2024

3D ballistic solar wind extrapolation. — We created a 3D method for extrapolating background solar wind speed in the inner heliosphere [1]. Our approach employs a pressure-corrected ballistic extrapolation method that uses solar coronal models as input data. The applied correction prevents the unphysical interactions between slow and fast plasma packets in our model. We also consider the coronal differential rotation which improves the fit compared to calculations with rigid rotation. The versatility of our model allows it to work with any input data providing solar wind speed on the solar source surface, making it applicable to various 2D solar corona maps, such as the WSA or the AWSoM datasets. The method propagates the solar wind from the solar source surface in 3D in the inner heliosphere, covering latitudes between ±50°. An example of the results can be seen in Figure 1. We validated our model using ACE solar wind measurements, demonstrating good correlation between our model and the measurements.

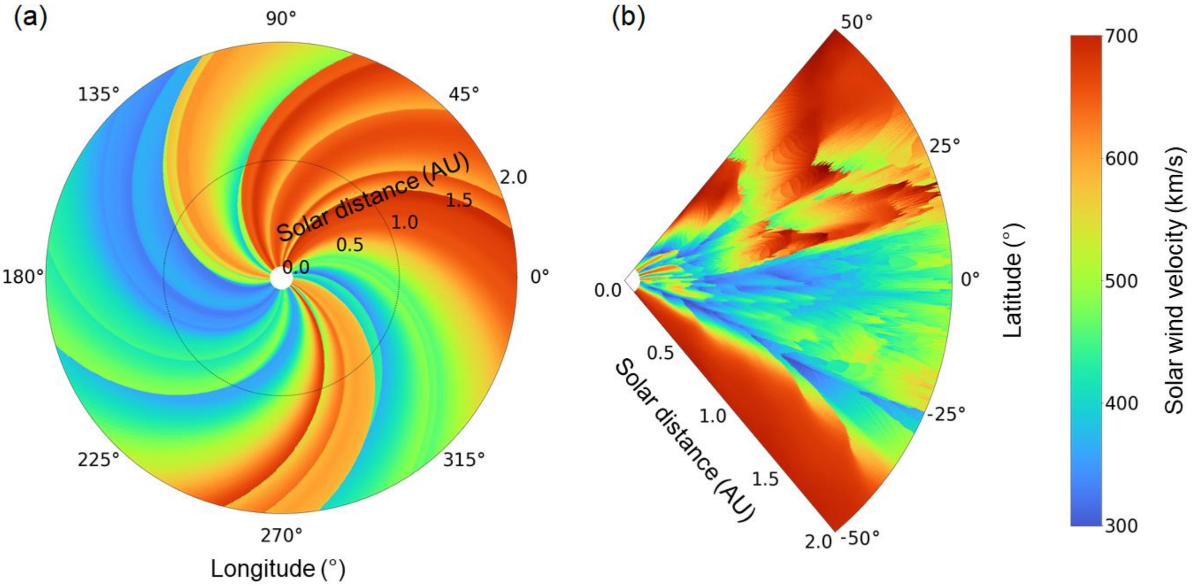


Figure 1. Solar wind speed in the Heliosphere according to our model (an example).

The effects of space weather on cometary ions. — We investigated the behavior of medium-energy cometary water-group ions based on Rosetta measurements during the high-activity period of Comet 67P (May to December 2015). Rosetta observed recurrent medium-energy ion peaks with maximum energies between 50 and 1000 eV while travelling in the magnetosphere of Comet 67P. We examined the connection between the solar wind dynamic pressure and the quantity and energy of these medium-energy ions. We established a strong correlation between solar wind dynamic pressure and the quantity of medium-energy ions. Although ion energy also changes depending on the solar wind pressure variations, we show that this parameter is significantly influenced by other factors, such as the production rate of the comet and the distance from the nucleus. The observed strong correlations can be explained by assuming that the source surface of these ions moves inward and outward, responding to fluctuations in solar wind pressure [2].

Directional discontinuities in the inner heliosphere. — The solar wind carries the magnetic field of the Sun frozen into its plasma. Abrupt changes in the direction of this magnetic field are called directional discontinuities, which can be caused by the spacecraft piercing boundaries of independent plasma regions, or by magnetic field disturbances travelling in the plasma. The former type is called tangential discontinuity (TD), the latter rotational discontinuity (RD). Differentiating between the two types is very important, but it is very difficult using spacecraft measurement data. In our paper [3], we provide a simple new method based on a comprehensive analysis of several plasma parameters, but requiring only magnetic field data in its final form, which can distinguish RDs and TDs better than previous methods. We also analyze the physical properties of the two populations.

References:

[1] https://doi.org/10.1051/swsc/2024010

[2] https://doi.org/10.1093/mnras/stae1556

[3] https://doi.org/10.1051/0004-6361/202450684

2023

Closed field line vortices in planetary magnetospheres. — We have shown [1] that the magnetosphere of giant planets has a strange new domain, in which the behavior of the plasma and the magnetic field is radically different from any previous expectations. The magnetic field lines of this domain are closed (attached to the planet with both ends) but do not rotate around the planet as expected. The middle points of these field lines are anchored in slowly moving plasma in the far magnetotail, so these points cannot orbit the planet. At the same time the footpoints of the field lines (where they are attached to the planetary surface) rotate together with the planet. Thus, the field lines of this domain are twisted into huge vortices. The plasma here, instead of orbiting the planet, also swirls in vortices (see Figure 1). Analysis of Cassini spacecraft data shows that this swirling motion does indeed occur in Saturn's magnetosphere. The new result completely changes the way we have thought about the magnetosphere of giant planets.

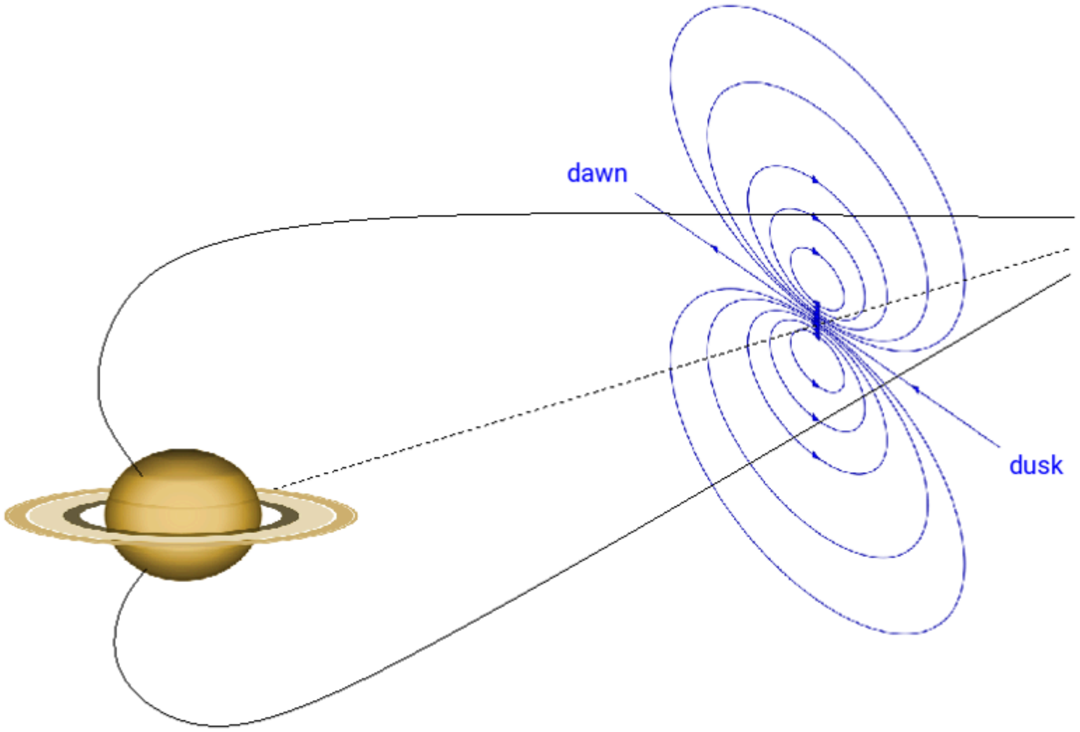


Figure 1. Plasma motion in the closed field line vortices of the Kronian magnetosphere.

Orientation of the stream interface in CIRs. — The behavior and structure of transients in the solar wind is a complex and exciting field of study. Its importance arises from the fact that these transients can affect the magnetosphere of Earth, sometimes even causing damages to the infrastructure. Although Coronal Mass Ejections (CMEs) are the primary focus of most of this research, Corotating Interaction Regions (CIRs) are just as important because they are also geoeffective. In our article [2], we utilized a computationally undemanding method to investigate the three-dimensional structure of CIRs close to the Earth, using in-situ data from space probes at the Lagrange-1 point. We performed four case studies to evaluate our method, determining the tilt of the Stream Interface (the region where the fast solar wind catches up to the slow solar wind) in each case. Our findings can be used to study how CIRs with differently tilted Stream Interfaces affect the magnetosphere, and, ultimately, to gain more information about geomagnetic storms.

References:

[1] DOI: 10.1093/mnras/stad030
[2] DOI: 10.1051/swsc/2023011

2022

Dayside transient phenomena and their impact on the magnetosphere and ionosphere. —Using numerical simulations and spacecraft observations, the members of an international research team reviewed the transient events of the dayside magnetosphere (Figure 1), created by the interaction of the terrestrial magnetosphere and solar wind discontinuities. Their global influence in the magnetosphere, the ionosphere, and the polar regions was clarified. The study produced a 150-page long review paper, which has been published on June 28, 2022, in the Space Science Reviews journal of the Springer Nature Group [1].

