generate directly from Level 1 magnetic data time series a Level 2 product made up of BINT and BEXT. The algorithm is based on the Adaptive Local Iterative Filtering (ALIF) technique [Cicone et al., 2016; Piersanti et al., 2017]. ALIF is able to decompose non-stationary time series into several intrinsic mode functions (IMFs) which are functions oscillating around zero, but not necessarily with constant frequencies and amplitudes. Then, by applying the statistical test described in Alberti and Piersanti [2016] and by a multiscale statistical analysis, the algorithm discriminates between the different intrinsic "macro-scales" of LEO satellite observations. Consequently, the algorithm is able to separate BINT from BEXT with high efficiency. We applied this algorithm to SWARM, DEMETER and CSES magnetic field data. We compared the evaluated BINT with both IGRF and CHAOS-6 model obtaining comparable results, leading the possibility to validate the IGRF model coefficients and increase the accuracy of CHAOS-like models. Concerning BEXT, our results lead to the identification

of different magnetospheric current systems across which each satellite orbits (such as the Ring Current, the Tail current and the Magnetopause current). Finally, the correct identification of the magnetospheric field in LEO satellite is of crucial role for the identification of the ionospheric origin field contribution.

S.1-0025-18 NATURAL ORTHOGONAL COMPOSITION ANALYSIS OF IONOSPHERIC DENSITY AND TEMPERATURE MAPS AT THE ORBIT OF SWARM

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The Earth's ionosphere is a very dynamical system whose dynamics is controlled by both the Earth's atmosphere and magnetosphere, and the solar irradiation. In particular, the geomagnetic activity which is driven by the changes of the magnetic field and plasma conditions in the interplanetary medium, affects the condition of the ionospheric plasma in terms of composition and dynamics. In this presentation, we investigate the changes of the ionospheric electron density and temperature as a function of the geomagnetic activity level, using data collected by the ESA-Swarm mission. The analysis is done by applying the Natural Orthogonal Composition (NOC) approach, capable of identifying the different patterns in terms of Empirical Orthogonal Functions (EOF) and Principal Components (PC).

S.1-0026-18 ASSESSING THE IONOSPHERIC ELECTRIC FIELD: COMPARISON BETWEEN CSES EARLY DATA AND SWARM MEASUREMENTS.

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The deep knowledge about the electric fields ruling the ionospheric electrodynamics is of crucial importance to understand both the ionospheric physics and the lithosphere-atmosphereionosphere coupling (LAIC). In particular, the occurrence of electromagnetic anomalies possibly related to the preparatory phases of large earthquakes requires disentangling it from those due to the forcing from the geospace, like those driven from solar events, or other phenomena of anthropogenic origin. The China Seismo-Electromagnetic Satellite (CSES), recently launched on 2 February 2018, has been designed to provide high quality data to characterize the electromagnetic environment in the ionospheric plasma. In the specific, it offers the possibility to measure the variation of electric field at the CSES altitudes (500 km), by means of an Electric Field Detector (EFD). To provide the first validation of such measurements in flight mode, we compare the early EFD data with the electric field estimation provided by the data and products of Swarm ESA constellation. Waiting for the coincidence between the local times of CSES and Swarm orbits, we exploit the 4.5 years of measurements by Swarm to obtain a climatological assessment of the ionospheric electric field to be compared to the CSES EFD measurements.

S.1-0027-18 IN FLIGHT PERFORMANCE OF THE ELECTRONICS OF THE HIGH ENERGY PARTICLE DETECTOR ONBOARD CSES

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In this paper we will present a description of the electronics of the High Energy Particle Detector (HEPD) onboard the China Seismo Electromagnetic Satellite (CSES) and its in flight performance. CSES is a scientific mission dedicated to monitoring electromagnetic, plasma and particles perturbations of atmosphere and inner Van Allen belts caused by solar and terrestrial phenomena and to the study of the low energy component of the cosmic rays (5 - 100 MeV for electrons and 15 - 300 MeV for protons). The satellite, launched on February 2nd, 2018 from the Jiuquan Satellite Launch Center (Mongolia), hosts several instruments onboard. The HEPD, built by the Italian "Limadou" collaboration, is able to separate electrons and protons and identify nuclei up to Iron. The HEPD comprises the following subsystems: detector, electronics, power supply and mechanics. The electronics can be divided into three blocks: silicon detector, scintillator detectors (trigger, energy and veto detectors) and global control and data managing. The trigger system allows switching between several configurations. Each trigger configuration corresponds to different field of view of the apparatus. It is possible to change the trigger configuration along the orbit to cope with different fluxes encountered.

S.1-0028-18 OVERVIEW OF THE CSES (CHINA SEISMO-ELECTROMAGNETIC SATELLITE) MISSION

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The CSES Collaboration

CSES (China Seismo-Electromagnetic Satellite) is a mission in collaboration between CNSA (Chinese National Space Administration) and ASI (Italian Space Agency). Realized by CEA (China Earthquake Administration) together with several Chinese Institutions and INFN (Italian National Institute of Nuclear Physics) in cooperation with IFAC-CNR, INAF (Italian National Institute of Astrophysics), INGV (National Institute of Geophysics and Volcanology) and other Italian institutions, it is in orbit since February 2nd 2018. The main objectives are the investigation of the near-Earth electromagnetic, plasma and particle environment and the study of the seismo-associated disturbances in the ionosphere-magnetosphere transition zone, the anthropogenic electromagnetic noise as well as the natural non-seismic electromagnetic emissions, mainly due to tropospheric activity. In particular, the mission aims at confirming the existence of possible temporal correlations between the occurrence of earthquakes of medium and strong magnitude and the observation in space of electromagnetic perturbations, plasma variations and precipitation of bursts of high-energy charged particles from the inner Van Allen belt. On board of the CSES satellite, orbiting Sun-synchronous at about 500 km of altitude with an inclination of 97.4°, there are installed two Particle Detectors, a Search Coil Magnetometer, a High-Precision Magnetometer, an Electric Field Detector, a Plasma Analyzer, two Langmuir probes, a GNSS Occultation Receiver and a Tri-Band Beacon. The multi-instrument payload allows, by measuring simultaneously several different parameters, a more reliable identification of the signature of the studied phenomena. The in-flight performance of the scientific payload and some preliminary results will be presented at the conference.

SPECIAL (S)

PLANETARY DATA MANAGEMENT AND EXPLOITATION (S.2)

S.2-0001-18 THE INTERNATIONAL PLANETARY DATA ALLIANCE: PROGRESS AND VISION FOR THE NEXT DECADE

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In the mid-1980s, as NASA planetary exploration expanded, it became apparent that a national archive that could handle digitized data was needed. NASA launched the Planetary Data System (PDS) in 1989 after considerable planning and development. Because most of the early planetary data originated from NASA missions, the international scientific community became familiar with PDS standards. Thus, when the European Space Agency (ESA) began producing planetary science data they adopted components of the PDS standards and developed the Planetary Science Archive (PSA). This occurred under version 3 (PDS3) of the PDS Standards. The PDS and PSA worked closely together to develop standards and share data. As additional agencies began developing unique missions of interest to the international community, two needs were identified: increased cooperation and collaboration to facilitate access to the individual archives, and modernization and implementation of standards.

