FinCOSPAR 2022

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Abstracts

FORESAIL-2: System Engineering Challenges for Cubesat Missions in High Radiation Orbits

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The FORESAIL-2 is a high orbit CubeSat mission, developed by the Finnish Centre of Excellence in Research of Sustainable Space (FORESAIL), funded by Academy of Finland.

The main mission goal of this 6U-cubesat is to measure the ULF waves of the magnetic field around the Earth along with radiation measurements in radiation belts. The satellite makes accurate magnetic field measurements in the pc5 frequency range and measures electron and proton spectra, to study the dynamics of the most penetrating radiation in the Van Allen belts.

This satellite has three main instruments: Relativistic Electron and Proton Experiment (REPE) by University of Turku, Magnetometer Aboard the foreSail-2 cubesaT (MAST), developed by Austrian Space Research Institute, and Plasma Brake (PB), developed by Finnish Meteorological Institute. The PB is designed to demonstrate orbital maneuvers and current measurements by thin electrostatic tether which extends tens of meters. The spacecraft also features a deployable boom for precision magnetometer MAST.

The satellite is designed for geostationary transfer orbit, where it will pass through the radiation belts around the earth frequently. At the same time, the satellite is built mostly from Commercial Off-the-Shelf (COTS) components. Therefore, the design process concentrates on understanding and mitigation of the radiation environment inside the spacecraft.

A detailed radiation simulation for the FORESAIL-2 mission has been made to optimize the shielding of the electronic components of the satellite. As the CubeSat standard is also limited by mass, a tradeoff between the shielding mass and the available space inside, that can be used for components, has been made. Due to the radiation and the low perigee of the orbit a mission lifetime of around 6 months is expected.

The satellite will produce daily at least 25MB of data which has to be downloaded.

As UHF and VHF cannot provide the required data rates with the available ground stations, S-band sleeved dipole antennas will be used in full duplex configuration for communication. To get enough electrical energy for all systems and to control the deployments, the attitude has to be managed. The spacecraft will spin-stabilize itself up to 100 degrees per second. The attitude determination and control system (ADCS) will use resistojet technology, due to the weak earth's magnetic field at these distances.

Abstracts

From petascale to exascale: The Vlasiator semi-lagrangian grid-based plasma simulation in the age of GPU supercomputing

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The curious host galaxies of narrow-line Seyfert 1 galaxies

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Narrow-line Seyfert 1 (NLS1) galaxies are young active galactic nuclei (AGN). According to the current classification model, NLS1 galaxies do not have relativistic jets and they exist solely in spiral galaxies. We used J- and a Ks- band data from the Nordic Optical Telescope (NOT) to study properties of NLS1 host galaxies. Twelve of our sources have been detected at 37 GHz, indicating that these sources do have powerful relativistic jets. We created colour maps of the sources and determined their morphologies by using a 2D image decomposition algorithm GALFIT. We successfully modelled twelve sources, out of which ten are believed to present disk-like morphology. None of our sources are elliptical galaxies. Based on our findings, we conclude that the current AGN paradigm of only massive elliptical galaxies being capable of launching and maintaining relativistic jets is seriously outdated and in need of an update.

Abstracts

Large-scale high-latitude dayside aurora (HiLDA) during IMF By prevailing conditions

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Thanks to the new generation scanning imager onboard the DMSP spacecraft (F16-F19), new pictures of the polar cap and auroral oval have emerged in recent years. This study investigates a type of large-scale aurorae located in the dayside polar cap, so-called HiLDA, observed by the DMSP/SSUSI imager. While HiLDA in the northern hemisphere was reported before under interplanetary magnetic field (IMF) positive By conditions, we show for the first time a HiLDA event in the southern hemisphere when the IMF negative By component was dominant. Our observations also show that HiLDA is highly dynamical: change in its forms, size, location, and development of fine structures during its long lifetime of hours. The co-occurrence of HiLDA and the duskside oval-aligned transpolar aurora (TPA) may be a common feature during IMF By prevailing conditions. Both are associated with the high-latitude reconnection and the cusp. The generation of HiLDA requires the relatively high upward field-aligned current and the relatively low electron density in the magnetospheric source region. The source region maps most probably to the high-latitude lobe tailward of the cusp, where the electron density is down to 0.03-3 cm(-3). The total energy flux of HiLDA electrons can be up to 50 mW/m(2), indicating HiLDA precipitation as a potential energy source that impacts the polar ionosphere-thermosphere system.

Abstracts

The Vlasiator Ionosphere: Progress Report

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Vlasiator is a hybrid-Vlasov simulation model employed to represent plasma processes in near-Earth space. Recent simulations have encompassed the whole Earth's magnetosphere domain in 3D at kinetic scales, thus showing that the employed hybrid kinetic Vlasov approach has become computationally viable. This opens new avenues and possibilities in magnetospheric modeling.

However, simulations were constrained in their treatment of inner magnetospheric processes up to now. The simulations' inner boundary model had been formulated to treat Earth as a perfectly conducting sphere, absorbing all infalling plasma and neglecting ionospheric dynamics. While this model proved to be sufficiently precise for the science goals in large-scale magnetospheric dynamics, an update was ultimately required.