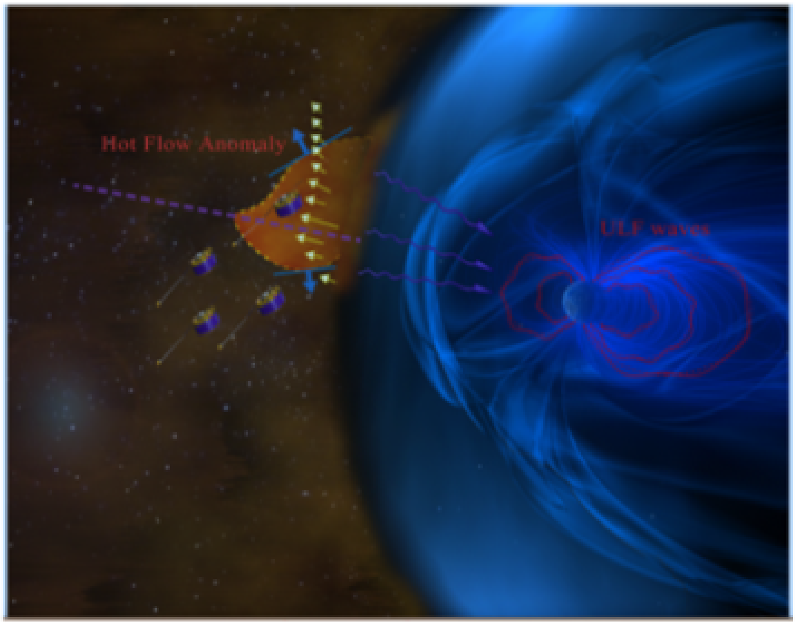


Figure 1. The hot flow anomalies are created by the interaction of the terrestrial bow shock and a tangential discontinuity in the solar wind. These phenomena trigger ultra-low frequency waves in the Earth's magnetosphere (credit: Peking University, [1]).

Improving ERT Imaging of Small-Size 2D Targets Using Different Strategies. — Electrical resistivity tomography (ERT) is a technique to observe subsurface objects and structures. Investigation of small-size two-dimensional (2D) targets requires arrays with a high horizontal resolution. The strategy which may provide the most accurate results, the economically most advantageous method, and a profit/investment optimized array set to solve problems of small 2D targets are presented. The presented strategies are recommended to apply when small 2D targets such as, e.g. pipes, trenches, tunnels, mining cuts, long straight caves, archaeological ruins (walls, basements), fractures, or dykes are studied [2].

Magnetic field irregularities in the ionosphere. — We investigate the space weather contexts of the solar and solar wind dynamics. Making use of the high-frequency three-component magnetic records of ESA's low-Earth orbit (LEO) Swarm mission the typical occurrences of irregular magnetic field fluctuations are explored in the high-latitude and equatorial geomagnetic regions. Relying on the turbulent nature of the irregularities, we develop an intermittency index (IMI) for the quantitative monitoring of the irregular magnetic fluctuations along the orbits of the Swarm spacecraft. It turns out, that in the equatorial region, the most intermittent fluctuations appear symmetrically about the dip equator, at +-10° magnetic latitudes, in post sunset magnetic local times. Clearly, this finding is explained by the appearances of equatorial spread F (ESF) and plasma bubble phenomena. The occurrence rate of equatorial irregularities exhibits a clear solar cycle dependence, being greater in solar maximum than in minimum. The space weather context of the equatorial irregularities is shown by the subtle correlation of these events with GNSS loss of lock (LOL) occurrences onboard Swarm spacecraft as well as with scintillation effects recorded in ground GNSS stations. In the polar region, IMIs are modelled by Adjusted Spherical Cap Harmonic analysis, for three levels of geomagnetic activity. The models exhibit intermittent fluctuations in two oval regions about the geomagnetic poles. It is suggested that the poleward region is coincident with the auroral oval, while the equatorward region is indicative to the ionosphere footprint of the plasmapause.

Inner southern magnetosphere of Mercury. — Mercury's southern inner magnetosphere is an unexplored region as it was not observed by earlier space missions. In October 2021, BepiColombo mission has passed through this region during its first Mercury flyby. The BepiColombo SERENA team investigated the ion content of this region. The dayside magnetopause and bow-shock crossing were much closer to the planet than expected, signature of a highly eroded magnetosphere. Different ion populations have been observed inside the magnetosphere, indicating various magnetospheric structures [3].

2021

Suprathermal Ions from Coronal Holes. — The relative abundances of thermal and suprathermal C, O, and Fe ions were analyzed and compared in solar wind streams from near-equatorial coronal holes during quiet periods of nearly two solar cycle minima [1]. Ion fluxes with energies of ~0.04–2 MeV/nucleon were studied using data from the ULEIS instrument aboard the ACE spacecraft together with thermal ions in the fast and slow (Maxwellian) solar wind using data from the SWICS instrument aboard ACE. The analysis was carried out for quiescent periods in 2006–2012 and 2015-17 when solar wind flows from near-equatorial coronal holes (CHs) were detected at 1 AU. Near the minimum of SC23, although they displayed large variability, the C/O and Fe/O ratios of suprathermal ions were, on average, near the corresponding relative abundances of the solar wind. During the decreasing solar activity phase of SC24 suprathermal Fe/O ratios matched those of solar wind ions from CHs. In both cycles the thermal and suprathermal Fe/O ratios exhibited a similar character of dependence on maximum solar wind speed (Fig.1). Our results suggest that the sources of suprathermal ions from CHs in low solar activity periods are accelerated solar wind thermal ions. The thermal and suprathermal Fe/O ratios were found higher in 2015-17 than those measured in 2006-2010.

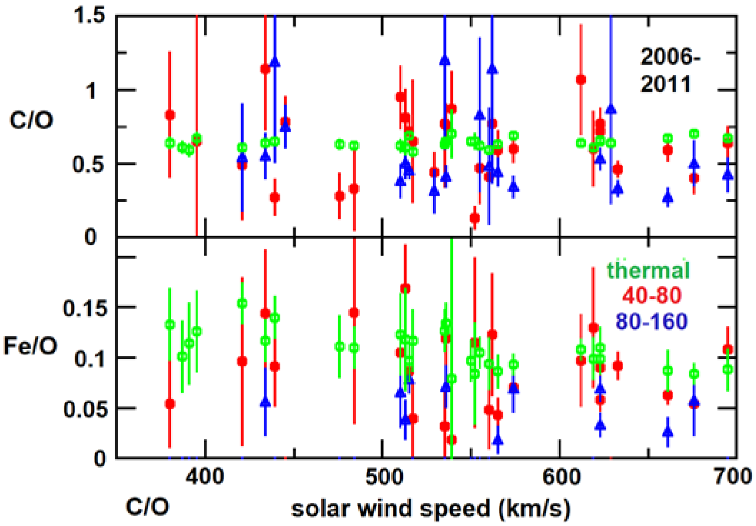


Figure 1. Values of C/O (upper panel) and Fe/O ratio (lower panel) as a function of the maximum speed of the solar wind from CHs in 2006–2011. Red dots and blue triangles represent the ratios of suprathermal ions with energies 40–80 keV/n and 80-160 keV/n, respectively; green circles are the ratios of thermal SW ions.

Jovian electrons at the Earth orbit. — The influence of the structure of inner heliospheric magnetic field was studied on the propagation of Jovian electrons from Jupiter to the Earth orbit [2]. Beginning from 1974, 13-month variations of relativistic Jovian electron fluxes were recorded by spacecraft near the Earth. 22 synodic cycles are analyzed. The best connection in each cycle was found within a narrow longitudinal interval with an angular divergence of the planets 230 ± 20○, when the Parker field line connecting the two planets is formed at solar wind speed 450 ± 50 km/s. Such invariability for more than 45 yr is improbable to be accidental. We attribute the observed phenomenon to the long-term presence of recurrent stationary structures in the solar wind generated near the Sun. This assumption is confirmed by comparing the time profiles of the solar wind speed measured over all solar rotations in the solar activity minima in 1975 and 2007–2008 (Fig. 2).

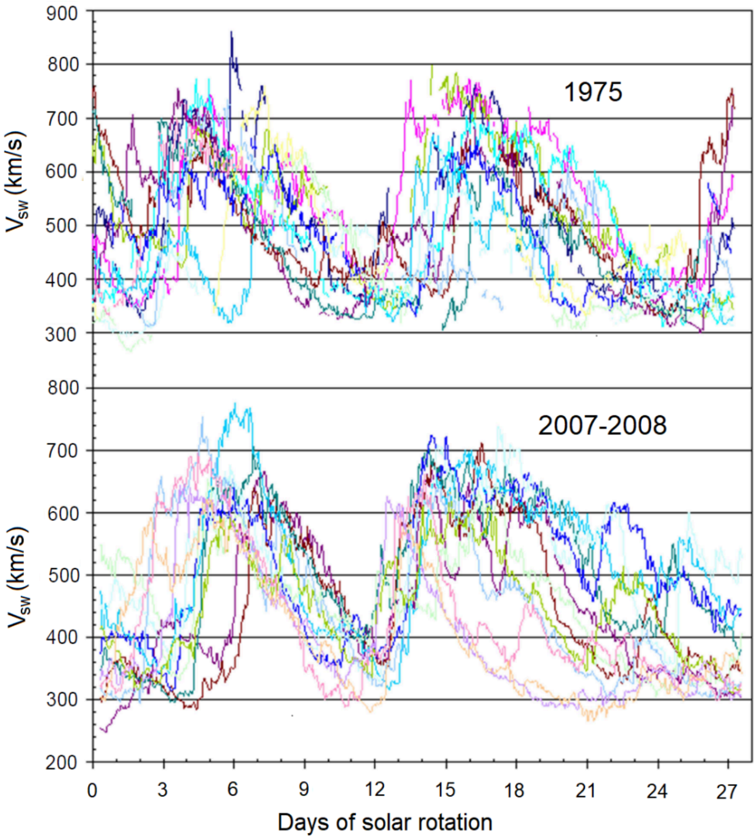


Figure 2. Composite picture of the solar wind speed profiles during consecutive rotations of the Sun in 1975 (upper panel) in the 13-month Earth-Jupiter synodic cycle in comparison with the speed profiles in 2007-2008 (lower panel). The speed curves are split into 27.3 day intervals and superimposed.

SERENA: Particle Instrument Suite. — The ESA-JAXA BepiColombo mission to Mercury will provide simultaneous measurements from two spacecraft, offering an unprecedented opportunity to investigate magnetospheric and exospheric dynamics at Mercury as well as their interactions with SW, radiation, and interplanetary dust [3]. The particle instrument suite SERENA (Search for Exospheric Refilling and Emitted Natural Abundances) is flying in space on-board the BepiColombo Mercury Planetary Orbiter (MPO). The only particle instrument aboard the BepiColombo Mercury Planetary Orbiter (MPO) is SERENA (Search for Exospheric Refilling and Emitted Neutral Abundances), which comprises four independent sensors: ELENA for neutral particle flow detection, Strofio for neutral gas detection, PICAM for planetary ions observations (Fig.3), and MIPA, mostly for SW ion measurements. SERENA is managed by a System Control Unit located inside the ELENA box. Our researchers participated in the paper, in which the scientific goals of this suite are described, and then the four units are detailed, as well as their major features and calibration results. Finally, the SERENA operational activities are shown during the orbital path around Mercury, with also some reference to the activities planned during the long cruise phase.