A group of individuals involved in mission archiving within the international planetary community met in 2006 to develop a mechanism for enhancing international access and collaboration [1]. The goal of this meeting was to develop an approach that would: 1) Give scientific communities world-wide access to data archives built upon similar standards; 2) Reduce cost of archiving and distributing science data by collaborating and sharing standards; 3) Ensure reusability of science data across agency/mission/instrument boundaries; 4) Coordinate archiving processes and plans; and 5) Improve and increase access to tools and services offered.

As a result of these interactions, the International Planetary Data Alliance (IPDA) was founded. Over the past decade, the IPDA has

grown significantly, with shared projects focused on achieving the goals. Over twelve agencies have joined the IPDA and participate in the Steering Committee. These agencies have supported a major upgrade of the Planetary Data System standards called “PDS4”. NASA and ESA are now operationally using PDS4 and all future planetary missions are adopting or planning to adopt it for archiving their data. Over the next decade, this will lay a foundation by which improved and increased access, tools, and services can be realized at a global scale.

This talk will provide an overview of the IPDA and discuss opportunities to increase use, access, and interoperability as an international data science platform for planetary science research.

[1] “Developing a Core Set of Data Standards for the IPDA”, Concept White Paper, January 2007.

S.2-0002-18 DATA MANAGEMENT PLANS AND PLANNING FOR SCIENTISTS IN THE EARTH AND SPACE SCIENCES

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In recent years, Earth and space science funding agencies worldwide have come to understand that publication of funded scientific results is only part of their mandate, they must also preserve and provide access to the data from which those results were derived. As a result, many new data systems and data archives have been created. Scientists are now frequently required to archive the data that they acquire, and to describe their archive plans in a data management plan (DMP) as part of the proposal process. Here we present the elements of a good data management plan, regardless of the funding agency. These elements include: beginning the planning process early, selecting the right archive, understanding the standards and practices of that archive, developing a realistic work plan (and budget), and allowing schedule margin for inevitable slippage. A key to creating a quality DMP is to start planning early and leave plenty of time to write the DMP. Even scientists who are experts in the archiving process may find that the archive they have delivered data to in the past has modernized or otherwise updated their standards or practices. Often it is not obvious where data should be archived, or even if an appropriate data system exists. Once the target archive or data system has been determined, it is important to learn that system’s standards and practices, including acceptable data formats, metadata requirements, nomenclature, and any additional required documentation. A clear understanding of the system requirements is required in order to develop a credible work plan and budget for the funding agency. The work plan should include a list of tasks, due dates, and should identify who will perform each task. Data must be documented clearly and completely. The documentation task should be assigned to a scientist who fully understands the data, its acquisition, and its processing and calibration. Some archives require external review of data and documentation. If required, the plan should include time for both the review and the response to the reviewer’s comments. Even if an external review is not required, having a Co-Investigator or colleague review the data set makes sense.

Data preparers are often so close to the data that they forget to document some of the details of the acquisition or processing that are required for others to use the data correctly. Some archives require or encourage inclusion of software used in the data processing. Well-documented software can be included with the archive documentation and/or uploaded to a public software repository such as GitHub (or NASA GitHub for NASA planetary data). Archiving should immediately follow data processing and not deferred to the end of the performance period. Documenting and archiving the data promptly insures that details of the process will not be lost in the interim. All of these components should be covered in the DMP. Lastly, given the long list of items that need to be determined prior to writing and then discussed in the DMP the value of starting the process early cannot be over stated.

S.2-0003-18 BUILDING THE DATA MANAGEMENT PLAN OF OBSERVATOIRE DE PARIS

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During the last decade, the production of science data increased in parallel with the decreasing cost of digital storage and the increase of data processing and computation capabilities. Science institute have to find a way to manage and preserve this data inflow. Most of the calls of funding agencies now require to provide a description of how the data produced in the projet will be managed (archiving, curation, distribution.) and published. This usually takes the form of a Data Management Plan. Funding agency also required more and more to select open source licences for any production of the project, for instance by enforcing FAIR (Findable, Accessible, Interoperable, Reusable) principles.

Founded in 1667, the Observatoire de Paris is the largest French national research center for astronomy. Nearly a third of all French astronomers are working in its five laboratories and institute. Located in Paris, Meudon and Nançay, they are all associated with CNRS (National Center for Scientific Research) and with the major scientific universities in the Paris and Orléans area. The research conducted at the Paris observatory covers all the fields of contemporary astronomy and astrophysics: the study of the Sun and Sun-Earth relations, planets and planetary systems, star formation, the interstellar medium, the formation and evolution of galaxies, astroparticles and cosmology, time and space metrology as well as the history and philosophy of science. The Library of the Observatoire is a service entirely devoted to research. Its two missions are to provide scientists with the most complete and pertinent documentation, and to enrich a 350 year old heritage, while at the same time thinking about what today's heritage will be, and what the future will bring. Although mainly destined for the scientists of the Observatoire, it is nevertheless also open to others: scientists from different disciplines and all countries, students, school children, the general public, who are welcome and for whom it organizes scientific and technical outreach activities.

Observatoire de Paris has listed a few services that needed to set up a way to formally manage their data more formally: the Informatics Department of the Observatory (DIO), which is hosting scientific computing servers and data storage facilities for the sciences teams of the observatory; the Paris Astronomical Data Centre (PADC), which provides interoperable access on data collections produced within the observatory; the Library of the observatory. Several teams (linked with projects funded by EU or space agencies) showed interest as well.

Several actions have now been started by the working group: Identification of the various sources of data and data collection in each department of the Observatory; Identification of the needs in term of citation (data collections, artifacts, documents, software.) and licences; study of possible authoritative delegations (e.g., on DOI attribution, long term preservation.) and to whom; proposing a Data Management Plan template to support science teams when applying for fundings. Those actions are all aiming at building a generic Data Management Plan for the Observatory, that would propose rules and practices for preserving, distribution and sharing science products.

The PADC team is deeply involved in data-related international data alliances, such as the International Virtual Observatory Alliance (IVOA), the International Planetary Data Alliance (IPDA), and the Research Data Alliance (RDA). This is ensuring that: (a) this study is conducted with up-to-date technologies and concepts, and that (b) the results of the study will be discussed and advertised in those international contexts.

S.2-0004-18 AGILE SCIENCE DATA CURATION IN THE PLANETARY SCIENCES

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The Planetary Data System (PDS) is an information model-driven service architecture that supports the capture, management, distribution, and integration of planetary science data captured in distributed data archives world-wide. The foundational principles of the PDS4 Information Model (IM), the core element of the architecture, were adopted from the Open Archival Information System (OAIS) Reference Model (ISO 14721) and the Metadata Registry Specification (ISO/IEC 11179) and were implemented in W3C XML (Extensible Markup Language). The PDS is unique in that the PDS4 IM drives the PDS4 infrastructure by providing the concepts, relationships, and constraints as a sharable, stable, and formally organized set of information requirements. These requirements are used to generate systems files for all aspects of PDS operations including XML Schemas for metadata collection and validation, data dictionaries, standards specifications, and configuration files for tools and services. Evolutionary change in the community is efficiently managed by a hierarchical governance scheme. This presentation will provide an overview of the roles played by the IM, principles of agile data curation, and how the IM enables agile data curation for the international Planetary Science community.

S.2-0005-18 THE EMIRATES SPACE DATA CENTER

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As part of the UAE's Emirates Mars Mission (EMM), we are constructing a data archive to preserve and distribute science data from this and future missions. The archive will be publicly accessible and will provide access to Level 2 and 3 science data products from EMM, as well as ancillary data such as SPICE kernels and mission event timelines. As a member of the International Planetary Data Alliance (IPDA), the UAE has committed to making its archive PDS4-compatible, and maintaining the archive beyond the end of the mission. EMM is scheduled to begin collecting science data in spring 2021, and the archive is expected to begin releasing data in September 2021.