Hence, Vlasiator is being extended by an ionosphere model, consisting of a method to couple field-aligned currents onto an ionosphere grid, a solver for the ionospheric potential with a semi-empirical conductivity tensor, and a mechanism for the resulting electric fields to affect source terms in the magnetospheric inner boundary.

This presentation gives a progress report on the state of the ionosphere in Vlasiator, showing how coupling of FACs from the magnetosphere to the ionosphere presents itself in large-scale 3D hybrid-Vlasov simulations and discusses future avenues to improve the model beyond the state of the art.

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Abstracts

MiniPINS - Miniature Planetary Sensor Packages for Mars and Moon

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MiniPINS is an ESA study led by the Finnish Meteorological Institute to develop and prototype miniaturised surface sensor packages for Mars and the Moon. The study aims at miniaturising the scientific sensors and subsystems, as well as identifying and utilizing commonalities of the packages, allowing to optimise the design, cut costs and reduce the development time. The project has passed its Preliminary Requirements Review in 2021 and is currently in phase B1.

MINS is a penetrator with approx. 25 kg mass, piggy-backed by another Mars mission spacecraft to Mars and deployed either from the approach orbit or Mars orbit. 4 penetrators are planned to be released to different landing sites on Mars. The design of MINS has significant heritage from FMI's MetNet mission design [1]. In the Martian atmosphere the penetrators undergo aerodynamic braking with inflatable breaking units (IBUs) until they reach the target velocity of 60-80 m/s for entering the Martian surface. The penetration depth target is up to 0.5 m, depending on the hardness of the soil. The geometry of MINS penetrator includes a thin section to improve penetrability to the soil, a medium section with 150 mm diameter to accommodate a 2U CubeSat structure inside, and a top section with a wider diameter to stop the penetration and avoid the top part to be buried inside the soil. The deployable boom is accommodated in the top section along with the surface sensors.

LINS is a miniature 7 kg station deployed on the Moon surface by a rover. The baseline carrier mission for LINS is European Large Logistics Lander (EL3). 4 LINS packages are deployed to different sites within the rover's traveling perimeter by the rover's robotic arm. LINS thermal design enables its survival during 14-day long Lunar nights when the temperature drops down to -170 C. LINS consists of a double structure, with external separated from the internal by PEEK blocks. The bottom of LINS can be completely in contact with the lunar regolith, since it is isolated from the internal one, and the space between can accommodate additional thermal insulation. Additional heating power is provided by 3W RHU of European design.

In addition to traditional space qualified components, both surface sensor packages plan to utilize COTS components, like commercially available sub-systems for CubeSats, and qualify them for mission environment. For MINS this means especially landing shock and temperature, for LINS temperature and radiation.

[1] Harri et al. (2017), The MetNet vehicle: a lander to deploy environmental stations for local and global investigations on Mars, Geosci. Instrum. Method. Data Syst., 6, 103-124

Abstracts

Icarus – Witnessing the erosion of a near-Sun asteroid

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Icarus is an ESA F-class mission proposed for F2. The goal of Icarus is to identify the mechanisms that drive the observed activity on asteroids with small perihelion distances, erode their surfaces, and eventually destroy them completely. The same mechanism may also be one of the main contributors to the meteoroid environment among terrestrial planets. Icarus will rendezvous with a near-Sun asteroid, and monitor it and its surroundings before, during, and after a perihelion passage to a heliocentric distance of about 0.2 au. The instrumentation includes a high-resolution imager, a hyperspectral imager, a neutral and ion analyzer, and a dust analyzer. The mission will also include a nanospacecraft which is capable of optional science such as very-high-resolution imaging and/or radar sounding of the interior of the target.

Abstracts

Tool for optimizing the scientific operations and performance of the Mars lander

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For space projects, the availability of energy is a critical factor. The farther we go from the Sun the power of solar irradiance is weaker, at Mars it is 43 percent compared to the Earth. A special feature of Mars is the opacity of the atmosphere, as well as possible dust storms and sand floating in the atmosphere, which affect the solar irradiance received by the lander on the surface.

The most common methods for generating electrical energy in Mars are solar panels and a radioisotope thermoelectric generator (RTG). RGT produces energy all the time, regardless of the prevailing solar irradiance. For smaller landers, a combination of solar panels and batteries is usually sufficient. The possibility of using RTG as part of the energy production system has been considered in this work.

Payload and service electronics set the starting point for the design of the energy and power generation system. In addition to the electrical requirements, the mass and space limitations brought by the lander have to be taken account. The introduced tool was designed in the frame of the MetNet Mission and ESA MiniPINS study and both landers are relatively small and limitations are e.g. with the mass and volume of the batteries and available solar panels as well as the RTG. The optimization tool developed in this work provides virtually limitless possibilities to modify the energy system parameters, but due to the limitations imposed by the landers, in this study we do not simulate unrealistic alternatives for the selected landers.

The introduced optimization tool was developed in two steps. First with MS Excel, which was used to define realistic starting points, e.g. the number of solar panels and batteries and testing the static operating modes at different solar irradiance densities and subsystem efficiencies. Second, we use a Python tool that includes all the features of the Excel tool and we can simulate the operations with variable solar irradiances at any time of the day and season with one minute resolution. The required solar irradiance data is acquired and extrated from the Mars Climate Database covering almost the whole Mars surface. The developed tool is designed to simulate operations more than one Martian year, so with the tool, user can cover and simulate all seasons in any location on the Mars.