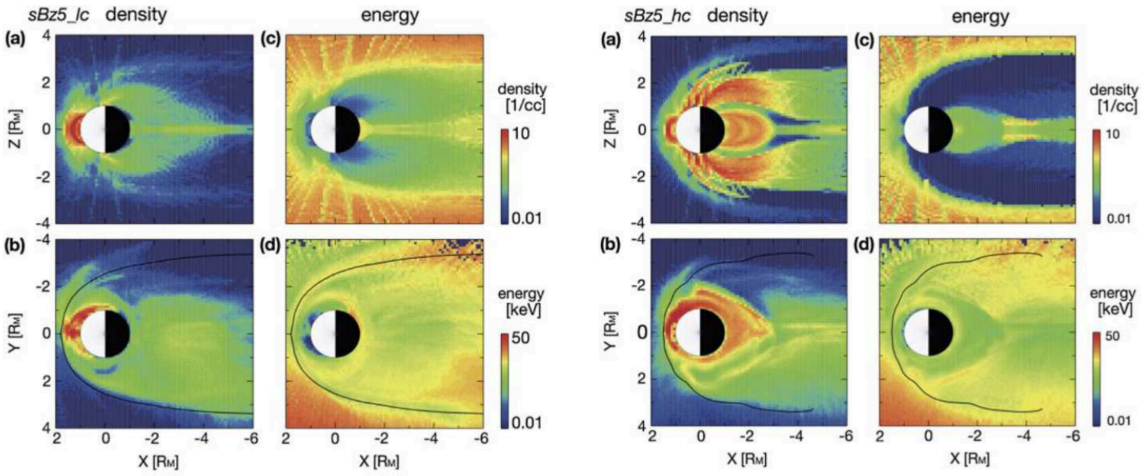


Figure 3. Na ion distribution under the same southward IMF (BZ = –5 nT) and solar wind conditions, for different assumptions of surface conductance. Upper panel: low conductivity; bottom panel: high conductivity. The resulting ion distributions are markedly different as the formation of an X-line further from the planet inhibits escape in the second case.

Coordinated observations in the inner Heliosphere. — During its cruise phase, the BepiColombo spacecraft will cover a wide range of heliocentric distances (0.28 AU–0.5 AU), which provides a great opportunity for coordinated observations, especially with the Solar Orbiter and Parker Solar Probe. Despite some payload constraints, many instruments onboard the spacecraft are operating before its orbit insertion around Mercury in December 2025. We reported a detailed catalogue of events, the various spacecraft configurations and the combined in-situ and remote sensing measurements from the different spacecraft. We summarized the identified science topics, the operational instruments and the method we have used to identify the windows of opportunity and discussed the plans for joint observations in the future. [4]

2020

Report of the scientific work performed in 2020 - There are two main activities in our team: we have been participating in **ESA Juice mission** since 2017, and our team has been taking part in the development of **ROSCOSMOS Trabant mission** since 2019.

The JUICE mission will survey the Jovian system with a special focus on the three Galilean Moons; Europa, Ganymede and Callisto. The JUICE spacecraft will be the first spacecraft ever to orbit a Moon (Ganymede) of a Giant planet. Juice will be launched on its nine-year journey on an Ariane rocket in May 2022 as an ESA interplanetary mission. The aim of the project is to research Jupiter and its moons.

The two power supplies developed by the Space Technology Team led by János Nagy were named NU_DCC and JDC_DCC *(Nadir Unit Direct Current Converter and JDC Direct Current Converter*), and their task is to provide power for 2 processor units and 4 sensors developed for the PEP Plasma Physics Instrumentation (PI Stas Barabash, IRF, Kiruna, Sweden). PEP's goal is to study the interaction between Jupiter's magnetosphere and its moons and the effect of the solar wind around Jupiter. The PEP is developed by wide international collaboration with teams from Sweden, Germany, the USA, Switzerland, Finland, France, Britain and Japan. The integration of PEP started after the 3 shipped cards of the NU_DCC were installed in the mechanical frame in Bern. Based on the tests, all devices have been working properly so far. The integration lasted until the begin of Octoberr 2020 and was successful. Presently the PEP is at Airbus premises where spaceship is assembled.

Figure 1. *Assembly of PEP parts in clean room at University of Bern. Janos Nagy (WRCP) and Jouni Rynö (FMI Helsinki).*

Figure 2. *Closing the thermo vacuum chamber in Bern where PEP's operation was tested from -170^{0}C up to +60^{0}C in a duration of 4 weeks.*

Trabant, Space technology team takes part in the development of the On-Board Computer – (OBC computer). OBC will receive sensors and forward measuring data to telemetry. In 2020, the OBC breadboard model was prepared, and the development of the operating software was started. In the software development, we will implement the drivers (drivers) that ensure the management of each adapter, including the management of the mass storage device to store measurement data.

Figure 3. *OBC breadboard model*

Figure 4. *Testing fast telemetry channel*

2020

The dynamics of the magnetic field free cavity around comets — The diamagnetic cavity is the innermost region of the magnetosphere of an active comet from which the magnetic field is expelled by the outflowing matter. This phenomenon, first detected around comet 1P/Halley, was extensively studied recently by the Rosetta comet chaser mission. Rosetta observed a surprisingly large diamagnetic cavity around comet 67P/Churyumov–Gerasimenko and revealed an unforeseen structure, rich and highly dynamic. We presented a simple (1+1)-dimensional analytic MHD model of the diamagnetic cavity, which for the first time explained the unexpected size and variability of the cavity [1]. In this model inward and outward moving time dependent solutions emerge, featuring distinct differences, in accordance with observations. The plasma density is increased in the entire magnetized region. The density enhancement is more pronounced for weak comets, resulting in a stronger interaction and hence the larger than expected cavity. Space weather effects determine the asymptotic plasma speed, thus driving the variations of the plasma properties observed near the cavity. Radial magnetic field and velocity profiles of the solutions are shown in Figure 1.

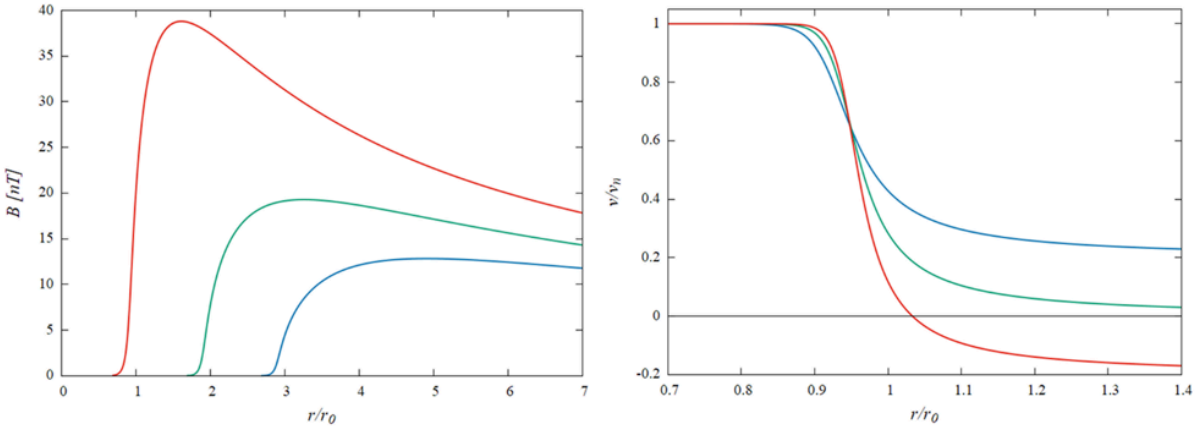


Figure 1. *Left panel: Radial profile of the magnetic field magnitude for different cavity size (r_0) parameters. Right panel: Radial velocity profiles for different space weather conditions.*

Plasma distribution around comet 67P in the last month of the Rosetta mission. — After accompanying comet 67P/Churyumov-Gerasimenko on its journey around the Sun and observing the evolution of its induced magnetosphere throughout the comet's life-cycle, the Rosetta operations concluded at the end of September 2016 with a controlled impact on the cometary nucleus. At that time, the comet was located more than 3.8 AU from the Sun, but the data still show clear indications of a small but well developed plasma environment around the nucleus. These observations, performed along multiple recurring elliptical orbits, allowed us to investigate the properties and spatial structure of the fading cometary magnetosphere. We examined the measured electron and neutral densities along these consecutive orbits, from which we were able to determine the structure of the plasma distribution (Figure 2) using a simple latitude and longitude dependent model [2].

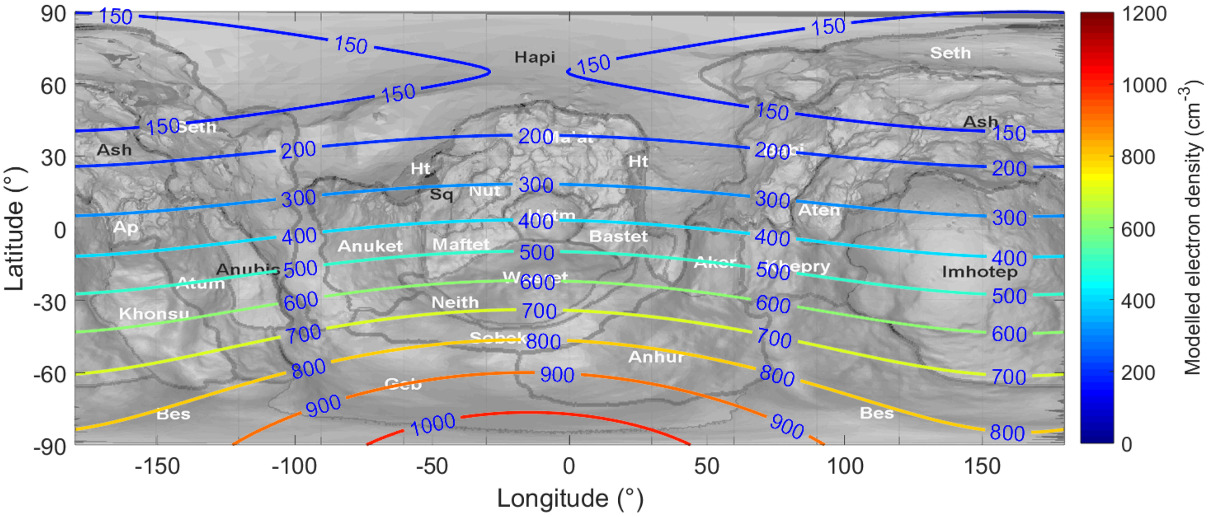


Figure 2. *Plasma distribution contours of the fading magnetosphere of comet 67P, projected to the surface of the nucleus.*

Participating in the planning and development of new space missions. — Our researchers are participating in two recently launched space missions: the Solar Orbiter mission to explore the inner Heliosphere [3], and the two-spacecraft BepiColombo mission investigating planet Mercury and its space environment [4]. We also contributed to a study proposing a new mission to Jupiter's moon Europa to characterize its habitability and search for extant life [5].