S.2-0006-18 INTERNATIONAL SUPPORT FOR SPACE MISSION GEOMETRY CALCULATIONS

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An important but often overlooked element of conducting engineering and science activities for a space science mission is the provision of means to compute a wide assortment of "observation geometry" calculations-items such as range or altitude; latitude and longitude of an instrument's boresight intercept with a surface; and phase, incidence and emission angles at the place of an observation. Such calculations are not generally easy to make, especially if high accuracy is required, but the algorithms and methods for doing so can be standardized and applied across all missions. With this in mind, NASA has implemented the Navigation and Ancillary Information Facility (NAIF)-a small group that has developed a multi-mission scheme named SPICE [1] for making these kinds of calculations.

First deployed during the Magellan mission to Venus in 1989, SPICE has become a widelyused method within NASA for providing engineers and scientists the geometry parameters needed for conducting portions of mission operations, for planning scientific observations, and for analyzing the science data returned from those observations. Observing its technical success and its freedom from export and licensing restrictions, and desiring consistent, reusable means for computing observation geometry, space scientists and space agencies around the globe have adopted the SPICE methodology [2].

This first-ever SPICE presentation at COSPAR outlines the kinds of calculations possible using SPICE and describes the various tools, services and data freely provided to its users.

The research described in this publication was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

[1] Spacecraft, Planet, Instrument, Camera-matrix, Events [2] https://naif.jpl.nasa.gov

S.2-0007-18 DATA COLLECTION, COLLABORATION, ANALYSIS, AND PUBLICATION USING THE OPEN DATA REPOSITORY'S (ODR) DATA PUBLISHER

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While large, homogenous scientific fields often have repositories and existing data standards (e.g. GenBank), for small communities in multidisciplinary fields (e.g. astrobiology) publishing and sharing data can be challenging. In development for nearly four years, the Open Data Repository's (ODR) Data Publisher software has been designed as a collaborative data publication tool for small groups of independent researchers who usually have few options for publishing data that can be utilized within their community.

ODR's Data Publisher aims to provide an easy-to-use software tool that will allow researchers to create and publish database templates and related data. The end product will facilitate both human-readable interfaces (embedded images, files, and charts) and machine-readable interfaces utilizing semantic standards. The web-based interface allows researchers to enter data, view data, and conduct analysis using any programming language supported by JupyterHub (https://github.com/jupyterhub/jupyterhub) or other cloud-based analytical tools (e.g. QAnalyze, https://www.qanalyze.com/about). This toolset makes it possible for a researcher to store and manipulate their data in the cloud from any internet capable device. Data can be embargoed in the system until a date selected by the researcher. For instance, open publication can be set to a date that coincides with publication of data analysis in a third-party journal.

The Data Publisher software runs on the standard LAMP (Linux, Apache, MySQL, PHP) stack to provide the widest server base available. The software is based on Symfony (www.symfony.com) which provides a robust framework for creating extensible, object-oriented software in PHP.

The software interface consists of a template designer where master database templates can be created and customized. A master database template can be shared by many researchers to provide a common metadata standard that will set a baseline for all derivative databases. Individual researchers can then customize the master template with specialized fields, file storage, or visualizations unique to their studies. This allows groups to create compatible databases for data discovery and sharing purposes while still providing the flexibility needed to meet the needs of scientists in rapidly evolving areas of research.

In conjunction with teams at NASA Ames and the University of Arizona, a number of pilot studies are being conducted to guide the software development so that it allows them to publish and share their data. These pilots include (1) the Astrobiology Habitable Environments Database (AHED), a central searchable repository designed to promote and facilitate the integration and sharing of all the data generated by the diverse disciplines in astrobiology; (2) a database containing the raw and derived data products from the CheMin instrument on the MSL rover Curiosity (http://odr.io/CheMin), featuring a versatile graphing system, instructions and analytical tools to process the data, and a capability to download data in different formats. Ongoing development will complete integration of third party meta-data standards and publishing data to the semantic web.

S.2-0008-18 VESPA, A PLANETARY SCIENCE VIRTUAL OBSERVATORY CORNER STONE

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The Europlanet H2020 program started on 1/9/2015 for 4 years. It includes an activity to adapt Virtual Observatory (VO) techniques to Planetary Science data called VESPA. The objective is to facilitate searches in big archives as well as sparse databases, to provide simple data access and on-line visualization, and to allow small data providers to make their data available in an interoperable environment with minimum effort.

The VESPA system, based on a prototype developed in a previous program [1], has been hugely improved during the first two years of Europlanet H2020: the infrastructure has been upgraded to describe data in many fields more accurately; the main user search interface (http://vespa.obspm.fr) has been redesigned to provide more flexibility; alternative ways to access Planetary Science data services from VO tools have been implemented; VO tools are being improved to handle specificities of Solar System data, e.g. measurements in reflected light, coordinate systems, etc. Current steps include the development of a connection between the VO world and GIS tools, and integration of Heliophysics, planetary plasmas, and mineral spectroscopy data to support of the analysis of observations.

Existing data services have been updated, and new ones have been designed. The global objective is already overstepped, with 34 services open and 20 more being finalized.

A procedure to install data services has been documented, and hands-on sessions are organized twice a year at EGU and EPSC; this is intended to favour the installation of services by individual research teams, e.g. to distribute derived data related to a published study. In complement, regular discussions are held with big data providers, starting with space agencies (IPDA). Common projects with ESA and NASA's PDS have been engaged, with the goal to connect PDS4 and EPN-TAP. In parallel, a Solar System Interest Group has just been started in IVOA; the goal is here to adapt existing astronomy standards to Planetary Science.

The Europlanet 2020 Research Infrastructure project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654208.

[1] Erard et al 2014, Astronomy Computing 7-8, 71-80. http://arxiv.org/abs/1407.4886

S.2-0009-18 A NEW SERVICE USING IPDA AND VIRTUAL OBSERVATORY TOOLS TO PROVIDE ABSOLUTE SOLAR SPECTRA AT GROUND

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In the framework of the Sun-Earth relations, the SOLSPEC spectrometer embarked on the International Space Station allowed to obtain solar spectra at different periods of the solar cycle and in particular at its minimum. Spectra are currently accessible via various virtual observatory services including at CDS (Centre de Donnees de Strasbourg, France)

ftp://cdsarc.u-strasbg.fr/pub/cats/VI/152 and via http://vizier.u-strasbg.fr/viz-bin/VizieR?- source=VI/152

Our colleagues ask for an adaptation in spectral resolution depending on the use, and also absolute solar spectra observed at ground for many configurations: zenith view, limb, sky, etc. Many requests have been made to us in this sense, and this service via a virtual Observatory portal seemed to us the most adapted to our situation. This tool is the result of IPDA and IVOA (International Virtual Observatory Alliance) collaboration.

Special (S)

Planetary Data Management and Exploitation (S.2)

S.2-0010-18 MASER: A TOOLBOX FOR LOW FREQUENCY RADIO ASTRONOMY

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The MASER (Measuring, Analysing and Simulating Radio Emissions) project provides a comprehensive infrastructure dedicated to low frequency radio emissions (typically < 50 to 100 MHz). The four main radio sources observed in this frequency are the Earth, the Sun, Jupiter and Saturn. They are observed either from ground (down to 10 MHz) or from space. Ground observatories are more sensitive than space observatories and capture high resolution data streams (up to a few TB per day for modern instruments). Conversely, space-borne instruments can observe below the ionospheric cut-off (10 MHz) and can be placed closer to the studied object.