Devices on the surface of Mars operate fully autonomously. In this case, the availability of energy and optimized use of it are key factors. The lander service electronics must be able to operate even in non-optimal situations and, if necessary, interrupt scientific operations. These operations are controlled by the so-called cyclograms, i.e. pre-programmed operation plans, implemented by the lander computer when required. In this work, we simulate cyclograms for different operating conditions using the developed optimization tool.

Abstracts

MEDA PS & HS: First months on Mars onboard Perseverance

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Finnish Meteorological Institute (FMI) has provided a pressure measurement device (MEDA PS) and a relative humidity measurement device (MEDA HS) for NASA’s Mars 2020 rover Perseverance which landed in Jezero crater in February 2021. The sensors are part of Mars Environmental Dynamic Analyzer (MEDA), a suite of environmental sensors provided by Spain’s Centro de Astrobiología. MEDA’s principal goals are to provide continuous measurements that characterize the diurnal to seasonal cycles of local environmental near-surface environment.

MEDA PS and MEDA HS are designed, built and calibrated by FMI. Main scientific goal of both devices is to measure the meteorological phenomena (pressure and humidity) of the Martian atmosphere and complement the previous Mars mission atmospheric measurements for better understanding of the Martian atmospheric conditions.

MEDA PS is a pressure measurement device based on silicon micro-machined capacitive Barocap® pressure sensors developed by Vaisala Inc. The technology of the Barocap® has been used before in multiple missions, including MSL Curiosity and upcoming Exomars 2022 surface platform. MEDA PS is located inside the temperature controlled Instrument Control Unit (ICU) and connected to the atmosphere through a dedicated pipe. MEDA PS will measure the dynamics of the Martian pressure environment and is also able to detect rapid pressure changes.

MEDA HS is a miniature relative humidity device based on polymeric capacitive Humicap® humidity sensors developed by Vaisala Inc. The same technology has previously been used in MSL Curisity and ExoMars 2016 Schiaparelli lander. The humidity device is mounted on the Remote Sensing Mast providing ventilation to the ambient atmosphere through a filter protecting the device from airborne dust.

MEDA has been designed to work continuously around the clock, logging the environmental magnitudes among the daily operation of the Perseverance rover. Both MEDA PS and MEDA HS have been operating flawlessly and their meteorological data is available in Planetary Data System (PDS). Both sensors have delivered high accuracy measurements from the Martian surface and will continue to provide important meteorological observations and to support MEDA and other M2020 investigations.

Abstracts

Over 20 year global magnetohydrodynamic simulation of Earth's magnetosphere

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We present our approach to modeling over 20 years of the solar wind-magnetosphere-ionosphere system using version 5 of the Grand Unified Magnetosphere-Ionosphere Coupling Simulation (GUMICS-5). As input we use 16 s magnetic field and 1 min plasma measurements by the Advanced Composition Explorer (ACE) satellite from 1998 to 2019. The modeled interval is divided into 28 h simulations, which include 4 h overlap. We use a maximum magnetospheric resolution of 0.5 Earth radii (Re) up to about 15 Re from Earth and decreasing resolution further away. In the ionosphere we use a maximum resolution of approximately 100 km poleward of +-58 magnetic latitude and decreasing resolution towards the equator. With respect to the previous version GUMICS-4, we have parallelized the magnetosphere of GUMICS-5 using the Message Passing Interface and have made several improvements which have e.g. decreased its numerical diffusion.

In total we have performed nearly 8000 simulations which have produced over 10 000 000 ionospheric files and 2 000 000 magnetospheric files requiring over 100 TB (10^14 bytes) of disk space. We describe the challenges encountered when working with such a large number of simulations and large data set in a shared supercomputer environment. Automating most tasks of preparing, running and archiving simulations as well as post-processing the results is essential. At this scale the available disk space becomes a larger bottleneck than the available processing capacity, since ideally the simulations are stored forever but only have to be executed once.

We compare the simulation results to several empirical models, as well as geomagnetic indices derived from ground magnetic field measurements, and show that GUMICS-5 reproduces many solar cycle effects in the magnetosphere and ionosphere.

Abstracts

Electric solar wind sail's applicability and demonstration status

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The electric solar wind sail (E-sail) works by tapping momentum from the solar wind with the help of long and thin metallic tethers biased at high positive voltage. The positive charge of the tethers is maintained by a high-voltage source and an electron gun. The purpose of the electron gun is to produce a current which is equal to the thermal electron current gathered by the charged tethers from the surrounding solar wind plasma. Both positive and negative tether cause Coulomb drag. The E-sail uses positive polarity because in the solar wind conditions it is easier to do so.

The simplest E-sail has one tether. The Multi-Asteroid Touring Mission has a fleet of ~ 5 kg nanospacecraft flying through the asteroid main belt and making flyby observations of asteroids, with an Earth flyby at the end to return the data. The single-tether configuration enables pointing of the spacecraft independently of the tether rotation.