2019

In our group activities, we strive to participate in several projects that include ESA Juice mission and ROSCOSMOS Trabant mission.
The JUICE mission will survey the Jovian system with a special focus on the three Galilean Moons; Europa, Ganymede and Callisto. The JUICE spacecraft will be the first spacecraft ever to orbit a Moon (Ganymede) of a Giant planet.

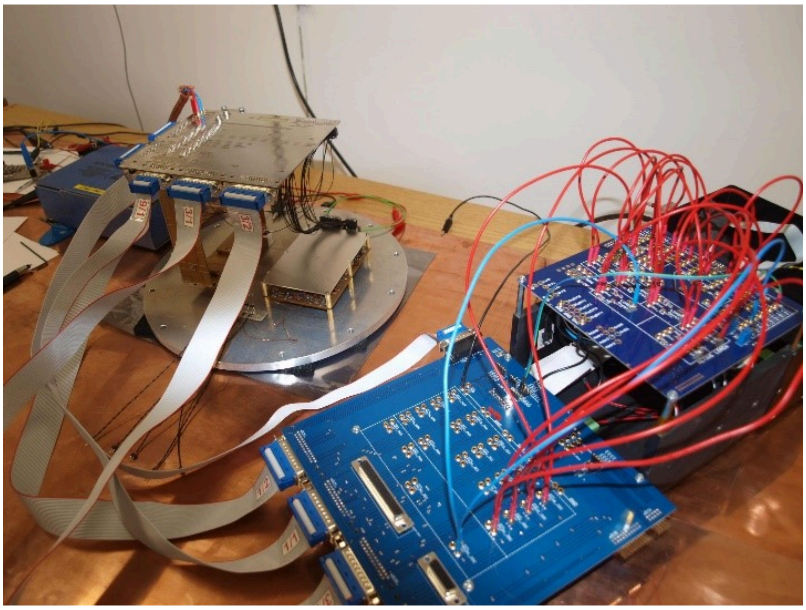


Figure 1. Test of flight DCC cards

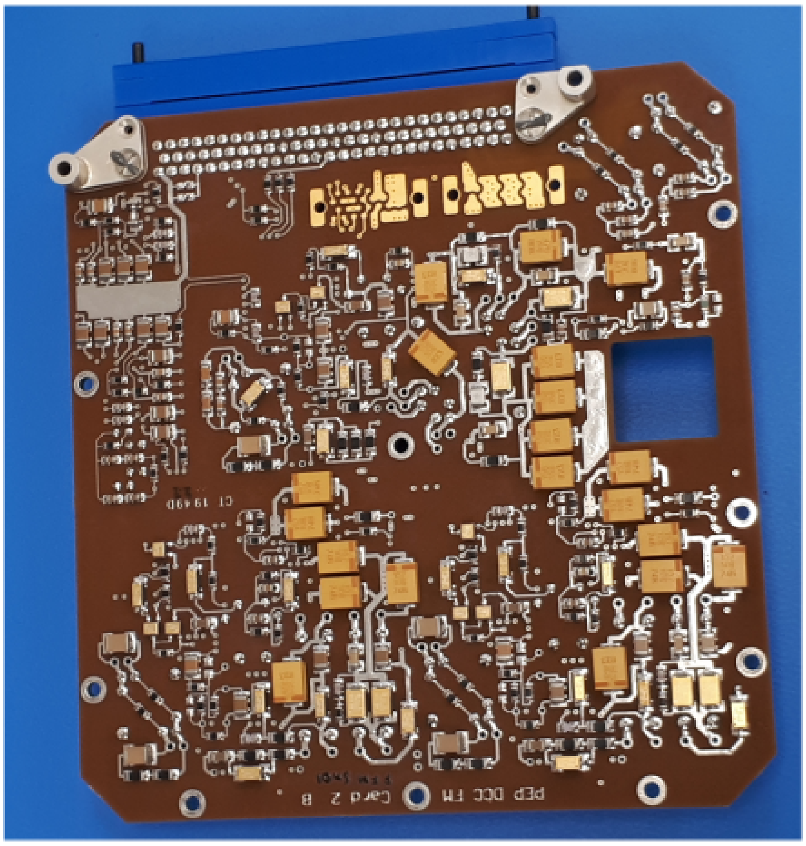


Figure. 2. DCC contains 4 cards

We are developing a switching power supply DCC for the Juice PEP (Particle Environment Package) project that converts the on-board 28 V supply voltage to 2 DPUs and 4 sensors of PEP experiment. PEP is developed in collaboration of several teams and its purpose is to investigate particle physical measurements in Jovian system. The planned launch date of Juice is May 2022.
The Trabant mission investigates space-weather processes using two microsatellites at 500 km altitude. We develop an onboard data acquisition computer for the Trabant experiment. The job of onboard computer is receiving scientific data from sensors to store and forward them during visibility on Earth. The on-board computer controls instruments and data sequences from them. Presently the engineering model development is ongoing.

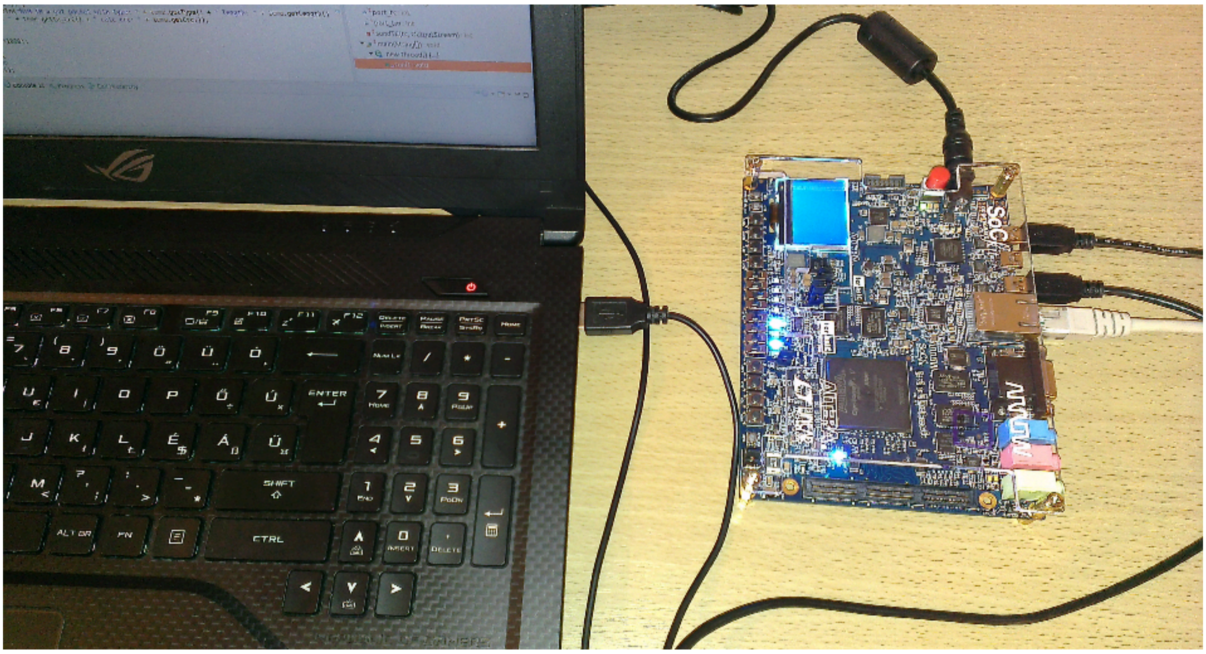


Figure 3. The board we currently use does not have a dedicated processor, instead we use the 2-core ARM Cortex-A9 implemented in the FPGA. This structure is justified by optimum utilization and reducing energy need

Suprathermal ions in the interplanetary space. — The ULEIS detector aboard the ACE spacecraft offers a continuous data set of suprathermal (0.04 to 2 MeV) ^{3}He, ^{4}He, C, O, and Fe ion fluxes in the interplanetary space at 1 AU from the Sun. The positive correlation of the quiet sun ion fluxes detected in the 23rd and 24th solar cycle (SC) with the parameters of solar activity and the inclination of heliospheric current sheet suggests that they predominantly originate from active processes on the Sun. Whereas the ion fluxes were lower in SC24 than in the previous one both in perturbed and quiescent periods, the temporal variations of ^{3}He/^{4}He, C/O and Fe/O rations are different and depend on the first ionization potential of the atoms. The maximum of the distribution of Fe/O was higher in SC23, the ^{3}He/^{4}He and C/O distributions are practically the same in the two cycles (Fig.1) [1].

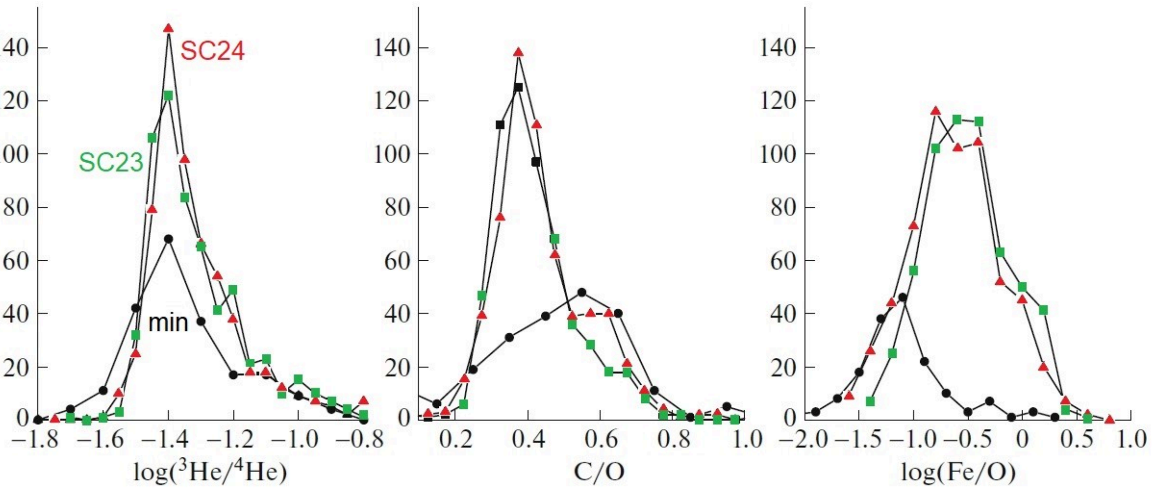


Figure 1. Distributions of 5-day flux averages of relative abundances of 80-160 keV/n ions 3He/4He, C/O, and Fe/O in the maximum of SC23 and 24 together with the minimum between them.

