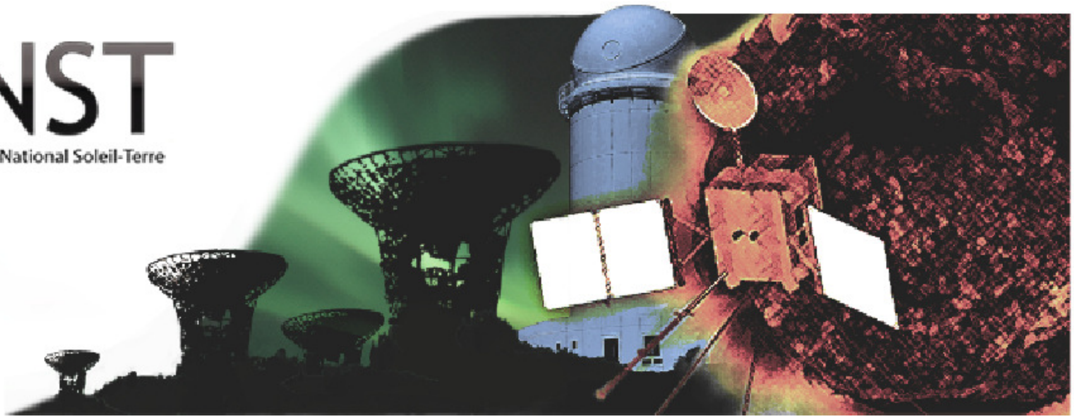

PNST : colloque scientifique et de prospective
Marseille, 8-12 janvier 2024

RÉSUMÉS ET LISTE DES PARTICIPANTS

Accès Web :

Site du colloque : https://pnst-2024.sciencesconf.org/

Site PNST : https://pnst.ias.u-psud.fr

PNST
Programme National Soleil-Terre

Le colloque scientifique et de prospective du PNST aura lieu du lundi 8 janvier (14h) au vendredi 12 janvier (12h) 2024 au village club du soleil de Marseille.

Ce colloque s'adresse à tous les chercheurs et étudiants de la discipline des plasmas magnétisés dans les environnements solaire et terrestre. Il traitera également du magnétisme solaire et stellaire et des plasmas planétaires qui sont aux interfaces du PNST avec la physique stellaire et la planétologie.

Le colloque comprendra 7 sessions scientifiques :

1. Simulations et outils numériques
2. Nouvelles missions et instrumentation (sol et espace)
3. Couplages entre enveloppes de plasma (ex : intérieur/couronne/vent solaire, vent solaire/magnétosphère, magnétosphère/ionosphère/haute atmosphère)
4. Transport d'énergie multi-échelles et turbulence (ex : Soleil, vent solaire, magnétosphères, échelles ionique et électronique, dynamo)
5. Mécanismes d'accélération des particules et chauffage du plasma (ex : couronne et vent solaires, magnétosphères, particules énergétiques)
6. Activité éruptive ou impulsive dans les plasmas (ex : couronne, magnétosphères terrestre et planétaires)
7. Relations Soleil-Terre et météorologie de l'espace (ex : observation/prévision de l'activité solaire, environnement spatial, conditions géomagnétiques, variabilité de l'irradiance)

ainsi que 6 tables rondes de prospective :

1. PNST et météorologie de l'espace
2. Services Nationaux d'Observation (SNO) du PNST
3. Prospective instrumentale (espace et sol)
4. Prospective numérique (HPC, HPDA, bases de données et cloud)
5. Communication vers le public, enseignement, science participative
6. Impact environnemental du PNST

Le colloque sera organisé autour des 7 thèmes en sessions orales contribuées et posters. Les posters seront au format A0 avec la plus grande dimension verticalement.