Several tools have been developed in the last decade for sharing space physcis data. Data visualization tools developed by The CDPP (http://cdpp.eu, Centre de Donnees de la Physique des Plasmas, in Toulouse, France) and the University of Iowa (Autoplot, http://autoplot.org) are available to display and analyse space physics time series and spectrograms. A planetary radio emission simulation software is developed in LESIA (ExPRES: Exoplanetary and Planetary Radio Emission Simulator). The VESPA (Virtual European Solar and Planetary Access) provides a search interface that allows to discover data of interest for scientific users, and is based on IVOA standards (astronomical International Virtual Observatory Alliance). The University of Iowa also develops Das2server that allows to distribute data with adjustable temporal resolution.

MASER is making use of all these tools and standards to distribute datasets from space and ground radio instruments available from the Observatoire de Paris, the Station de Radioastronomie de Nancay and the CDPP deep archive. These datasets include Cassini/RPWS, STEREO/Waves, WIND/Waves, Ulysses/URAP, ISEE3/SBH, Voyager/PRA, Nancay Decameter Array (Routine, NewRoutine, JunoN), RadioJove archive, swedish Viking mission, Interball/POLRAD. MASER also includes a Python software library for reading raw data.

The Europlanet H2020 Research Infrastructure project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654208.

S.2-0011-18 COORDINATING PYTHON DEVELOPMENT FOR HELIOPHYSICS

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Python has become the programming language of choice of many researchers in Heliophysics. Many groups have developed analysis tools that are very useful, but up until now there has been little support for coordination between them. We have initiated a Python working group to bring together developers from all of these different projects, in order to share knowledge and lessons learned, develop standards and recommendations for best practices, and support existing Python libraries used by multiple projects. We are working with the SunPy, SpacePy, pysat, CDF, SPEDAS, and tplot projects, and anticipate reaching out to others as they are identified. In 2018 we plan to identify community needs for project support and new development, establish recommendations for coding standards and standard libraries, and build a team website to collect information and provide links to projects and documentation.

S.3-0001-18 NASA'S PLANETARY DEFENSE COORDINATION OFFICE AT NASA HQ

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NASA and its partners maintain a watch for Near-Earth Objects (NEOs), asteroids and comets that pass within Earth's vicinity, as part of an ongoing effort to discover, catalog, and characterize these bodies and to determine if any pose an impact threat. NASA's Planetary Defense Coordination Office (PDCO) is responsible for:

Ensuring the early detection of potentially hazardous objects (PHOs) - asteroids and comets whose orbits are predicted to bring them within 0.05 astronomical units of Earth's orbit; and of a size large enough to reach Earth's surface - that is, greater than perhaps 30 to 50 meters; • Tracking and characterizing PHOs and issuing warnings about potential impacts; • Providing timely and accurate communications about PHOs; and • Performing as a lead coordination node in U.S. Government planning for response to an actual impact threat.

The PDCO collaborates with other U.S. Government agencies, other national and international agencies, and astronomers around the world. The PDCO also is responsible for facilitating communications between the science community and the public should any potentially hazardous NEO be discovered. In addition, the PDCO works closely with the United Nations Office of

Outer Space Affairs and the Committee on the Peaceful Uses of Outer Space to support international collaborations on Near Earth Objects. The PDCO is NASA's representative as a leading member of the International Asteroid Warning Network (IAWN) and the Space Missions Planning Advisory Group (SMPAG), multinational endeavors endorsed by the United Nations for an international response to the NEO impact hazard, established and supported by the space-capable nations. In this paper, we provide an overview of the office's many and varied planetary defense endeavors. We will also provide opportunity for more collaborations for a global and a national communications effort.

S.3-0002-18 DART ASTEROID THREAT MITIGATION TEST

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The Double Asteroid Deflection Test (DART) will be the first space experiment to demonstrate the kinetic impactor method of asteroid impact hazard mitigation. DART is part of the AIDA international cooperation between ESA and NASA, where the NASA DART mission will impact the small moon of the binary asteroid 658034 Didymos in October, 2022 and change its orbit. This change will be measured by ground-based observatories to confirm the amount of deflection. The second component of AIDA is the ESA Hera mission which is planned to rendezvous with the Didymos binary asteroid, to measure the outcomes of the DART kinetic impactor test, particularly the size and depth of the DART impact crater, and the changes in the Didymos binary system orbital and rotational dynamics. These measurements will provide the first measurements of momentum transfer efficiency from a kinetic impact at full scale on an asteroid representative of the impact hazard, where the impact conditions of the projectile are known. The DART impact on the 160 m moon of Didymos will decrease the binary orbit period by 7 minutes, assuming momentum transfer efficiency of unity. The DART impact may induce librations of several degrees amplitude, depending on the moon's axial ratio. It will furthermore make a 7 m to 20 m diameter crater depending on target properties and other impact conditions, and it will release a volume of particulate ejecta that may be directly observable from Earth or even resolvable as a coma or an ejecta tail by ground-based telescopes.

S.3-0003-18 STATUS OF THE EUROPEAN CONTRIBUTION TO AIDA: THE HERA MISSION

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The original proposal of the Asteroid Impact Deflection Assessment (AIDA) consisted of NASA's kinetic impactor, the Double Asteroid Redirection Test (DART), and ESA's Asteroid Impact Mission (AIM), a spacecraft with a sophisticated payload that would observe the binary asteroid Didymos before, during, and after the DART impact on the asteroid moon. However, while AIM received considerable interest by some ESA member states on the Ministerial Conference in 2016, it did not reach full funding. Since then, the European component has been redesigned. The new mission, called Hera, is optimized to reach the mission goals with a simplified spacecraft and a small baseline payload. The instruments are the Asteroid Framing cameras (flight spares of the Dawn Framing Cameras), a lidar, and a cubesat carrying the ASPECT imaging spectrometer. The design leaves ample margin for additional payload contributions by interested partners. We will present the status of the ongoing studies of the Hera mission, and the plans for the investigation of Didymos in cooperation with DART.

S.3-0004-18 BINARY ASTEROID (65803) DIDYMOS: OBSERVATIONS OF AND CONSTRAINTS ON THE BINARY SYSTEM

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The binary near-Earth asteroid (65803) Didymos is a planned target for the Asteroid Impact Deflection Assessment (AIDA) mission. AIDA will be the first space experiment to demonstrate asteroid impact hazard mitigation by using a kinetic impactor to deflect an asteroid. It is an international cooperation, consisting of two mission elements: the NASA Double Asteroid Redirection Test (DART) mission and the ESA Hera rendezvous mission. The primary goals of AIDA are (i) to test our ability to perform a spacecraft impact on a potentially hazardous near-Earth asteroid and (ii) to measure and characterize the deflection caused by the impact. The AIDA target will be the secondary member (satellite) of the binary asteroid Didymos, with the deflection experiment to occur in late September or early October, 2022. The DART impact on the secondary at 7 km/s is expected to alter the binary orbit period by about 4 minutes and this period change will be measured by Earth-based observatories. The Hera spacecraft will characterize the asteroid target and monitor results of the impact in situ at Didymos. The DART mission is a full-scale kinetic impact to deflect a 150m diameter asteroid, with known impactor conditions and with target physical properties characterized by the Hera mission.