Short large amplitude magnetic structures at Saturn. — We analyzed the physical properties and evolutionary characteristics of Short Large Amplitude Magnetic Structures (SLAMS) upstream of the quasi-parallel bow shock of Saturn, using the measurements of the Cassini Plasma Spectrometer (CAPS) and the Magnetometer (MAG) instruments onboard of the Cassini spacecraft. Locally the SLAMS act as a fast mode shock wave, with several features (ion beam reflection, multiple beams, deceleration and plasma heating) that are in agreement with the near-Earth observations. We also detected whistler precursor waves (Fig.2) associated with the SLAMS events multiple times. The frequency of the upstream ULF waves (from which the SLAM structures arise) detected at Saturn is lower than it is at Earth, which has an effect on the spatial extension of the observed magnetic structures [2].

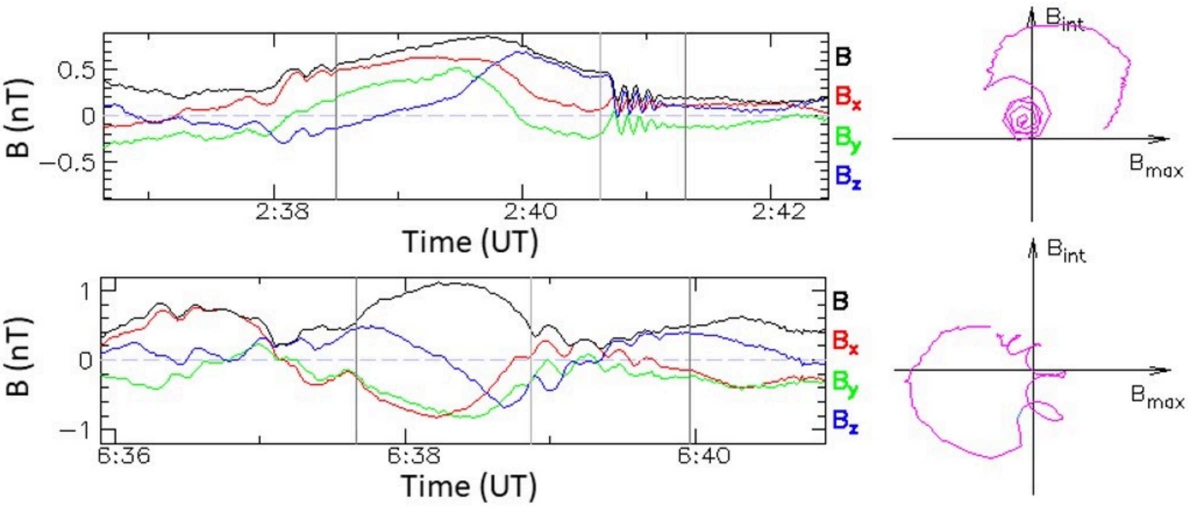


Figure 2. Two cases of SLAMS whistler precursor waves detected on December 10th, 2004 (top) and October 8th, 2005 (bottom) with the corresponding hodograms shown in the inserts on the right.

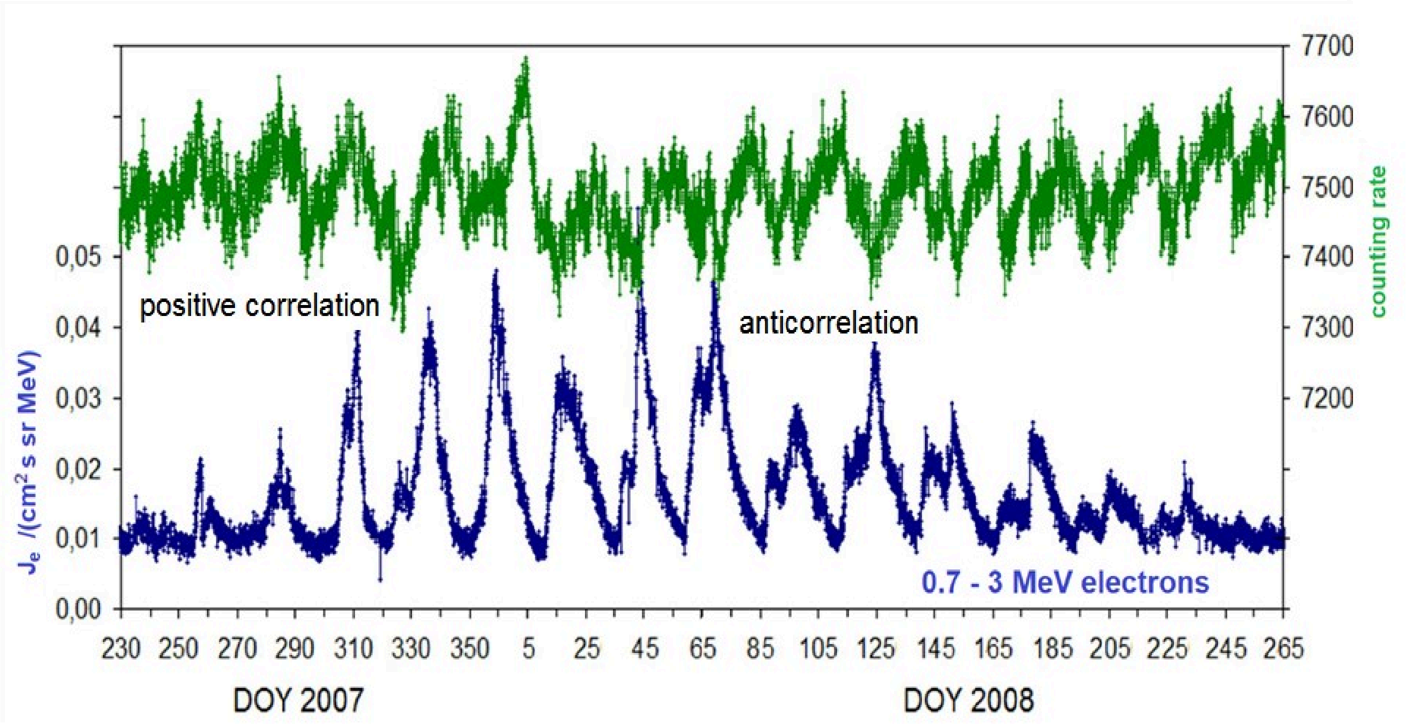
Solar wind pressure at comet 67P. — We determined a proxy for the solar wind pressure around comet 67P/Churyumov-Gerasimenko for the time interval between late April 2015 and January 2016. The pressure proxy is based on magnetic field data. Since the spacecraft was deep inside the induced magnetosphere of the comet in that time period, direct measurement of the solar wind pressure was impossible. We compared our pressure proxy to solar wind pressure extrapolated to comet 67P from near-Earth measurements. After exclusion of disturbances caused by transient events, we found a strong correlation between the two data sets [3].

2018

Our research group studies space plasma processes in the Solar System through spacecraft observations and modeling. The main topics of our investigations are Solar System Bodies and Magnetospheres as well as Space Weather. We are involved in numerous space missions at all stages from design to data exploitation in collaboration with the Space Technology research group and our international partners. This year one of these missions reached an important milestone: BepiColombo, a spacecraft to explore Mercury and its environment, was launched on 20th October 2018. Another important achievement of this year is that we helped to create the Europlanet Society, an association to congregate all European planetary scientists and enthusiasts.

Space Weather – Jovian electrons and solar wind structures

During very low solar activity like in 2007-2008 extremely long-lasting stationary solar wind speed structures can exist near and beyond the Earth for up to 14 solar rotations. These structures modulate the fluxes of both MeV energy Jovian electrons and >50 MeV galactic protons. We attribute this modulation to the formation of a magnetic trap, explaining the 26.1 day period of electron peaks. The effect on electrons and protons is, however, different: while the flux of electrons increases as they are trapped in a magnetic structure, the proton flux decreases due to enhanced convection and adiabatic deceleration during the increase of solar wind speed.



Space Weather – Space weather propagation

Participating in the Europlanet 2020-RI project, our group is working on a new solar wind propagation method. Solar wind propagation is a key to predict space weather parameters at certain distances from the Sun. Background solar wind and transients have to be handled separately. For this reason our group has created a database of identified transient events as seen on different space-based instruments and developed a new solar wind propagation method, called Magnetic Lasso propagation.

This is a problem-tailored propagation tool that concentrates on the exact location where the prediction should be most accurate. The method works ballistically, but compared to the simple ballistic approach, the Magnetic Lasso method is based on reconstructing the ideal Parker spiral connecting the target with the Sun by testing a previously defined range of heliographic longitudes. The model takes into account the eventual evolution of stream–stream interactions and handles these with a simple model based on the dynamic pressure difference between the two streams.