PNST
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Thème 1 : Simulations et outils numériques

Programme National Soleil-Terre

Overview of scientific and space weather forecasting tools provided by the Solar Terrestrial ObseRvations and Modeling Service (STORMS)

Matthieu Alexandre

IRAP, Université Toulouse III - Paul Sabatier, Observatoire Midi-Pyrénées, CNRS

We present an on-going effort to develop a public infrastructure to support research in heliophysics as well as space-weather forecasting. STORMS combines a wide range of observation and in situ measurements with heliospheric models to study and model the influence of solar activity on the near-Earth environment. Supporting operations and observational campaigns of space missions, such as Solar Orbiter, is an important goal for this service. The Magnetic Connectivity Tool, operational since 2019 has become a central tool for forecasting where Solar Orbiter should point its instruments during its coordinated remote-sensing and in situ campaigns. It determines the regions of the solar surface that may be connected with a spacecraft in a near future. Predicting solar wind properties is achieved by combining coronal and heliospheric models (Multi-VP, Pluto, 1D-MHD). Analysis of multi-point imaging to derive the 3-D structure of solar wind structures such as Coronal Mass Ejections (CMEs) and Corotating Interaction Regions (CIRs) is also performed (Shock Tool). Daily forecasts provides prediction to the scientific community and end users. As a community service, STORMS allows « run on request » simulations for users, helping them in studying a particular event. This is available through the VSWMC Virtual Space Weather Modelling Center and can be coupled with other models (EUHFORIA). Further STORMS services will integrate runs-on-demand of the new multi-species IRAP Solar Atmosphere Model (ISAM) and a full database of 3-D MHD simulations.

Nouvelles données et services offerts à la communauté par le CDPP

Nicolas André (1)

Nicolas Aunai (2), Menouar Azib (3), Myriam Bouchemit (1), Baptiste Cecconi (4), Philippe Garnier (1), Vincent Génot (1), Christian Jacquey (1), Alexis Jeandet (2), Aurélie Marchaudon (1), Ronan Modolo (5), Frederic Pitout (1), Ilya Plotnikov (1), Benjamin Renard (3)

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Dans cette présentation nous présenterons les derniers développements du CDPP, le centre national des plasmas spatiaux. Nous détaillerons les nouvelles données issues d'observations, de simulations numériques et de la mise en œuvre de techniques d'apprentissage automatique, ainsi que les nouvelles fonctionnalités offertes par les outils et services du CDPP pour l'étude de l'héliophysique, du système magnétosphère-ionosphère terrestre, de la planétologie, et de la météorologie spatiale.

Development of Machine Learning Techniques at CDPP for Event Detection in Multivariate Time Series Data

Menouar Azib (1,2)

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(1) IRAP, Université Toulouse III - Paul Sabatier, Observatoire Midi-Pyrénées, CNRS
(2) Akkodis

Recently, we introduced a novel deep-learning supervised approach for event detection in multivariate time series data. This method incorporates three distinct novelties compared to existing supervised deep-learning techniques. Firstly, it operates on regression instead of binary classification. This means it doesn't rely on labeled datasets where each point is specifically marked. Instead, it requires reference events defined as time points or intervals. Secondly, it exhibits robustness by employing a stacked ensemble learning meta-model. This meta-model combines various deep learning architectures, including traditional feed-forward neural networks (FFNs) and cutting-edge models like transformers. To support practical implementation, we've developed a Python package called eventdetector-ts that complements our proposed method. Compatible with Python 3, it can be easily installed via the Python Package Index (PyPI). In this paper, we not only present our method but also conduct a performance comparison against diverse architectures based on binary classification such as CNNs, LSTMs, and Transformers. This comparative analysis focuses on the detection of Martian bow shock crossings using the data of Mars Express (MEX) provided by CDPP-AMDA.

Un nouveau système orthogonal de coordonnées magnétiques : Le Dipôle Excentré Généralisé

Pierre-Louis Blelly (1)

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(1) IRAP, Université Toulouse III - Paul Sabatier, Observatoire Midi-Pyrénées, CNRS