Remote (mostly Earth-based) observations of Didymos are an important part of the mission. Their two main goals are following: 1) A pre-characterization of the target binary asteroid, which is necessary for designing and planning the spacecraft mission. 2) Measurement of a change of the secondary orbital period caused by the DART impact, which provides a back-up for a case Hera does not happen or fails. In our talk, we will overview photometric observations of the Didymos system that were obtained in 2003 (discovery of the Didymos secondary), 2015 and 2017. We will present what constraints they place on parameters of the binary system, in particular the secondary's orbital period, relative semi-major axis and eccentricity, the secondary-to-primary mean diameter ratio, orientation of the secondary's orbit in space, primary's rotation period and albedo. We will also discuss how more observations planned to be taken in 2019-2022 will further improve our knowledge of the binary system, including determination of a drift of the secondary's orbit by the BYORP effect and estimation of the secondary's equatorial elongation and spin period.

S.3-0005-18 DIDYMOS BINARY SYSTEM DYNAMICS AND PHYSICAL PROPERTIES INVESTIGATIONS FOR THE DART MISSION, INCLUDING OUTCOMES OF THE DART IMPACT

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The Double Asteroid Redirection Test (DART) mission concept currently under development is designed to be the first meaningful demonstration of a kinetic impactor for planetary defense against a small body impact hazard. Its mission target, the binary Near-Earth Asteroid (NEA) system 65803 Didymos, has been the subject of studies organized through the dynamical and physical properties working group of the DART Investigation Team. These studies have been aimed at: 1) characterizing the Didymos system's pre-impact dynamics, and un-perturbed and perturbed time evolution thereof, consistent with all observation data; 2) modeling changes to the system's dynamics that may be induced by the DART spacecraft's impact with the secondary during the system's October 2022 close approach to Earth; and 3) determining how physical properties can be inferred based on current knowledge. This talk focuses on the first two items.

For the first item, we have developed and maintained a Didymos Reference Model (DRM). This includes a radar and lightcurve derived primary shape model, but only has assumed axial ratios for an elongated ellipsoidal secondary, as available data doesn't support obtaining a secondary shape model. The primary diameter is 780 m ±10%, the secondary's mean equivalent volume diameter is 163 18 m. The primary rotation period and binary orbital period are well constrained from photometric lightcurve data, at 2.2600 0.0001 hr and 11.920+0.004/-0.006 hr, respectively. From the latter, and the mean separation of 1180+40/-20 m, a system mass of (5.278 0.54) 1011 kg is obtained. However, the individual component masses (and most critically, the secondary mass) are not yet distinguished. Derived bulk density is in turn only constrained to 2104 kg m−3 30%. Binary orbit eccentricity is bounded small (<3%) and the binary orbit pole is known within several degrees, but we currently assume on average synchronous rotation of the secondary and near-alignment of both body spin poles with the orbit pole. It is notable that depending on actual primary size, mass, and density values allowed within these constraints, the primary may be at or extremely close to spin disruption, meaning having equatorial regions with net outward acceleration, requiring cohesive strength.

As for long-term time evolution of the pre-impact dynamics, we have examined external tides, solar radiation pressure, and thermal re-radiation (BYORP) effects, and inter-component tidal energy dissipation. But greater focus has been on high fidelity simulation of the dynamics over shorter time frames appropriate to the mission duration, including planned post-impact ground-based observation. We have performed Full Two Body Problem (F2BP) simulations of Didymos instantiations consistent with the DRM. Example results show the expected modes of motion given full coupling between primary and secondary body rotation and binary orbit (e.g. spin-orbit co-precession, secondary libration). These modes are all expected to be as relaxed as possible pre-impact, but the minimum forced libration amplitude has been characterized given choice of secondary shape parameters/ shape model. Following detailed output comparison of two independent code implementations of the same symplectic integrator and polyhedral formulation of mutual gravitational potential of the components, we conducted a broader F2BP simulation benchmarking exercise. This used four test systems and involved participants with various numerical integrators and various force and torque models based on various other mutual potential formulations (e.g. higher-order inertia integrals, packed cubes/spheres). We compared metrics of both computational cost, and accuracy/precision loss with respect to conserved quantities and differential geometric properties of the underlying dynamics, to inform selection of the best simulation methodologies for different contexts.

For our examination of the potential effects of the DART impact on the dynamics, we obtained terminal approach and impact conditions from the mission design team. Nominally, the 500

kg DART spacecraft would impact at 6.0 km s–1 along a direction nearly opposed to (164°

from) the secondary's binary orbit velocity vector, tilted 16° out of the binary orbit plane, and with approach solar phase angle of 60°. This is expected to reduce the binary orbit period by a few minutes, with mission requirements to achieve >73 seconds period change, measured to accuracy of <7.3 seconds (1σ). An independent estimate of the secondary mass is also desired, to obtain a measure of the kinetic impactor momentum transfer

enhancement parameter β. However, currently β is highly uncertain and there also exists targeting dispersion about the nominal (optimal) impact location on the secondary. In light of this, we have conducted sparse raster sampling of β values and impact locations, and performed F2BP simulation of the postimpact dynamics in each case. This has allowed determination of which dynamical modes are excited and by how much, with particular focus on the induced libration amplitudes. It has also bounded the probability of breaking on-average synchronous rotation of the secondary.

S.3-0006-18 SIMULATING THE DOUBLE ASTEROID REDIRECTION TEST (DART): EFFECTS OF IMPACT PARAMETERS ON MOMENTUM ENHANCEMENT FROM A KINETIC IMPACTOR

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The Double Asteroid Redirection Test (DART) is a NASA mission concept to test the kinetic impact deflection of an asteroid. DART would target the moon of the binary system Didymos ("Didymoon"), impacting at 6 km/s to change the moon's orbital period. DART represents the first direct test of the kinetic impactor theory for planetary defense. The momentum enhancement of Didymoon from the DART spacecraft is parameterized by and depends on the initial spacecraft momentum (pspacecraft) and the momentum of ejecta excavated during crater formation (pejecta): =1+(pejecta/pspacecraft), with momenta tracked in the direction of intended deflection. An important part of mission development is determining the expected outcome of the impact, including crater formation and momentum enhancement from the impact.

Impact modeling is one of the primary tools to be used to interpret the results of the kinetic impact deflection, to infer the physical properties of the target asteroid, and to advance our understanding of impact processes on asteroids. The DART team utilizes several state-of-the-art hydrocodes to simulate possible outcomes of the encounter. Target properties, including cohesion, porosity, and internal structure, may have significant effects on the momentum enhancement from a kinetic impact used to deflect an asteroid. Initial statistical analyses and modeling efforts suggest that the yield strength of the material, porosity, target cohesion and internal friction, and internal structure are the most important parameters to consider. Material porosity can come in the form of "microporosity" where there is void space among grains in the material, or "macroporosity" where the void space is along large-scale cracks or between large boulders if the asteroid is a "rubble pile". Both of these porosity types will affect the ejecta generated following impact, and thus the eventual momentum enhancement from the kinetic impact. Simulations of impacts into rubble piles show a wide range of momentum enhancements depending on the particulars of the internal structure, internal porosity, and where the impact occurs. Depending on the structure of the target (e.g., amount, size, and location of large boulders), impact outcomes can vary significantly. If the spacecraft were to impact onto a large, strong boulder, for instance, the cratering process and ejecta flow field will be significantly different than if the spacecraft were to impact into weaker granular matrix between boulders. In general, crater size and ejecta material (and thus, β) are dominated by boulder material and whether the impactor strikes matrix or boulder material first. The internal damage propagation within the target is also sensitive to the presence of boulders, which may imply that disruption behavior is different.