For multi-tether E-sails, the most stable tether rig dynamics is accomplished with ~ 16-30 tethers. A 30-tether E-sail produces 300 mN thrust at 1 au if one uses 20 km long tethers. Aluminium is a feasible material for such tethers. To keep the tether rig mechanically stable, the tips of the main tethers are connected by auxiliary tethers. The auxiliary tethers are also metallic and under voltage. If the tethers are galvanically connected in so-called TI-configuration, one can control the tether spinrate independently of thrust vectoring. In a heliocentric orbit there is a secular change of the spinrate caused by the orbital Coriolis effect. It must be compensated by spinrate control to enable a long duration mission.

North Star is a planned multi-tether pathfinder mission that flies at high speed out of the solar system, carrying a ~ 1 kg scientific payload, for example measurement of the universe's background light outside of the zodiacal cloud. North Star features a parabolic antenna that doubles as a solar concentrator and an attachment frame for the E-sail tether reels. Although it is a deep space mission, the ~ 25 kg North Star does not need an RTG (radioisotope thermoelectric generator) because it is fully solar powered.

At least with present technology, the maximum thrust of the E-sail is less than 1 newton, which makes it suitable to propel spacecraft whose mass is at most a few thousand kilograms. Thus, crewed E-sail missions are unlikely.

Three cubesats (AuroraSat-1, FORESAIL-1, ESTCube-2) are forthcoming whose mission is to deploy a few tens of metres of tether, charge it and measure the Coulomb drag that it experiences in low Earth orbit ionospheric plasma ram flow. AuroraSat-1 is launched Q2-2022 and the other two in 2022/23. Later cubesats (FORESAIL-2/3 and ESTCube-3) are under planning to try and measure the Coulomb drag effect in higher orbits that approach or reach the solar wind.

Abstracts

Spatio-temporal development of large scale auroral electrojet currents relative to substorm onsets

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Auroral electrojets are an integral part of the ionospheric current system and during auroral substorms the currents change rapidly. The latitudinal profile of the electrojets can be estimated from Low Earth Orbit satellites. To study the temporal and spatial evolution of the currents relative to the substorm onsets, we combine electrojet data derived from the Swarm satellite mission of European Space Agency with the substorm database derived from the SuperMAG ground magnetometer network data. We obtain statistics for the development of the integrated current and latitudinal location of the auroral electrojets. The major features of the westward electrojet derived from the Swarm data are found to be in accordance with earlier studies. Furthermore, after the onset the latitudinal location of the maximum of the westward electrojet determined from Swarm data is shown to be mostly located close to the SuperMAG onset latitude in the local time sector of the onset regardless of where the onset happens. In addition, the statistics show that the SuperMAG onset corresponds to a strengthening of the order of 100 kA in the median amplitude of the westward integrated current in the Swarm data.

On the possibility and relevance of small-scale dynamo action in the Sun

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Abstracts

Space weather advisories for civil aviation: Experiences gathered by the PECASUS service

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Finnish Meteorological Institute is leading the Partnership for Excellence in Civil Aviation Space weather User Services (PECASUS) which serves as one of the four global space weather centers providing airliners with advisories on space weather phenomena according to the standards of the International Civil Aviation Organization (ICAO). The space weather impact areas of ICAO interest include Global Navigation Satellite Systems (GNSS), long-distance HF communication (HF COM), and enhancements of radiation levels (RAD) at flight altitudes. In GNSS the parameters to be followed are the scintillation indices (S4 and σφ) and the Total Electron Content (TEC), while in HF COM the critical parameters are solar X-ray flux, Kp-index, Cosmic Noise Absorption as measured by riometers at 30 MHz, and depression in the Maximum Usable Frequency (MUF). Enhancements in radiation (microS/h) are estimated with a model addressing Solar Energetic Particles' interaction with the atmosphere. For each parameter ICAO has given thresholds excesses of which should trigger advisory issuances by the on-duty global space weather center. The advisories contain information about severity of the impact (moderate or severe), its onset time, geographic extent, and expected duration.

In the presentation we will discuss the lessons learnt during the first two years of official operations. It has appeared that particularly in scintillation and post-storm MUF depressions issuing advisories in a sensible way can be challenging. Both phenomena can have sporadic appearance both in time and in space. In such situations the goal is to provide users with clear and accurate information on prevailing storm conditions without overwhelming them with too many advisories. The Ad Hoc Coordination Group which includes representatives from the four global centers and from the user community is searching consolidated solutions for advisory formulation also in these challenging situations. Some aspects from that work will be discussed in the presentation, as well.

Abstracts

Type II radio bursts and their association with coronal mass ejections

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Metre wavelength type II solar radio bursts are the signatures of shock-accelerated electrons in the 'middle' corona. A study of these bursts can give information about the initial kinematics, dynamics, and energetics of CMEs in the absence of white-light observations, for example, a stealth CME. We investigate the occurrence of type II bursts in solar cycles 23 and 24 and their association with coronal mass ejections (CMEs). We also explore the possibility of the occurrence of type II burst in the absence of a CME. We performed a statistical analysis of all type II bursts that occurred in the solar cycle 23 and 24 and found the temporal association of these radio bursts with CMEs. We also categorized the CMEs based on their linear bursts and angular width and studied the distribution of type II bursts with 'fast', 'slow', 'wide' and 'narrow' CMEs. Our analysis shows a total of 768 and 435 type II bursts in solar cycles 23 and 24, respectively. We found that 80% and 95% of the type II bursts were associated with CMEs in solar cycles 23 and 24, respectively. Most of the type II bursts in both the cycles were related to 'fast' (54 %) and 'wide' (79 %) CMEs. We also set a typical drift rate and duration for type II bursts, 0.1-0.4 MHz/s, and 5-20 min, respectively. The results indicate that most of the type II bursts had a white-light CME counterpart; however, there were a few type II which may be related to flare blast waves.