La dynamique de l'ionosphère terrestre est fortement contrainte par deux systèmes de coordonnées associés aux milieux avec lesquels l'ionosphère est en interaction : une représentation géodésique (ou géocentrique) qui est associée à la dynamique de l'atmosphère neutre et une représentation magnétique associée à la magnétosphère. La conséquence de cette dualité est qu'il faut en permanence alterner entre les deux représentations pour caractériser les couplages et l'idéal est alors d'utiliser des systèmes de coordonnées orthogonaux. Si cela ne pose pas de problème pour la composante géodésique, la composante magnétique est dépendante d'une représentation en harmoniques sphériques (ex. IGRF) qui n'offre pas de système de coordonnées orthogonales sans simplification : en réduisant aux trois premiers coefficients on a le dipôle centré et en réduisant aux huit premiers coefficients on a le dipôle excentré. Si ces représentations sont bien adaptées loin de la planète et à hautes latitudes, elles peuvent poser problème à base altitude, notamment dans l'ionosphère de la région équatoriale. Pour surmonter ces difficultés, nous avons développé un système orthogonal de coordonnées magnétiques qui s'adapte à toute représentation du champ magnétique, en particulier celles avec une représentation en harmoniques sphériques. Son intérêt est qu'elle s'apparente à une représentation dipolaire tout en gardant les spécificités de la géométrie du champ, comme par exemple la géométrie particulière de la région équatoriale. Pour cela, nous l'avons appelé Dipôle Excentré Généralisé (DEG ou GED en anglais). Dans ce poster, nous présenterons les bases de ce système en mettant en avant les éléments caractéristiques. Nous présenterons également les éléments de la métrique associée que l'on peut calculer, ainsi que les méthodes mises en œuvre pour construire ce système.

Generation mechanism and beaming of Jovian nKOM from 3D numerical modeling of Juno/Waves observations

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The narrowband kilometric radiation (nKOM) is a Jovian low-frequency radio component identified as a plasma emission produced in the region of the Io plasma torus. Measurements from the Waves instrument onboard the Juno spacecraft permitted to establish the distribution of nKOM occurrence and intensity versus frequency and latitude.
We have developed a new 3D geometrical model called LsPRESSO (Large scale Plasma Radio Emission Simulation of Spacecraft Observations), that can simulate at large scale, the plasma emissions occurrence observed by a spacecraft. With this model, we propose a new method to discriminate the generation mechanism, propagation mode, frequency, beaming and radio source location of plasma emissions. Here, this method is applied for the study of the nKOM observed by the Juno/Waves spacecraft to identify which conditions best reproduce the observed occurrence distribution versus frequency and latitude. This study modeling is based on the VIP4 internal Jovian magnetic field model and a diffusive equilibrium model of the plasma density in Jupiter's inner magnetosphere. Our method applied to LsPRESSO allows us to exclude the two main nKOM models published so far, and to show that the emission must be produced at the local plasma frequency and beamed along the local gradient of these frequencies in the direction of decreasing frequencies. We also prove that depending on its latitude, Juno observes two distinct kinds of nKOM : a low frequency nKOM in ordinary mode at high latitudes and a high frequency nKOM in extraordinary mode at low latitudes. Both radio source locations are found to be distributed near the centrifugal equator from the outer edge to the inner edge of the Io plasma torus.

Open solar data, data products, and tools at MEDOC

Eric Buchlin (1)

Stéphane Caminade (1), Susanna Parenti (1), Barbara Perri (2), Frédéric Auchère (1), Nima Traoré (3), Khalil Ashkar (1), Dominica Leung (4)

(1) IAS, CNRS, OSUPS, Université Paris-Saclay (2) Dept. d'Astrophysique/AIM, CEA/IRFU, CNRS, Université Paris- Saclay (3) DSI Group (4) CNES

MEDOC (Multi-Experiment Data and Operation Centre), initially created as a European data and operation centre for the SoHO mission, has grown with data from other solar physics space missions, from STEREO to SDO, and now Solar Orbiter. In addition to observational data, MEDOC also provides datasets derived from observations (maps, catalogues...), tools for data analysis and interpretation, and numerical simulation results. We will present the current and future MEDOC interfaces, including APIs and VO services, data formats, implementation of DOIs, and how they contribute making MEDOC data Findable, Accessible, Interoperable, and Reusable (FAIR).