Further simulations are underway in order to fully explore this parameter space and map out the possible outcomes for the DART impact, and to estimate from the measured deflection of Didymoon.

Portions of this work were prepared by LLNL under Contract DE-AC52-07NA27344. LLNL-ABS746064.

S.3-0007-18 MOMENTUM ENHANCEMENT DUE TO HYPERVELOCITY IMPACTS INTO CONSOLIDATED AND POROUS ROCK

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We have been exploring the momentum enhancement that occurs when impactors strike metals, rock, and now pumice at hypervelocity [1-3]. Momentum enhancement is the effect that the crater ejecta created by the impact leads to more momentum transferred to the impacted body than solely the momentum of the projectile. It is desirable to quantifying momentum enhancement to provide needed information in the event hypervelocity impactors are considered in deflecting celestial bodies such as asteroids or comet nuclei. In momentum enhancement experiments it has been observed that the size scaling of momentum enhancement is not linear for impacts into consolidated materials. In particular, experiments clearly show for metals and suggest for consolidated rock that as the size of the impactor increases, the momentum enhancement increases more than would be expected based on impactor size. Experiments suggest, however, that this may not be the case for pumice. To understand the momentum enhancement and its potential size scaling behavior, we have performed impacts using the Southwest Research Institute range firing projectiles at speeds of 2 to 2.1 km/s. Aluminum projectiles had diameters of 2.54 and 4.45 cm, which is a relatively large scale based on most momentum enhancement studies which are performed with small caliber light gas guns. The targets impacted as simulants for asteroids were consolidated rock and pumice. We believe this scale is large enough that in working with the pumice we obtain a representative response and not an impact-location-specific response. This paper includes the previously published data as well as new data and presents new computations and discussion of momentum enhancement mechanisms to better understand the impact event. [1] "Scale Size Effect in Momentum Enhancement," by J. D. Walker, S. Chocron, D. D. Durda, D. J. Grosch, N. Movshovitz, D. C. Richardson, and E. Asphaug, Procedia Engineer-ing 58, 240-250, 2013. [2] "Damage Modeling, Scaling and Momentum Enhancement for Asteroid and Comet Nucleus Deflection," J. D. Walker and S. Chocron, Procedia Engineering 103, 636-641, 2015. [3] "Momentum Enhancement due to Hypervelocity Impacts into Pumice," J. D. Walker, S. Chocron, Donald J. Grosch, Daniel D. Durda, and K. R. Housen, Procedia Engineering 204, 130-137, 2017.

S.3-0008-18 MOMENTUM ENHANCEMENT FROM HYPERVELOCITY CRATER EJECTA OF ANHYDROUS AND HYDROUS POROUS TARGETS

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Porosities of asteroids range from 0 to >50%, with most >20%. Meteorites, which sample asteroids, have a similar range. Since porous targets react differently to hypervelocity cratering than non-porous targets, it is critical to measure the response of asteroid samples to impacts. To quantitatively determine the momentum transfer from hypervelocity impact cratering we suspended targets in front of a large rectangular grid in the vacuum chamber at the NASA Ames Vertical Gun Range. Each target was impacted by a 1/16" or 1/8" Al-sphere shot at 4 to 6 km/s. Using high-speed video images we measured the recoil speed of each target and determined the momentum multiplication factor (β), the ratio between the recoil momentum of the target and the momentum of the impactor. We impacted 5 samples of the CV3 carbonaceous chondrite Northwest Africa (NWA) 4502 with a mean porosity of 2.1%, 7 samples of the ordinary chondrite NWA 869 with a mean porosity of 6.4%, 4 samples of the ordinary chondrite Saratov with a porosity of 15.6%, a sample of terrestrial serpentine, one of the two clay minerals that dominate the composition of the hydrous CI chondrites, with a mean porosity of 18.8%, and 2 samples of terrestrial pumice with a mean porosity of 70%, to cover a wide porosity range. We found that for the anhydrous samples β decreased with increasing porosity, consistent with hydrocode modeling. However, the β values we measured are larger, with β = 3.37 for NWA 4502, 2.70 for NWA 869, 2.08 for Saratov, 4.93 for serpentine, and 2.15 for pumice, than results from hydrocode modeling for 5 km/s impacts into relatively strong, porous rock targets. The β value for the moderate porosity (18.8%) hydrous serpentine target (β = 4.93) is more than twice the β value for the anhydrous Saratov targets, which have comparable porosities. This result suggests that the hydration of the serpentine target substantially enhances the momentum transfer, likely by the jetting of water vaporized in the hypervelocity cratering event. Comets, with their high ice content, should be even more affected by vapor jetting. Even the most porous rock targets we impacted had substantial momentum enhancement from crater ejecta. For our most recent impacts we documented the target shape by 3D laser scanning, and measured the grain and bulk densities, porosity, and compressive strength of the targets to facilitate comparison with hydrocode modeling. The momentum enhancement due

to crater ejacta should be considered in design of kinetic impact deflection missions and modeling of the alteration of asteroid orbits by collisions.

S.3-0010-18 NEOTWIST: CHANGING THE SPIN STATE OF (25143) ITOKAWA

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Predicting the total momentum delivered onto a target asteroid constitutes one of the challenges of kinetic impactor-based orbit deflection methods. In spite of numerous laboratory experiments and considerable modeling efforts, uncertainties in the direction and magnitude of the momentum carrying material excavated during the impact remain uncomfortably large. Field-testing of kinetic impactors is, therefore, crucial to verifying ejecta models and credible momentum enhancement factor (β) predictions. The NEOTωIST mission concept could deliver such a validation by changing the spin state of the asteroid (25143) Itokawa. Targeting a well-characterized object off-center yields a change in the rotation state that is proportional to the momentum enhancement factor. Consisting of an impactor, a flyby vehicle and CubeSat chasers, the NEOTωIST concept would constrain β through direct observation of the ejected material, as well as through a complementary tracking of changes in the asteroid's spin state via ground-based observations. In this contribution, we show that the currently envisioned impact scenario would alter Itokawa's principle rotation period by several minutes - well above the detection limit of ground-based facilities. We, furthermore, present optimum potential impact locations on Itokawa that would allow for an accurate determination of the momentum enhancement factor. This information about the NEOTωIST concept is pre-decisional and is presented for planning and discussion purposes only.

S.3-0011-18 A NEW CONCEPT OF ASTEROID MITIGATION USING EXPULSION PAYLOAD IN SPACECRAFT SYSTEM

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The recent studies by international space university identify Thermonuclear Devices; Directed energy system gives a set of recommendations for better preparation to mitigation of the asteroid. This study is highly drawback to develop experimental work in the future. This paper presents a suitable experimental work in real time model to mitigate of Asteroid and compares the performance with simulation work through Liquid Hydrogen Liquid Oxygen propellants. This principle can be achieved by spacecraft System that carries an explosive payload which is including liquid Hydrogen, liquid oxygen, laser beam, Arduino Controller. The trajectory dispenses the Spacecraft at a distance of a few asteroid diameter while doing this we have to control the radio frequency transmission in the earth so that the Arduino controller can be changed in active mode. The continuously liquid Hydrogen Liquid Oxygen onto the Asteroid surface, at this same time, ignite the liquid propellants throughout the laser beam in order to vaporize the surface material, hence transferring a continuous force to the Asteroid. We modify evaporation process so that vapor highly growth to demonstrate the function exits. Therefore a multi spacecraft system might be applicable to Asteroid with size > 200m.