Abstracts

Performance and Design of COTS Components-based Magnetometer for FORESAIL-1 CubeSat

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Magnetometers are among the most typical payloads on satellite missions. As the size and cost of satellites decrease, the requirements for magnetometers evolve. Small size and low power consumption must be combined with low cost while achieving performance satisfying stringent requirements set by modern science missions. These requirements have inspired the development of the Magnetometer Technology Test Instrument (MATTI). Developed by Aalto University, the novel magnetometer will fly as a secondary payload on-board the FORESAIL-1 CubeSat, a mission developed by the Finnish Centre of Excellence in Research of Sustainable Space (FORESAIL), funded by Academy of Finland.

The instrument's primary objective is to demonstrate and validate performance parameters in orbit. MATTI is based on commercial off-the-shelf (COTS) components available and affordable for a wide range of actors, and a successful performance demonstration can encourage developing more low-cost COTS-based science instruments for space applications. In addition, MATTI will serve as a learning platform for future missions, like FORESAIL-2, with more stringent requirements set for magnetic experiments.

The compact design of MATTI is based on three orthogonal anisotropic magneto-resistive (AMR) sensors that measure the total magnetic field vector. By using high current pulsing through the sensors, a technique typical for high performance AMR-sensing applications, great performance can be achieved while maintaining low power consumption. After a high accuracy analog-to-digital converter the signal processing is performed digitally. MATTI is designed to measure fields with frequencies below 15 Hz in a range of at least ±100 000 nT, and to achieve a noise floor less than 1 nT/sqrt(Hz). Digitally configurable data rates allow adapting to different mission phases when needed.

The launch of FORESAIL-1 and thus the beginning of the mission of MATTI is projected for the summer 2022. As the launch approaches, a final campaign to calibrate MATTI and characterize the achieved performance has recently been carried out, showing that the performance requirements are achieved. This is encouraging for scientists and engineers that might consider a COTS components-based approach for designing future low-cost science instruments for space missions.

Abstracts

Ionospheric Precipitation of Particles in the first 6D hybrid-Vlasov Vlasiator simulation

Thijs Luttikhuis (1), Maxime Grandin (1), Lucile Turc (1), Markus Battarbee (1), Yann Pfau-Kempf (1), Urs Ganse (1), Maxime Dubart (1), Konstantinos Papadakis (1), Harriet George (1), Jonas Suni (1), Markku Alho (1), Hongyang Zhou (1), Maarja Bussov (1), Vertti Tarvus (1), Konstantinos Horaites (1), Ivan Zaitsev (1), Giulia Cozzani (1), Fasil Tesema (1), Evgeniy Gordeev (1), Minna Palmroth (1,2)

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One of the most noticeable effects of solar-terrestrial physics is the aurora which regularly appears in the polar regions. This polar light is the result of charged particles originating from the magnetosphere that enter the Earth's atmosphere, which are called precipitating particles. We present the first results on auroral proton precipitation into the ionosphere using a 3-dimensional simulation of the Vlasiator hybrid-Vlasov model, driven with a southward interplanetary magnetic field and steady solar wind parameters. The hybrid-Vlasov approach describes ions through their velocity distribution function in phase space (3-dimensional ordinary space and 3-dimensional velocity space), while electrons are represented by a massless charge-neutralizing fluid. Vlasiator is a global model of near-Earth space, modelling the whole region of near-Earth space including the Earth's magnetosphere (whole dayside and part of the magnetotail), the magnetosheath, as well as the foreshock region and some solar wind. The initial conditions of Vlasiator are set as a Maxwellian distribution of particles with similar conditions as the incoming solar wind and the Earth's magnetic field is modelled as a non-tilted dipole. The inner boundary of the simulation domain extends 4.7 Earth radii. The precipitating proton differential number flux within 0.5–50 keV for this run is determined from the proton phase-space density contained within the bounce loss-cone, which has been set at a constant angle of 10 degrees everywhere. To find the precipitation of particles at ionospheric altitudes (in this case a height of 110 km above the Earth's surface), the magnetic field lines have been traced from the inner boundary of the Vlasiator domain onto the ionosphere using the Tsyganenko model. The resulting differential number fluxes and integral energy fluxes in the Vlasiator run have been compared to data of the Precipitation Electron/Proton Spectrometer (SSJ) instrument of the Defense Meteorological Satellite Program (DMSP), measuring precipitating protons from 30 eV to 30 keV, for several satellite overpasses during events with similar solar wind conditions as in the Vlasiator run. Typical values of the total integral energy flux are between 10^5 and 10^8 keV cm-2 s^-1 sr^-1. We discuss the similarities and the discrepancies between the Vlasiator proton fluxes and the DMSP observations.