New insights into the consequences of different interplanetary conditions on the near-Hermean environment

Emanuele Cazzola (1,2)

Dominique Fontaine (1), Ronan Modolo (2)

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In this work we investigate the effects of different interplanetary conditions on the near-Mercury's dynamics by means of hybrid simulations. In fact, along its orbit Mercury experiences significantly different environments in terms of interplanetary magnetic field (IMF) intensity and direction, as well as solar wind density and velocity.
In particular, we show the variations occurring in the bow-shock / magnetosheath / magnetopause system under a Parker's spiral IMF configuration as the orbit passes from the Aphelion position at 0.47 AU to the Perihelion position at 0.30 AU, as well as the effects of solar winds at different velocities. We observe these boundaries being significantly compressed towards the planetary surface as result of the interaction with high dynamic pressure and/or high Alfenic Mach number conditions. Moreover, a quasi-radial IMF configuration leads to the formation of an intense foreshock region concurring to further affect the boundaries characteristics.
Finally, one of the main consequences of such a variable near-planet magnetic dynamics is the different rate, intensity and energy distribution of the interplanetary particles capable of precipitating onto the planetary surface. These particles are thought to be one of the main source of the neutrals seen in the exosphere. We observe that the precipitation mainly occurs along the open-lines magnetic cusps regions. Unlike what found from some past simulations, these regions show a significant longitudinal displacement from the north-south meridian line probably due to the quasi-radial configuration, as well as a latitudinal displacement towards the equatorial plane as the incoming solar wind compression increases. Additionally, the presence of a compressed magnetosphere / bow-shock scenario concurs to increase the precipitation rate in the equatorial regions.

MASER, un modèle de SNO science ouverte

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La paradigme de la Science Ouverte et les principes FAIR (Findable, Accessible, Interoperable, Reusable) vise à favoriser le retour scientifique, et renforcer la confiance dans la production scientifique. Nous présentons comment le Service National d'Observation MASER (Mesures, Analyses, et Simulations d'Emissions Radio) implémente la Science Ouverte à travers l'articulation de solutions existantes, et n'ajoutant de nouveaux éléments, seulement lorsque cela est nécessaire.
Le service MASER est une boîte à outil "science ready" et "science ouverte" dédiée aux données dépendantes du temps pour la radio-astronomie basse fréquence. Les principaux produits de données de ce domaine sont des "sepctres dynamiques", i.e., des séries temporelles spectres consécutifs, avec la même configuration d'observation. Les phénomènes physiques observés sont reliés à des instabilités plasma et aux particules énergétiques dans des plasmas magnétisés. Ainsi, la radio-astronomie est un outil de diagnostic à distance pour les plasma astrophysiques.
MASER couvre quatre besoins identifiés par cette communauté scientifique :

1. découverte de produits de données,
2. Exploration des collections de données, avant de charger de gros volumes (souvent plusieurs To de fichiers),
3. Enregistrement et distribution d'annotations sur les spectres dynamiques radio,
4. Accès aux collections en Python.

Les solutions MASER sont fondées sur les protocoles IVOA pour la découverte des données (standard EPN-TAP), sur les outils IHDEA pour l'exploration des données à distance, et un format spécifique développé par MASER pour les annotations (inspiré de GeoJSON). Le service MASER propose aussi un service de calcul à la demande pour le code ExPRES (Exoplanetary and Planetary Radio Emission Simulator) et bientôt pour le code ARTEMIS-P (Anisotropic Ray Tracer for Electromagnetics in Magnetospheres, Ionospheres and the Solar wind, including Polarization).
Le service propose aussi un entrepot de données pour partager les collections de données collections, les catalogues d'annotations, les documentations, ainsi que les "supplementary materials" associés à des publications du domaine. Chaque produit ou collection du dépôt est citable avec un DOI, et la "landing page" contient des métadonnées web semantique (schema.org), afin de maximiser la visibilité des enregistrements. L'entrepot MASER prépare la communauté concernée à Recherche Data Gouv, l'entrepot national de données.

Outils numériques adaptés au transfert radiatif et au calcul des champs de vitesse à la surface du Soleil

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Nous présenterons deux familles de codes numériques permettant l'interprétation des données spatiales solaires et stellaires passées (SoHO), en cours (Hinode, SDO, IRIS, Solar Orbiter) ou futures.