S.3-0012-18 DEFLECTING LARGE AND MEDIUM SIZE ASTEROID TRAJECTORIES BY A NUCLEAR ARRAY (FEW-DOZEN) TRACTORS, EJECTING COHERENTLY AS FOUNTAINS, THE SAME SOIL MASS.

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Rarest large (km size) or more common medium (tens-hundred meter size) incoming asteroid may be deflected by their trajectories by the landing of an array of micro robotic nuclear engines tractors (ton sized), located and landed on the asteroid surfaces, able to dig the asteroid icy (or dust) surface while propelling it as an effective a mass momentum fountain jet array: the asteroids skin (ice, dust) ejections and their consequent bending might drive the asteroid easely far from the Earth impact target if a programmed pre-cursor landing occur years before. Eventual tuned planetary gravity bending may amplify the success. The need for mini and midi asteroid test capture and safe parking in nearby orbits, may guarantee a a wide array of stations, mostly in a robotic ibernated state, offering a safe and solid multi body system for an early and fast two body hit in deflection of a greater incoming asteroid The asteroid skin ejection system it is an ideal tool in future planetary defense. References: D.Fargion, Asteroid Deflection: How, Where and When?, Chin. J. Astron. Astrophys. Vol. 8, Supplement, 399-411, (2008)

S.3-0013-18 AVOIDING ARMAGEDDON: LONG-TERM ASTEROID ORBIT DEFLECTION OPTIMIZATION

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Catastrophic asteroid impacts are among the few natural disasters that can in principle be averted using current technology. Should an asteroid be discovered and predicted to impact our planet near a population center, humankind may have the option of sending a space mission to alter the potentially hazardous object's trajectory. A kinetic impactor spacecraft, for instance, could transfer momentum to the asteroid through a high-velocity collision, thus avoiding a future impact on our planet. Differences in asteroid shape and composition, however, cause the magnitude and direction of the delivered momentum to be to some degree uncertain. Without accurate information on where an asteroid is "parked" after a deflection attempt, the same object may become a concern for planetary defense at a later date. In the worst case, the target asteroid enters a so-called "gravitational keyhole," retaining a high probability to collide with our planet. In order to avoid such scenarios, we demonstrate how to best target an asteroid during a kinetic deflection maneuver so as to minimize the chances of an Earth impact in the foreseeable future.

S.3-0014-18 OBSERVATIONAL SITES CHARACTERIZATION FOR THE FLY-EYE SURVEY TELESCOPE

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The issue of protecting ground infrastructures and space assets from the hazards coming from space, i.e. space debris, Near-Earth-Objects (NEO) and Space Weather, has recently gained momentum. In Europe it is addressed by the Space Situational Awareness Programme (SSA) of the European Space Agency (ESA) as well as at European Commission level. Within this framework it is foreseen the deployment of a European network of sensors for the detection of space objects able to trigger and support impact monitoring activities. The so-called "Fly-Eye" telescope with its unique optical design guaranteeing a wide-field (6.7°x6.7° FoV) and a highsensitivity (down to 21.5 visual magnitude) is a key element to this end. In survey mode this telescope allows to timely detect small NEOs approaching the Earth and to efficiently catalogue space debris in a wide range of orbital regimes, from high LEO (Low-Earth Orbit) up to the geostationary ring. The first-light of the ESA SSA Fly-Eye telescope devoted to NEO survey is expected by end 2019.

In order to investigate observational sites in Italy which could satisfy the SSA observational requirements we have analyzed different locations taking into account sky pollution, cloud coverage and seeing values. Both space and ground-based data were used. Cloud coverage data have been obtained from Earth observation satellites at different scale resolution (MODIS ACQUA, MODIS TERRA, MSG) and epochs. Seeing evaluation is based on existing data and/or in-situ ground-based seeing monitor equipments. The sky brightness was estimated by using NOAA (VIIRS/DMSP) and World Atlas 2015 (F. Falchi et al. 2016) maps. Due to the peculiarity in which NEO and space debris survey

are expected to operate, logistic considerations were also taken into account. We present the outcome of the resulting trade-off analysis which shows the advantages and drawbacks of each site, eventually leading to identify those which could satisfy the technical and operational needs of running a NEO/space debris based on Fly-eye telescopes.

S.3-0015-18 ON-ORBIT MONITORING OF METEOR IMPACTS USING CUBESATS

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The Chelyabinsk meteor event of 2013 showed the potential dangers of an asteroid impact. Luckily, the meteor resulted in airburst that released about 500 kilotons of energy (more than 30 times the explosive power of the nuclear bomb that hit Hiroshima). There were no known space or ground assets that were able to provide timely detection and early warning. This motivates the need for a early-warning surveillance system which can help us better prepare for such dangers.

Networks of spacecraft are necessary to characterize and constantly monitor near-Earth threats such as meteor impacts. Networks of CubeSats are ideally suited because of the low-development cost and for demonstrating continuous monitoring of rare phenomena. In this presentation, we propose development of a prototype, single spacecraft called, SWIMSat (Space-based Wideangle Impact of Meteors Satellite). The satellite will monitor meteor impacts. SWIMSat will be ideally located in Low Earth Orbit which enables rapid deployment for relatively low-cost. SWIMSat will be coupled with state of the ground assets managed by the University of Arizona including the Catalina Sky Survey The advent of newly available, low-cost CubeSat technology makes it feasible to start now, within the scope of a university program, and achieve sizable gains towards the security of near-Earth space within a low cost budget.

In this presentation, we present the latest design of SWIMSat. SWIMSat will be a 3U CubeSat with an onboard visible, wide-angle camera to perform autonomous imaging, detection and target tracking. Image processing will be performed on the CubeSat using state-of-the-art Field Programmable Gate Arrays. Furthermore, the spacecraft will use an off-the-shelf attitude control system

from Maryland Aerospace called MAI 400 to provide a few degrees of pointing stability. Continuous monitoring by a team of humans is not feasible. Hence the spacecraft will utilize a suite of smart, autonomous control software that will detect and track a meteor entry event. Meteor entry detection presents its own challenges as these events are relatively rare. Our work has focused on developing advanced-physics based simulations to recreate these entry events for use by our image detection algorithms.

Our simulation work show that by having swarms of CubeSats monitor these events from multiple locations it is possible to triangulate the position of the meteor in real-time, obtain readings on their size and possibly composition. Using this swarm, it maybe possible to measure the meteor in multiple wavelengths, including visible, near-IR,IR and hyperspectral camera to determine composition of the meteor and its potential for ground impact. Thanks to rapid advancement and miniaturization of electronics we are on pathway towards developing a lowcost on-orbit solution to meteor impact monitoring.

S.3-0016-18 CLOSEST VISIT OF ASTEROID PHAETHON -3200 IN 2017: DETAILED DAILY OBSERVATIONS BY ICSP 24IN REFLECTOR

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Phaethon-3200 came very close to the Earth in December 2017. ICSP observatory IERCOO pointed its two telescopes (one 24 Inch reflector named Vashista, and the other 10 inch Arundhati) exclusively to study its trajectory on a daily basis for about two weeks bracketing the closest approach day on December 16th, 2017. We present detailed results on the orbital changes, intensity variations and deviations from predictions.