Abstracts

Science with the James Webb Space Telescope

Seppo Mattila

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In this talk I will give a brief overview of the scientific capabilities of the James Webb Space Telescope (JWST) and its instruments. I will describe what kind of science programmes will be carried out during the first few months of the science operations. Finally, I will describe the potential offered by JWST for observations of extragalactic astrophysical transients including distant supernovae and electromagnetic counterparts of gravitational wave sources.

Simulations of improved glint observations over snow for CO2M

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To meet the climate change mitigation targets, global greenhouse gas emission monitoring is needed. In the Arctic and boreal regions, continuous monitoring can inform on the expanding anthropogenic activities and their emissions as well as the changing carbon cycle and natural CO_2 uptake in the changing climate. However, in the high latitudes there are numerous properties making observations difficult: large solar zenith angles, frequent cloud cover and snow.

Snow surfaces are highly forward-scattering and therefore the traditional nadir-viewing geometries over land might not be optimal and instead the strongest signal could be attainable in glint-like geometries. In addition, the contributions from the 1.6 µm and 2.0 µm CO_2 absorption bands need to be evaluated over snow. In this work, we examine the effects of a realistic, non-Lambertian surface reflection model of snow based on snow reflectance measurements on simulated top-of-atmosphere radiances in the wavelength bands of interest. The radiance simulations were carried out with various different viewing geometries, solar angles and snow surfaces. The effect of off-glint pointing was also investigated.

There are three main findings of the simulation study. Firstly, snow reflectivity varies greatly by snow type, but the forward reflection peak is present in all examined types. Secondly, glint observation mode was found to be more reflective than nadir observation mode over snow surfaces across all the examined wavelengths bands and geometries. Thirdly, the weak CO_2 band had systematically greater radiances than the strong CO_2 band which could indicate a greater significance in retrievals over snow.

ESA SNOWITE is a feasibility study funded by European Space Agency for examining how to improve satellite-based remote sensing of CO_2 over snow-covered surfaces. It is a cooperative project between Finnish Meteorological Institute, Finnish Geospatial Research Institute and University of Leicester. The primary aim of the project is to support the development of the upcoming Copernicus CO_2 Monitoring Mission (CO2M).

Abstracts

Asteroid photometric phase functions from Gaia observations

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Photometry is an important tool for characterizing the physical properties of asteroids. An asteroid's photometric lightcurve and phase curve refer to the variation of the asteroid's disk-integrated brightness in time and in phase angle (the Sun-asteroid-observer angle), respectively. They depend on the asteroid's shape, rotation, and surface scattering properties, and the geometry of illumination and observation. We present Bayesian lightcurve inversion methods for the retrieval of the asteroid's phase function, the unambiguous phase curve of a spherical asteroid with equal scattering properties. A collection of such phase functions can give rise to a photometric taxonomy for asteroids. In the inverse problem, on one hand, there are four classes of lightcurves that require individual error models. The photometric observations can be absolute or relative and they can be dense or sparse in comparison to the rotation period of the asteroid. On the other hand, the observations extend over varying phase angle ranges, requiring different phase function models. The photometry of the ESA Gaia space mission extends, typically, over a range of phase angles, where the photometric phase curve tends to be linear on the magnitude scale. The ground-based photometry can reach small phase angles, where the asteroids show an opposition effect, a nonlinear increase of brightness on the magnitude scale towards zero phase angle. We provide error models for all four classes of lightcurves and make use of linear or linear-exponential phase functions for phase angles below 50 degrees. We validate the modeling with the help of a numerical forward simulation followed by the application of the inverse methods and we apply the inverse methods to sparse absolute Gaia (from Data Release 2) and dense relative ground-based lightcurves and obtain absolute magnitudes and phase functions, with uncertainties, for nearly 500 asteroids. Finally, Gaia Data Release 3 is due in June 2022, allowing us to apply the methods to some 150,000 asteroids with high-precision photometry.

Abstracts

FORESAIL-1 cubesat mission to measure radiation belt losses and demonstrate de-orbit

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FORESAIL-1 satellite is the first small satellite mission in the series of scientific small satellite missions developed by the Finnish Center of Excellence Research in Sustainable Space. The satellite is a three-unit CubeSat whose primary mission is to measure radiation belt losses and demonstrate new de-orbit technology utilizing electrostatic tether. The development of the satellite started in 2018 and has proceeded to the final flight model verification and acceptance phases. The satellite is expected to be launched during summer 2022 on a Falcon 9 rocket.

The primary payload of the satellite is a Particle Telescope (PATE). The scientific objective of the PATE instrument is to measure the energy and flux of energetic particle loss to the atmosphere with a representative energy and pitch angle resolution over a wide range of magnetic local times utilizing a telescope and satellite's spinning motion. In the later phases of the mission, a shorter telescope is used to measure Energetic Neutral Atoms (ENAs) originating from the Sun.

The satellite's secondary payload is a Plasma Brake (PB) de-orbiting experiment. In the experiment the Plasma Brake is used to reel out a 60-meter-long tether out utilizing the satellite's spin motion. When deployed, the tether is charged with -1 kV potential to interact with the plasma environment in the outer ionosphere to create a plasma brake -force lowering the satellite's orbital velocity. The objectives are to demonstrate the existence of the plasma brake effect by lowering the orbit during the mission and eventually propellantless de-orbit capability at the end of the mission.