Il s'agit d'une part de codes de transfert radiatif hors ETL en 1D et 2D dédiés à diverses structures solaires (protubérances, filaments, chromosphères, ...) et stellaires. Certains de ces codes, en géométries 1D et 2D cylindriques, ont été développés à l'IAS. Le transfert radiatif (méthode de Feautrier) est calculé à la fois pour les continus et pour les raies appartenant à divers systèmes atomiques (H, He, Mg, Ca, Fe, Ni) et les champs de vitesse sont également inclus. D'autres codes développés à l'IRAP, en géométries 1D et 2D cartésiennes, incluent des méthodes désormais numériquement éprouvées comme MALI (Multi-level Accelerated Lambda Iteration). Une version 2D hors ETL incluant le traitement de l'équilibre d'ionisation de l'hydrogène et le transfert du continu de Lyman est accessible. Dans ce contexte, un benchmark spécifique au traitement de l'équilibre d'ionisation ainsi qu'une documentation idoine sont en cours de préparation. La plupart de ces codes sont maintenant disponibles, avec leur documentation, sur le site MEDOC à l'adresse suivante : https://idoc.ias.u-psud.fr/MEDOC/Radiative%20transfer%20codes

Il s'agit d'autre part de l'algorithme Coherent Structure Tracking (CST), un ensemble de codes IDL et Fortran 90 calculant le champ de vitesses horizontales à la surface du Soleil. Il utilise les granules solaires comme traceurs. Ces codes utilisent en entrée des images d'intensité SDO/HMI (hmi.Ic_45s), avec un pas temporel de 45s. Ils sont également disponibles sur le site MEDOC à l'adresse suivante : https://idoc.ias.universite-paris-saclay.fr/MEDOC/CST%20codes
La partie IDL est en cours de transcription en Python.

IRIS : a radiative transfer simulation tool for space-based GHG observation missions - Application to the Uvsq-Sat NG mission

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Frédéric Romand (2), Antoine Mangin (2), Mustapha Meftah (1)

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This presentation highlights IRIS, a Python tool for the simulation of space-based greenhouse gas (GHG) observation missions, currently in development. IRIS simulates radiative transfer from solar irradiance to top-of-atmosphere radiances at the entrance of a space-borne instrument, accounting for the passage through Earth's atmosphere and reflection from the terrestrial surface. The simulator will incorporate modules for instrument simulation (applying spectral response functions, noise, calibration biases) and greenhouse gas retrieval using a Levenberg-Marquardt algorithm.
The tool is designed to run a significant number of simulations addressing various geophysical, observational, and instrumental configurations. It can currently simulate low spectral resolution (2.5 nm) radiances and transmittances using the Py6S Python wrapper for the 6SV radiative transfer code. These first-order simulations will provide orders of magnitude of radiances at the sensor level, and enable acquisition conditions to be fine-tuned. Subsequently, another radiative transfer tool will be integrated into IRIS to obtain highly resolved TOA radiance spectra. These spectra will be used to accurately simulate the instrument and assess the mission's capacity to retrieve GHGs. The foreseen code for this task is SCIATRAN.
The impact of different conditions on radiances and transmittances have been obtained for the preparation of the Uvsq-Sat NG mission. IRIS represents a crucial tool for the development of space-based GHG observation missions.

Nature of Solar Wind Turbulence at Electron Scale

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Solar wind turbulence at electron scale is generally thought to be governed primarily by kinetic Alfvén waves (KAW), but the monofractal behavior observed is a puzzling problem that contradicts the standard properties of intermittency. In this Letter, we investigate this long-standing problem using direct numerical simulations (DNS) of three-dimensional electron reduced magnetohydrodynamics (ERMHD). Both weak and strong KAW turbulence regimes are studied in the balanced case. After recovering the expected theoretical predictions for the magnetic spectra, a higher-order multiscale statistical analysis is performed. This study reveals a striking difference between the two regimes, with the emergence of monofractality only in weak turbulence, whereas strong turbulence is multifractal. This result, combined with recent studies, shows the relevance of collisionless weak KAW turbulence to describe the solar wind at electron scale.