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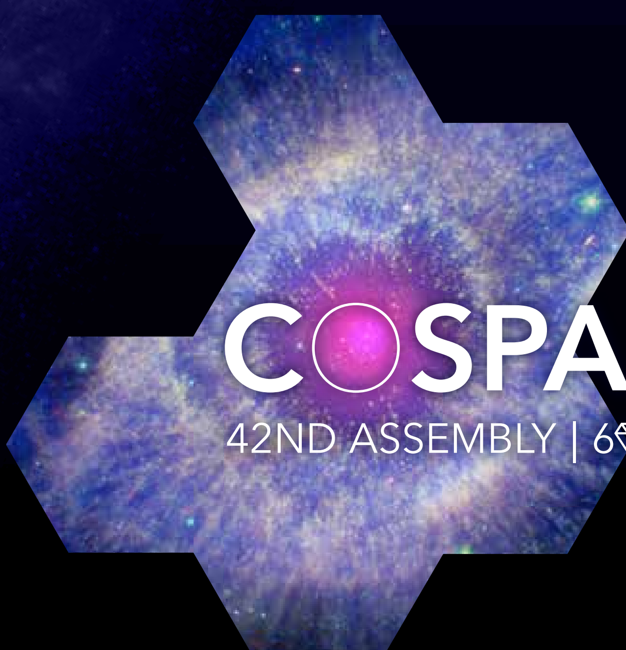
Interdisciplinary Lectures (SIDL)



COSPAR 2018

42ND ASSEMBLY | 60TH ANNIVERSARY

INTERDISCIPLINARY LECTURES (SIDL)

DISCOVERING EARTH'S RADIATION BELTS – SIX DECADES OF ASTONISHING ACHIEVEMENT (SIDL1)

SIDL1-0001-18 DISCOVERING EARTH'S RADIATION BELTS - SIX DECADES OF ASTONISHING ACHIEVEMENT

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Discovering Earth's Radiation Belts - Six Decades of Astonishing Achievement Daniel Baker and Mikhail Panasyuk 2017-18 marks the 60th anniversary of the dawn of the Space Age. The first artificial "moon" of our home planet, Sputnik (Russian for "companion"), was launched into low Earth orbit on 4 October 1957 by the then Soviet Union. While Sputnik 1 was little more than a radio beacon, it showed the entire world that Intercontinental Ballistic Missiles (ICBMs) - at the core of Cold War military arsenals - could also launch satellites into space. Shortly after the launch of Sputnik 1, Soviet scientists launched the second spacecraft into Earth's orbit on 3 November 1957. It was a much larger and more sophisticated vehicle. The satellite was the first to place into space a living creature - the dog Laika. Officially, Sputnik was launched in the framework of the International Geophysical Year. In addition to biological experiments, on board Sputnik 2 Soviet scientists under the leadership of Prof. Sergei Vernov of Moscow State University placed a detector for measurement of radiation in space - a Geiger-Muller counter. January 31, 1958, saw the launch by the United States of Explorer 1 into Earth orbit. James Van Allen and his team from the University of Iowa had radiation detectors on board Explorer I. It is interesting that Van Allen used the same type of radiation detectors as Vernov did: Geiger-Muller tubes as detectors for cosmic radiation measurements. The first results obtained by the pioneers of exploration of outer space was a truly epoch-making: they led to the discovery of new natural phenomena - the Earth's radiation belts - a phenomenon that was not predicted before the start of the space age. This discovery was the beginning of the formation of a new science - Space Physics. This presentation will describe the development of the first space missions and will provide a broad overview of the subsequent 60 years of radiation belt science.

INTERDISCIPLINARY LECTURES (SIDL)

LARGE-SCALE QUANTUM COMMUNICATION NETWORK WITH SATELLITES (SIDL2)

SIDL2-0001-18 LARGE-SCALE QUANTUM COMMUNICATION NETWORK WITH SATELLITES

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Free-space quantum communication with satellites opens a promising avenue for global secure quantum network and large-scale test of quantum foundations. Here we report a serial of experimental progresses on free-space quantum communication over long distance. In the meantime, Chinese Quantum Science Satellite has been launched on August 16th 2016. Through nearly one year of efforts, we have achieved the three major scientific goals-satellite-based entanglement distribution over 1200km and test of quantum nonlocality under strict Einstein's locality condition, ground-to-satellite quantum teleportation, and satellite-to-ground quantum key distribution. Recently, we also realized satellite-relayed quantum secured communication between China and Europe at locations separated by 7600 km. Our work pays the way for global quantum network and ultimate test of quantum nonlocality in outer space.

SIDL3-0001-18 GAIA: THE GALAXY IN 6 DIMENSIONS

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Gaia was launched in 2013, and is now scanning the sky to accurately measure the positions and motions of about 2 10^9 point like sources of $3 < G < 21$ mag, with the main goal of reconstructing the 6D phase space structure of the Milky Way. The sky will be repeatedly scanned (70 times on average) for five years or more, adding the time dimension, and the Gaia data are complemented by mmag photometry in three broad bands, plus line-of-sight velocities from medium resolution spectroscopy. This impressive dataset will have an impact on various areas of astrophysics, from solar system objects to distant quasars, from unresolved galaxies to nearby stars, from binaries and extrasolar planets to light bending experiments. The second data release, DR2, is foreseen for the 25 of April 2018, therefore the COSPAR meeting is nicely timed to describe the release content and present some of the first results obtained with Gaia DR2 data.

SIDL4-0001-18 ECONOMIC VALUE OF A MORE ADVANCED CLIMATE OBSERVING SYSTEM

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The climate science community has done a heroic job of using space based Earth observations to estimate climate change despite the fact that few of those observing systems were designed with climate change requirements, and most require substantial corrections and modifications. But what if we designed a global observing system specifically for climate change science, rather than using a collage of non optimal weather and research observations? How much faster could we unscramble anthropogenic climate change from natural variability and observation uncertainty? What would be the economic value to the world of such a system? What is the right amount for society to invest in climate research to narrow climate prediction uncertainties? What is the return on investment? How would we design such a system? The presentation will address these questions and demonstrate that the value of such a system is surprisingly large and is controlled by the accuracy of the observations.

The presentation will also suggest key elements needed in the design of an advanced climate observing system. Our current climate observations are extremely important, but they are far from optimal. Improved methods can better understand and communicate to society the right amount to invest in future climate observations.

INTERDISCIPLINARY LECTURES (SIDL)

SEARCHING FOR LIFE OUTSIDE THE EARTH, IN OUR SOLAR SYSTEM AND BEYOND (SIDL5)

SIDL5-0001-18 ASTROBIOLOGY FROM EARTH TO MARS AND BEYOND!

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Astrobiology begins right here on Earth studying the extreme environments that our planet offers and testing hypotheses with modeling and laboratory analyses. Understanding from such investigations must then be translated to predicting where we may find life elsewhere in our Solar System and even beyond in our galaxy. We study unique lifeforms on Earth and the physical and chemical biosignatures, that is traces of life, that they leave behind. Such traces can be used to provide a “Field Guide to Unknown Organisms” for developing life detection instruments, ideas for space missions to find life, and insights into ancient life on Earth. Examples from the extensive work to date and that to come in the future illustrate the prospects for finding life in our Solar System and beyond.

INTERDISCIPLINARY LECTURES (SIDL)

OCEAN WORLDS OF THE OUTER SOLAR SYSTEM (SIDL6)

SIDL6-0001-18 OCEAN WORLDS OF THE OUTER SOLAR SYSTEM

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Ocean Worlds of the Outer Solar System