The satellite's avionics platform has been designed to be a precursor platform for the following beyond the LEO missions to the solar wind. Thus, the avionics system has been designed for high reliability and radiation tolerance in focus. The complete avionics system has been designed and tested in Aalto University, allowing greater flexibility on satellite's system design and component selection. The avionics platform utilizes both emerging inexpensive radiation hardened components and traditional COTS electronic components. The avionics system consists of a cold-redundant On-board Computer (OBC), Power Conditioning and Delivery Unit (PCDU), Battery pack (BATT) and UHF-band Telemetry, Tracking and Commanding (TT&C) radio subsystem. The satellite TT&C subsystem operates over radio amateur UHF-band utilizing Skylink-protocol which was developed for the platform. To achieve a spin motion required by the main payloads, the platform has an integrated magnetorquer based attitude determination and control system.

Abstracts

Evolution and assessment of hemispheric snow mass based on satellite data analysis

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Supporting Paris Agreement with space-based carbon dioxide observations

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During the last decade satellites have revolutionized global monitoring of human emissions. The space-based air quality observations, like nitrogen dioxide and sulphur dioxide, show in an efficient way where the air is most polluted, but also confirm air pollution reductions and reveal unknown sources. Recently also methane leakages from oil and gas sector have been detected by the ESA's air quality flagship satellite Sentinel 5P highlighting an economically efficient way for mitigating climate change by reducing un-reported greenhouse gas emissions.

Following the success of air quality observations, high hopes emerge also for revealing sources and sinks of carbon dioxide (CO2), the most important anthropogenic greenhouse gas responsible for the climate change. The present CO2 observations from space are temporally sparse and lack spatial coverage. A true game-change is expected by Copernicus Anthropogenic CO2 Monitoring Mission (CO2M) developed by ESA and planned to be launched in 2025. The mission will form the satellite component for the EU funded independent monitoring and verification system (MVS) capacity in support of the Paris Agreement and climate change mitigation.

In this presentation, satellite observations of CO2 and the on-going developments towards CO2 MVS are discussed.

Abstracts

Properties of cavitons and spontaneous hot flow anomalies in a global hybrid-Vlasov simulation

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The foreshock is a region upstream of Earth's bow shock characterised by the ultra-low frequency (ULF) waves generated by the interaction between shock-reflected particles and the solar wind. The non-linear evolution of the ULF waves can lead to the formation of cavitons, a type of transient structure, where the plasma density and magnetic field magnitude are simultaneously decreased well below their levels in the surrounding ULF wave field. Another similar transient type found in the foreshock are spontaneous hot flow anomalies (SHFAs), which additionally display enhanced temperatures in their interiors. Both of these transients are carried by the solar wind towards the bow shock, where SHFAs are believed to play a part in the shock reformation. Further, it is thought that cavitons may evolve into SHFAs by accumulating shock-reflected ions in their interiors. In this study, we use a global hybrid-Vlasov simulation to investigate the properties and evolution of cavitons and SHFAs in Earth's foreshock. We find that a third of the observed cavitons evolve into SHFAs, and a comparable amount of SHFAs form without a prior caviton stage. Inspection of the transients' propagation speed shows that the transients propagate upstream in the solar wind rest frame while they are carried towards the bow shock. We find that transients closer to the shock display larger depletions of density and magnetic field magnitude, and SHFAs have a larger propagation speed in the solar wind rest frame compared to cavitons.

Abstracts

Global hybrid-Vlasov simulations of foreshock waves and their transmission into the magnetosphere

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The foreshock is the region of near-Earth space extending upstream of the bow shock and populated with shock-reflected particles. It is home to intense wave activity in the ultra-low frequency (ULF) range, in particular “30-second” waves, named after their typical period at Earth. These waves are thought to be the main driver of ULF wave activity in the Pc3 range (10 – 45 s) observed routinely in the dayside magnetosphere and on the Earth’s surface. A handful of case studies with suitable spacecraft conjunctions have allowed simultaneous investigations of the wave properties in different geophysical regions, but the global picture of the wave transmission from the foreshock into the magnetosphere is still not known. In this study, we analyse global numerical simulations performed with the hybrid-Vlasov model Vlasiator to investigate Pc3 wave activity in near-Earth space. The simulations enable us to study the waves in their global context, and compare their properties in the foreshock, magnetosheath and dayside magnetosphere, for different sets of upstream solar wind conditions. We find in particular that the upstream Alfvén Mach number impacts strongly the wave power in all geophysical regions. The orientation of the upstream magnetic field, and thus the position of the foreshock, control the distribution of wave power in the dayside magnetosphere. We discuss the implications of these results for the propagation of foreshock waves across the different geophysical regions, and in particular their transmission through the magnetosheath.