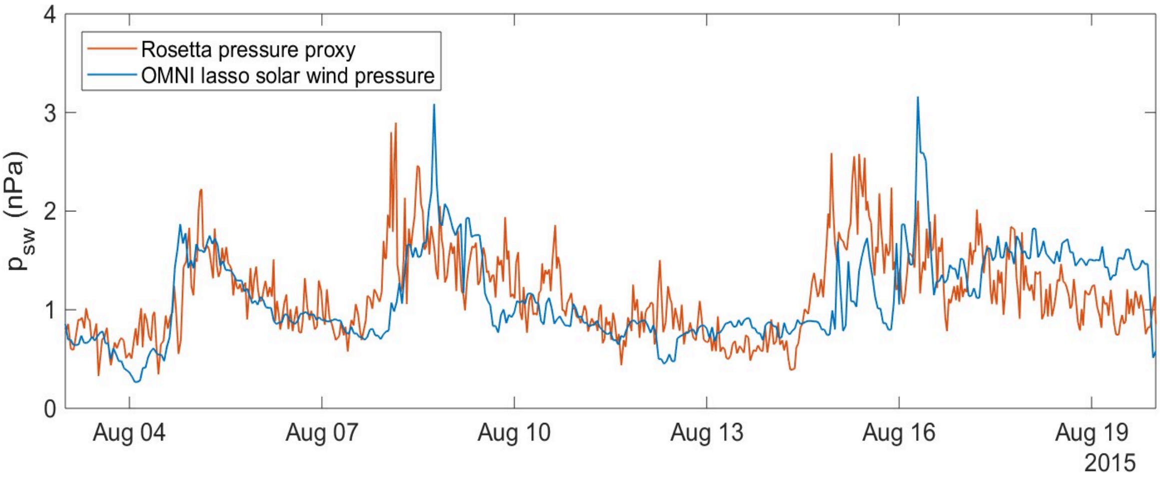
The model has the advantage that it can be coded easily and fitted to the problem; it is flexible in selecting and handling input data and requires little running time.

Space Weather – Estimating the solar wind pressure using magnetic field measurements deep inside the magnetosphere

The solar wind dynamic pressure is an important parameter of space weather, which plays a crucial role in the interaction of the solar wind with the planetary plasma environment. In an induced cometary magnetosphere, the magnetic pressure in the pile-up region (where the magnetic field is compressed and slowed down upstream of the cometary nucleus) is balanced by the external solar wind dynamic pressure.

Our investigations have revealed that the magnetic pressure can be approximated by the magnetic field measurements performed by Rosetta in the inner regions of the induced magnetosphere of comet 67P/Churyumov-Gerasimenko between April 2015 and January 2016. From this, we determined the external solar wind dynamic pressure around the comet. To validate this Rosetta pressure proxy we then compared it to solar wind pressure extrapolated to comet 67P from near-Earth.

Our pressure proxy is useful not only for other Rosetta related studies but also serves as a new, independent input database for space weather propagation to other locations in the Solar System.

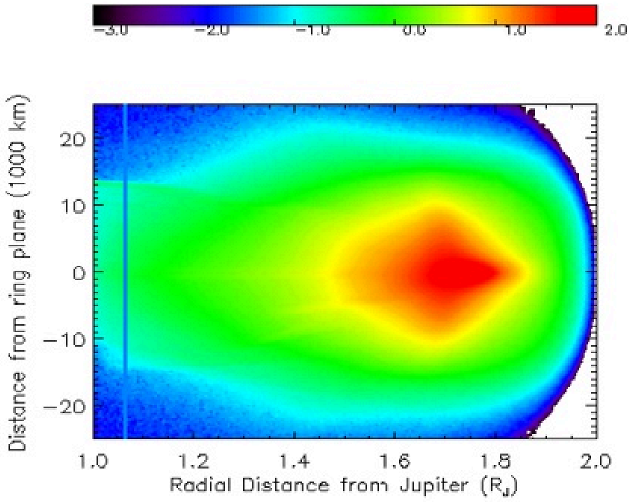


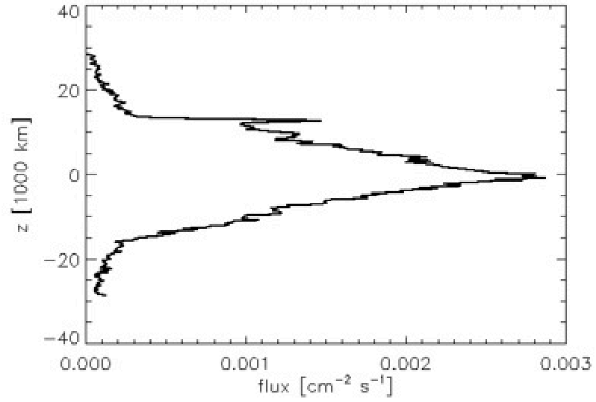
Magnetospheres – Plasma conditions and the structure of the Jovian ring

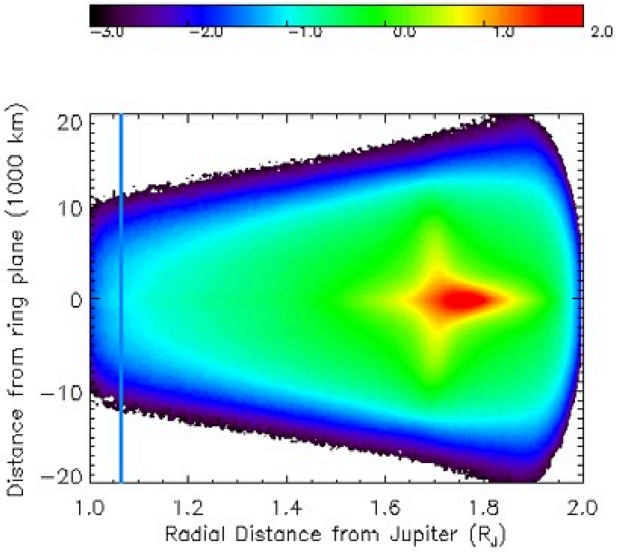
We explored the dynamics of small charged dust particles in Jupiter's innermost magnetosphere and showed that the systematic charge variation of the grains results in surprisingly short lifetimes. Assuming a constant production of small dust particles via continual micrometeoroid bombardment of the larger parent bodies of the main ring, this model reproduces remote sensing observations of the ring/halo region at Jupiter made by Voyager, Galileo, Cassini, and New Horizons spacecraft and observations from the ground by the Keck telescope during ring plane crossings. We use this model to compare the dust impact rates observed by the JUNO mission, which has been traversing the rings multiple times since 2016.

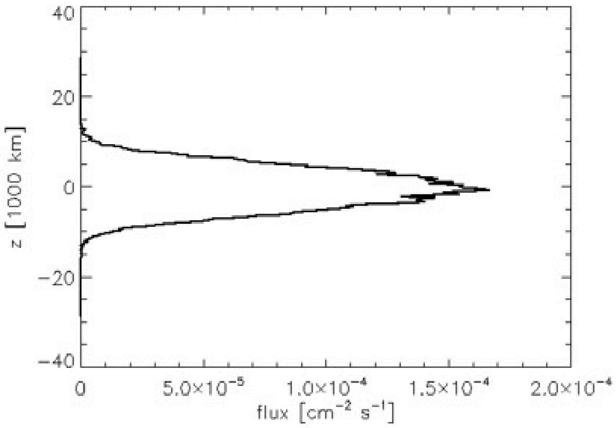
The figure below shows the spatial distribution of the Jovian dust halo for various sized particles, and their flux to the Juno spacecraft following a nearly vertical path (blue lines) crossing the ring plane at 1.06 RJ.

The initial cursory comparison of the data and model prediction seems to match the spatial extent of the Jovian ring/dust halo, at least indicating that our models deciphered the complex dynamics of small charged dust particles near Jupiter.









Magnetospheres – The theory of the diamagnetic cavity of comets

Recent observations of the Rosetta mission provide comprehensive plasma data about a multitude of diamagnetic cavity crossing events and reveal a surprisingly large diamagnetic cavity around comet Churyumov-Gerasimenko featuring an unforeseen, rich and very dynamic structure. The classical description of the cavity – although very successful in explaining many aspects of the observations – concentrates on solving a single equation in the long distance and zero resistivity limit. We found that exact analytical solutions of the complete set of equations exist for a more general case. These solutions provide new insights into the properties and dynamics of the phenomenon. The generalized solutions show that the magnetic field does not drop to zero immediately inside the cavity, but features a rapid exponential decay instead. Outside the cavity as the distance increases the magnetic field approaches the classical solution. The plasma velocity first drops rapidly as the plasma enters the cavity boundary; for larger distances it decreases as 1/r towards its asymptotic value. We can find inward and outward moving solutions possessing distinctly different properties and explaining the dynamic nature of the cavity. The plasma density has a peak just outside the cavity, the density enhancement is more pronounced for weak comets, resulting in stronger than expected interaction and thus larger cavity.

2018

Description of the yearly scientific work.

We are participating in the ESA Juice project, which will arrive at Jupiter in 2030, eight years after its start in 2022. It will take measurements for two years around Jupiter. We develop high-reliability power supply units, DCC (direct current converter) for this program. The goal of the DCC is to ensure power for redundant DPU and 4 sensors of PEP experiment. After several meetings and discussions our preliminary plans to realize the job was accepted by PEP team. Figure 1shows the EM1 model (engineering model). Its goal was to make a working model for integration of EM version of PEP instrument. The EM1 after detailed tests worked correctly. In 2018 we delivered EM1 model for integration ongoing tests in Kiruna. Figure 2 shows separate DCC for a sensor called JDC developed by our team.

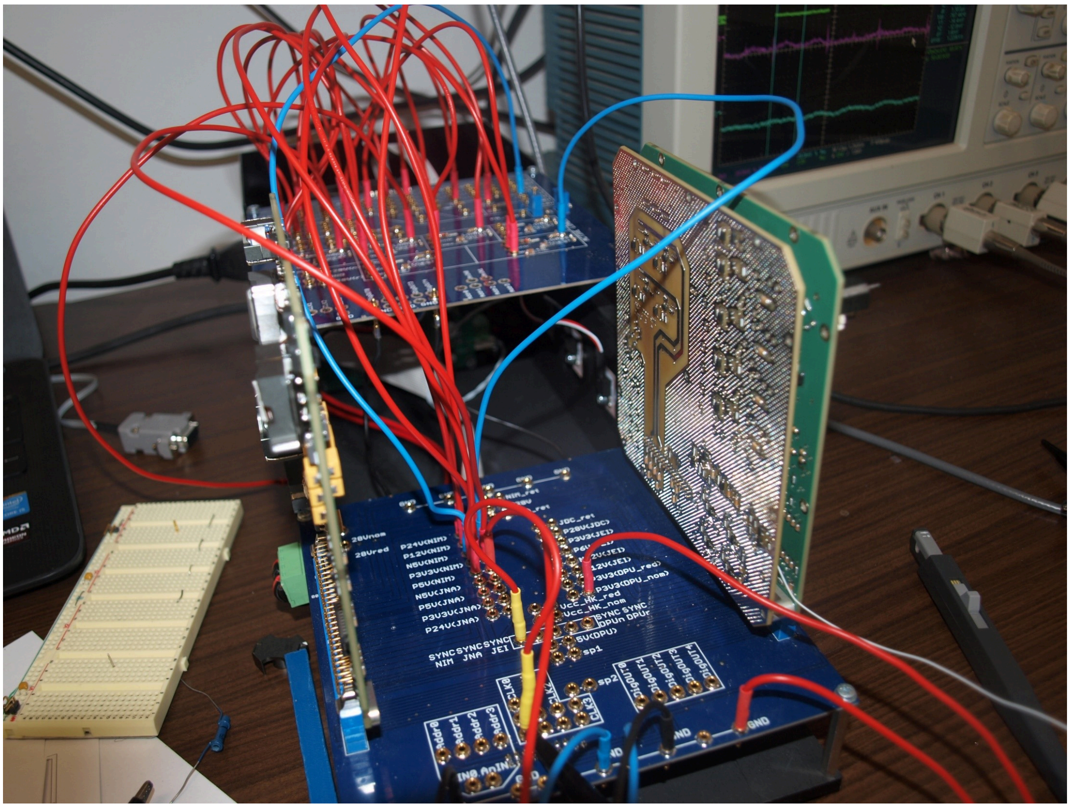


Figure 1. The EM1 model of DCC is under testing.