EISCAT future prospects for Finnish Research Community

Thomas Ulich

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Abstracts

The EZIE satellite mission for measuring ionospheric electrojet currents

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The Electrojet Zeeman Imaging Explorer (EZIE) mission will study the auroral electrojets using remote sensing of the magnetic perturbations they create. EZIE was selected as a NASA heliophysics mission of opportunity in December 2020, and is currently under development at the Johns Hopkins Applied Physics Laboratory for a launch in 2024. The mission consists of 3 identical 6U cubesats, each of which will carry 4 compact spectropolarimeters that measure the Zeeman splitting of molecular oxygen thermal emissions around 118 GHz. Remote sensing utilizing the Zeeman effect gives information about the magnetic field at the location where the emissions originate. In this case the signal comes from about 80-85 km altitude in the upper mesosphere or lower thermosphere, much closer to the ionospheric electrojet currents than traditional ground- or satellite-based magnetometers. This allows smaller spatial structures of the electrojets to be investigated. By combining 4 measurement directions from each of the 3 satellites flying in a string-of-pearls configuration, a detailed picture of the electrojet current systems can be obtained. In addition to the auroral electrojets, also the equatorial electrojet as well as the mesospheric/thermospheric wind and temperature will be studied.

Abstracts

Magnetic-local-time dependency of radiation belt electron precipitation: impact on polar ozone

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The radiation belts are regions in the near-Earth space where solar wind electrons are captured by the Earth's magnetic field. A portion of these electrons is continuously lost into the atmosphere where they cause ionization and chemical changes. Driven by the solar activity, the electron forcing leads to ozone variability in the polar stratosphere and mesosphere. Understanding the possible dynamical connections to regional climate is an ongoing research activity which supports the assessment of greenhouse-gas-driven climate change by a better definition of the solar-driven variability. In the context of the Coupled Model Intercomparison Project Phase 6 (CMIP6), energetic electron and proton precipitation is included in the solar-forcing recommendation for the first time. For the radiation belt electrons, the CMIP6 forcing is from a daily zonal-mean proxy model. This zonal-mean model ignores the well-known dependency of precipitation on magnetic local time (MLT), i.e. its diurnal variability. Here we use the Whole Atmosphere Community Climate Model with its lower-ionospheric-chemistry extension (WACCM-D) to study effects of the MLT dependency of electron forcing on the polar-ozone response. We analyse simulations applying MLT-dependent and MLT-independent forcings and contrast the resulting ozone responses in monthly-mean data as well as in monthly means at individual local times. We consider two cases: (1) the year 2003 and (2) an extreme, continuous forcing. Our results indicate that the ozone responses to the MLT-dependent and the MLT-independent forcings are very similar, and the differences found are small compared to those caused by the overall uncertainties related to the representation of electron forcing in climate simulations. We conclude that the use of daily zonal-mean electron forcing will provide an accurate ozone response in long-term climate simulations.

Abstracts

Observation-based modelling of the energetic storm particle event of 14 July 2012

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Occasionally, particle detectors on board spacecraft measure strong intensity enhancements when an interplanetary shock driven by a coronal mass ejection (CME) crosses the spacecraft. Such events are referred to as energetic storm particle (ESP) events and are believed to be the result of continuous particle acceleration and trapping at the CME-driven shock. In this work, we present the results of a modelling effort of the ESP event of 14 July 2012 using the energetic particle acceleration and transport model named ‘PArticle Radiation Asset Directed at Interplanetary Space Exploration’ (PARADISE), together with the solar wind and coronal mass ejection (CME) model named ‘EUropean Heliospheric FORcasting Information Asset’ (EUHFORIA). The simulations illustrate both the capabilities and limitations of the utilised models. We show that the models capture some essential structural features of the ESP event; however, for some aspects the simulations and observations diverge. We describe and, to some extent, assess the sources of errors in the modelling chain of EUHFORIA and PARADISE and discuss how they may be mitigated in the future.

Abstracts

Magnetospheric Responses to Solar Wind Pc5 Density Fluctuations From 2D Hybrid Vlasov Simulation

Hongyang Zhou, Lucile Turc, Yann Pfau-Kempf, Markus Battarbee, Vertti Tarvus, Maxime Dubart, Urs Ganse, Markku Alho, Maxime Grandin, Harriet George, Andreas Johlander, Jonas Suni, Maarja Bussov, Kostis Papadakis, Kosta Horaites, Ivan Zaitsev, Giulia Cozzani, Minna Palmroth

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Ultra-low frequency (ULF) waves in the Pc5 range, with periods between 150 – 600 s, play a key role in the dynamics of Earth's magnetosphere, in particular through their interaction with radiation belt electrons. One important source of magnetospheric Pc5 waves are fluctuations of the upstream solar wind parameters in the same frequency range. Pressure variations in the solar wind are thought to result in a forced breathing of the magnetosphere, as the magnetosphere would expand and compress in response to the changing upstream conditions, which drives ULF waves inside the magnetosphere. The details of the interaction of these solar wind variations with the Earth's bow shock and magnetosheath, their impact on the magnetosheath plasma properties and how the fluctuations would change before reaching the magnetopause, remain however unclear. In this study, we investigate the influence of externally-driven density variations in the near-Earth space using global 2D simulations performed with the hybrid-Vlasov model Vlasiator. The new time-varying boundary setup in Vlasiator allows us to set Pc5 periodic density pulses coming from the upstream. The density pulses cause the breathing motion of the bow shock, create clear stripes of variations inside the magnetosheath, and modulate the electromagnetic ion cyclotron (EMIC) and mirror modes. We characterize the spatial-temporal variations of waves on the simulation plane within the magnetosheath and discuss the potential impact on the near-Earth environment.