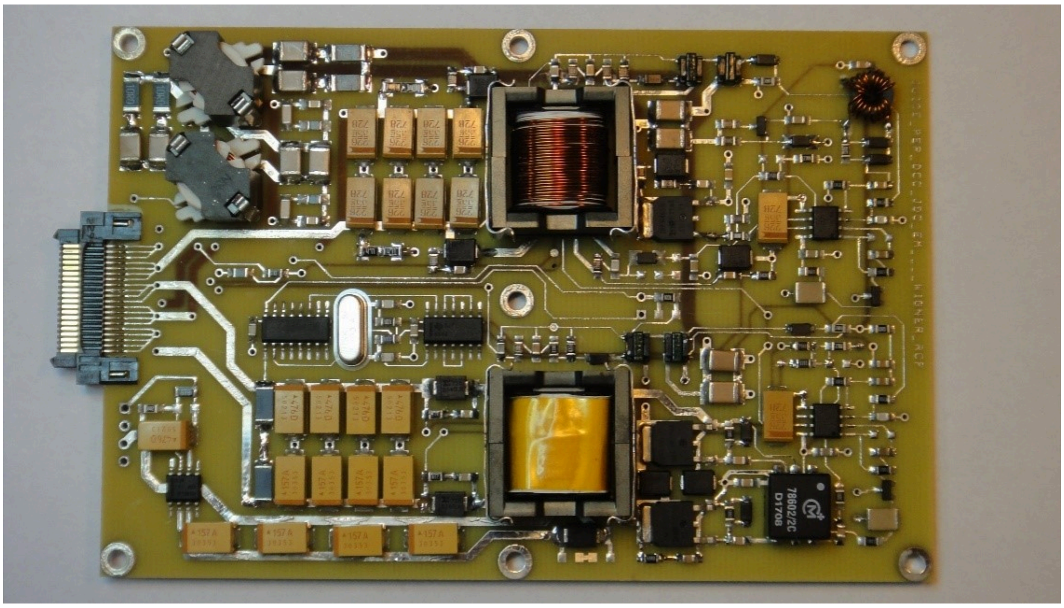


Figure 2. shows DCC for JDC sensor.

BepiColombo launched on Ariane-5 launcher from the Kourou Space Center on October 20 at 3:45 AM. The target of the spacecraft is Mercury. Two separate units, the European MPO (Mercury Planetary Orbiter) and the Japanese Mio (also known as Mercury Magnetospheric Orbiter, MMO), will be on track in 2025 around the Inner Planet of the Solar System. We participated in the development of the PICAM (Planetary Ion CAMera) ion-mass spectrometer in this project. The Picam acts as a camera for charged particles to study the chain of surface ionization processes. Our team's engineers have developed the PICAM low voltage power supply and the BepiColombo space probe simulation environment with the involvement of SGF.

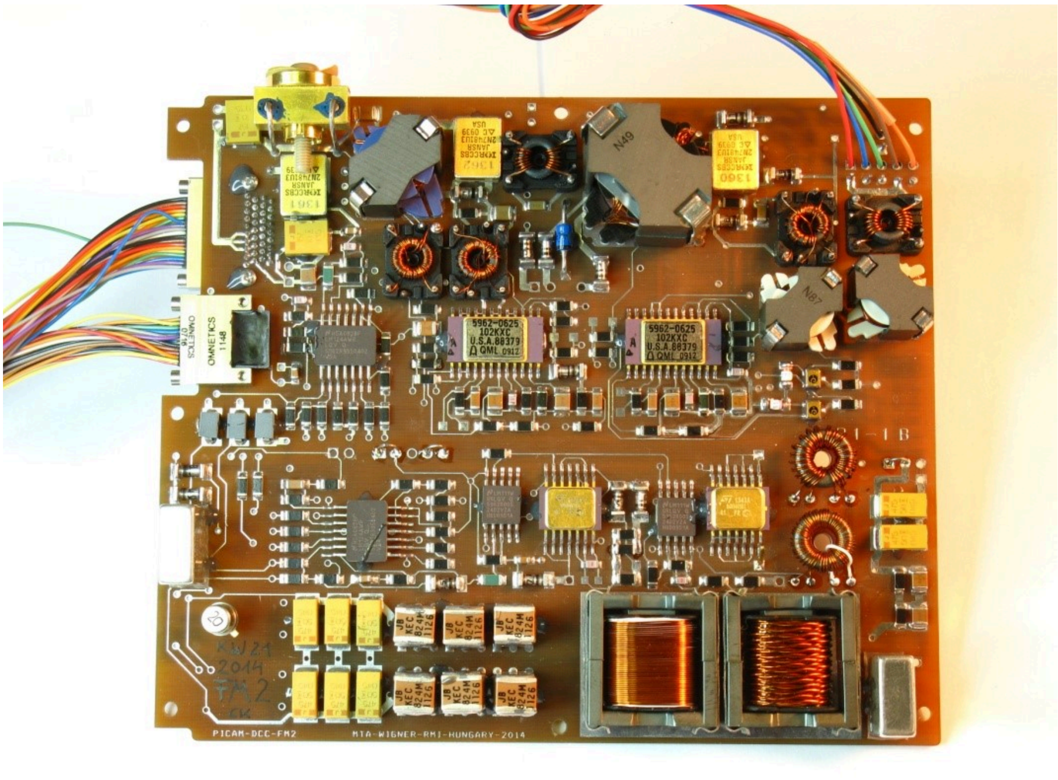


Figure 3. The engineering model of Picam power supply unit.

2017

The long duration of space exploration projects is presented by one of the longest interplanetary missions, the NASA-led Cassini-Huygens mission which ended on 15th September, 2017. Cassini-Huygens involved 17 countries, including our team. The purpose of the mission was the exploration of Saturn and its Titan moon. The mission-carrying missile was launched in Cape Canaveral in 1997 and reached the Saturn area in 2004. Researchers of our institute and our team participated in the development of EGSE (Electronic Ground Support Equipment) for monitoring equipment and calibration systems, the on-board magnetometer (MAG) and the plasma spectrometer (CAPS).

We are involved in the tender of the Zero Magnetic Laboratory in Fertőboz. Our team was modeling ideas of physicists to select optimal implementation. Fig.1. shows the built model (1:6) of the Ruben-5 coil arrangement for external magnetic field attenuation.

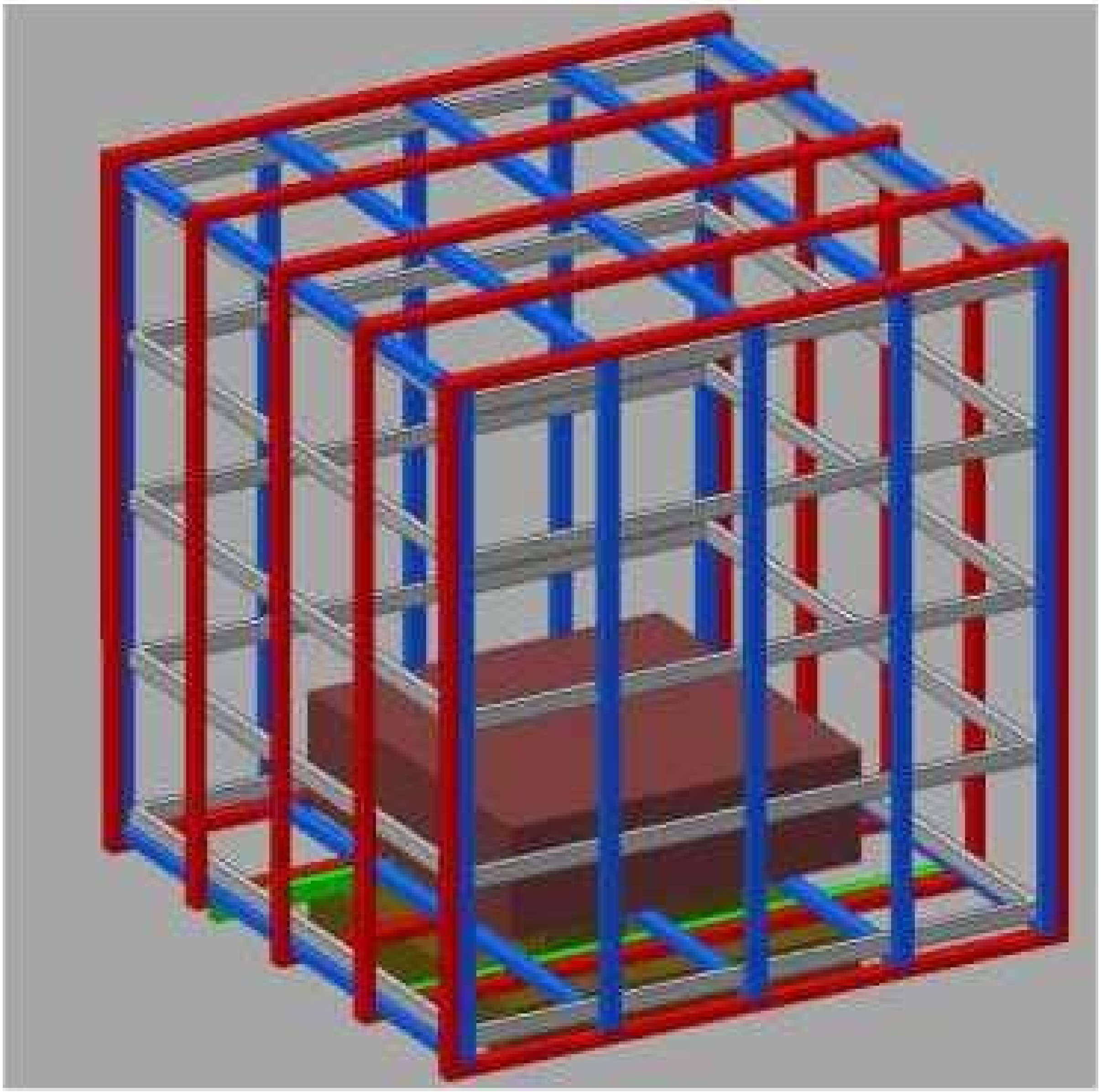


Figure 1. *The model of Zero Magnetic Laboratory, and plan of coil system arrangement.*

We are participating in the ESA Juice project, which will arrive at Jupiter in 2030, eight years after its start in 2022. It will take measurements for two years around Jupiter. We develop high-reliability power supply units for this program. Juice has been redesigned several times over the past few years due to weight and performance problems, which also affected the power supply unit we developed. In 2017, the engineering models were produced and then delivered to the Swedish Institute of Space Physics in Kiruna.

2017

The main focus of our research group is space plasma physics, we study plasma processes in our Solar System through spacecraft observations and modeling. We are involved in numerous space missions at all stages from design to data exploitation in collaboration with the Space Technology research group. The Rosetta mission (2004/2014-2016) has provided us with a huge amount of data about the cometary plasma. In 2017 we took farewell of the Cassini spacecraft that orbited Saturn for 13 years, and started to prepare for the next mission to a giant planet and its moons: the JUICE spacecraft, which targets Jupiter and its satellites. We use previous solar mission results to develop reliable solar wind prediction tools both in house and in international collaboration as part of the Europlanet Planetary Space Weather Services team.

Modeling dust delivery from Enceladus to the moons of Saturn. — The active geysers in the south polar region of Enceladus are sources of dust particles that sustain the vast E-ring of Saturn, extending out beyond Titan at 20 Saturn radii. The dynamics of the small micron and submicron particles escaping from Enceladus is primarily set by Saturn’s gravity, plasma drag, radiation pressure and electromagnetic forces. We developed simulations to follow different sized (0.1-5 micron) dust particles from Enceladus till their ultimate demise: being ejected from Saturn's magnetosphere, or hitting one of its moons. We determined the expected size, speed and spatial distributions of the impacting particles and identify their predicted anisotropies bombarding the leading/trailing hemispheres of the moons, possibly offering an explanation for their observed brightness features (Fig. 1).

Cometary Physics. — We calculated the diamagnetic cavity boundary distance around Comet 67P/Churyumov-Gerasimenko using various methods. We found that the global outgassing rate determines the position of the boundary with local pressure variations being suppressed, while the rapid changes in the external solar wind pressure at the position of the comet can explain the intermittent nature of the cavity crossing events (Fig. 2).

Interplanetary space. — The heliospheric magnetic field was investigated by the analysis of near-earth interplanetary measurements. It was shown, that structures recurrent with the solar rotation are persistent for a long time, both in the polarity (magnetic sectors) and the magnitude of the magnetic field. The origin of those structures are different, and also, the rotation period of the magnetic field enhancements, associated to Corotating Interaction Regions is slightly smaller than that of the magnetic sectors. The different rotation period suggests a major re-arrangement of the solar magnetic field during the declining phase of the solar cycles.

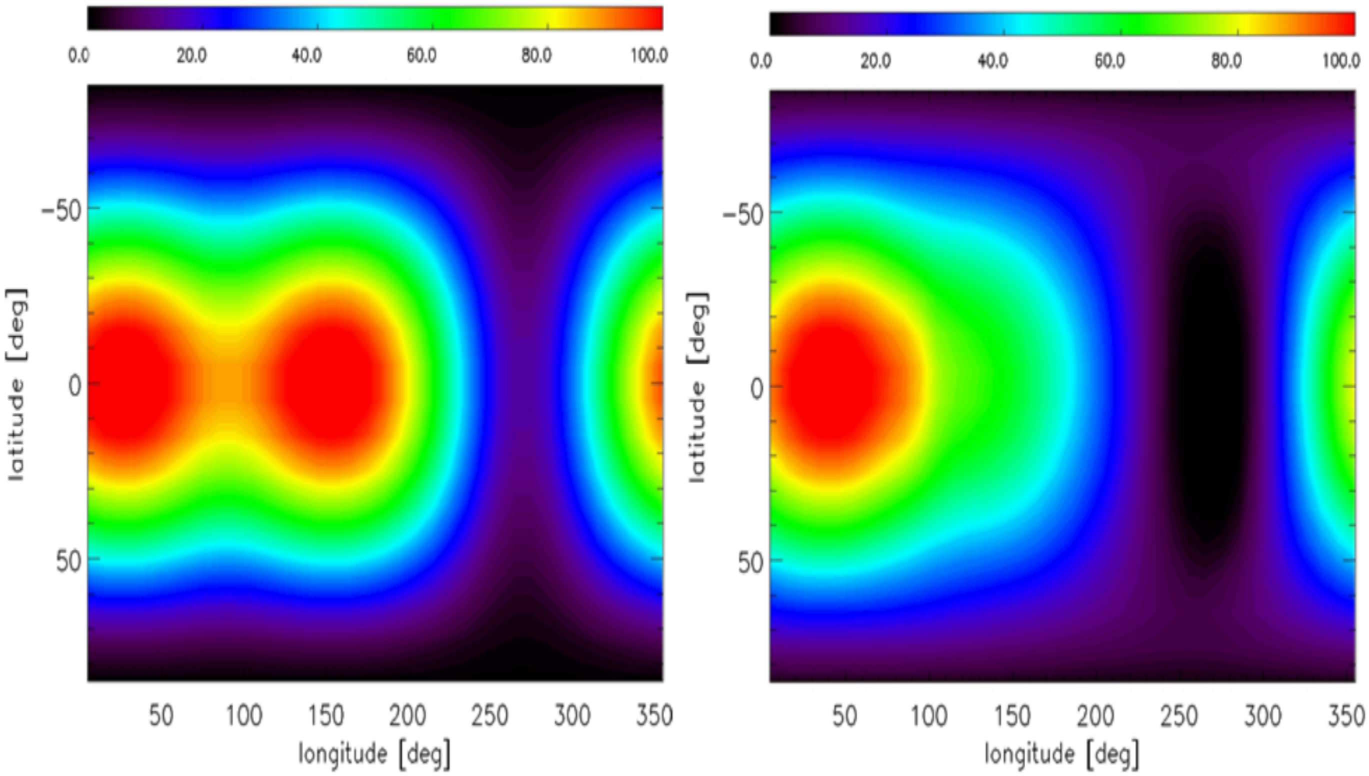


Figure 1. *The color plates show the E ring dust deposition map on the surface of moons Enceladus (left) and Titan (right). The longitude is measured from the anti-Saturnian direction and the 90 degrees marks the leading side of the moons. The modeled dust deposition rates are: 3400 kg/day for Enceladus and 460 kg/day for Titan. (Other moons, Mimas, Tethys, Dione and Rhea were modeled also.)*

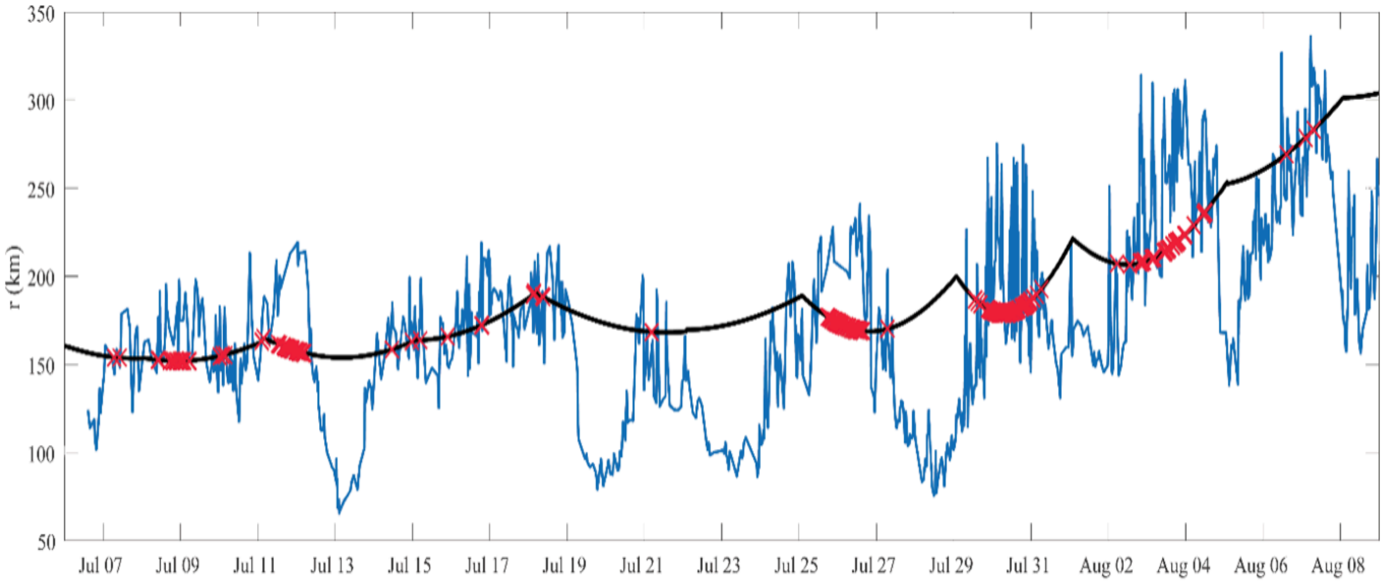


Figure 2. *Calculated cavity distance in July and August of 2015. The red signs mark the observed cavity crossing events, the black line is the distance of the Rosetta spacecraft from the cometary nucleus, and the blue line is the calculated distance of the cavity boundary from the nucleus.*

Suprathermal ions in the heliosphere. — By comparing the intensity peaks observed in the fluxes of suprathermal He, C, O, and Fe ions during the last two solar maxima we found marked differences and suggested that these ions were accelerated to suprathermal energies under different conditions in the solar corona.