Modélisation statistique de la climatologie long terme de la scintillation ionosphérique

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L'ONERA / DEMR développe depuis plusieurs années l'outil STIPEE (Scintillation Tool for Ionospheric Propagation Event Evaluation). Ce dernier permet la génération de séries temporelles de signaux électromagnétiques affectés par la scintillation ionosphérique.
Les travaux récents menés dans le cadre d'études R&T CNES ont permis de régresser le comportement statistique long terme de la scintillation d'amplitude et de phase impactant les récepteurs GNSS. Pour cela, différentes bases de données ont été utilisées dont les mesures d'indices de scintillation ont été inversés. Ainsi à haute latitude les bases de données NMA (Norwegian Mapping Authority) ainsi que CHAIN (Canadian High Arctic Ionospheric Network) ont été utilisées couvrant le cycle solaire 24. Les mesures de scintillation de phase ont été inversées afin de modéliser le comportement statistique long terme, en décrivant la force intégrée de la turbulence ionosphérique alors que la vitesse de déplacement des inhomogénéités est modélisée par le modèle Superdarn. A faibles latitudes, ce sont les bases de données SAGAIE (en Afrique sub-saharienne) et Kourou qui ont été utilisées pour inverser l'indice d'amplitude S4 et régresser les caractéristiques des inhomogénéités ionosphériques.
Ainsi l'outil STIPEE propose aujourd'hui une modélisation de l'impact de la scintillation sur les signaux électromagnétiques la traversant, qui est fonction de la météorologie spatiale et des conditions solaires, et à toute latitude. Une série de fonctionnalités permet de recréer des séries temporelles d'amplitude et de phase, et les indices de scintillation typiques de signaux GNSS.

BibHelioTech : cataloguing and documenting all heliospheric events

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Richard Hitier (2), Axel Dablanc (3), Nicolas Aunai (4), Dominica Leung (5), Camille De Salabert (6)

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We present BibHelioTech a project aiming at cataloguing heliospheric events reported in the scientific literature. The algorithm analyses papers to extract start/stop times of events, the mission and instruments used, and the regions of space ; it also provides metrics on the pertinence of each interval. The catalogues can be ordered by mission or regions of space, and will be provided as a meta information while a user browses data in its favourite analysis software. The information that a given interval has already been studied, and a direct link to the original paper, will thus be provided. We believe BibHelioTech will greatly enhance the reproducibility of scientific results, help to perform statistical analysis, in line with Open Science principles. A web interface connected to the large ISTEX database, together with performances of the tool, will be demonstrated.

Simulations de l'environnement de Mercure pour l'analyse des mesures électrons de BepiColombo

Léa Griton (1)

Filippo Pantellini (1), Karine Issautier (1), Ahmed Houeibib (1)

(1) LESIA, Observatoire de Paris, Sorbonne Université, CNRS, Université Paris Cité

We aim to establish the boundaries of Mercury's magnetosphere through a comparison of the drops and rises of the electron density revealed by PWI/SORBET, during BepiColombo's first and second swing-bys of Mercury carried out on 1 October 2021 and 23 June 2022, with global 3D magnetohydrodynamic simulations. SORBET was switched on during both swing-bys and its radio spectra were re-analysed using a new method based on the theory of the quasi-thermal-noise spectroscopy and adapted to measurements registered with a non-deployed antenna (as planned for the entire cruise phase). In parallel, magnetohydrodynamical (MHD) global simulations of Mercury's magnetosphere were run under different solar wind conditions. Profiles of the electron density obtained from SORBET data were compared with three MHD simulations, using different values for solar wind sonic Mach numbers and plasma β. Some of those drops and rises of electron density are clearly identified with the boundaries of the magnetosphere (bow shock, magnetopause, and boundary of a region dominated by closed magnetic field lines) on the inbound part of the first Mercury swing-by. On the inbound part of the first swing-by, a good match is found between the SORBET data and the MHD simulations, revealing the quick reorganisation of the Mercury's magnetosphere in a variable solar wind. This study also highlights the essential role of the electron density in the future detection of Mercury's magnetosphere boundaries once BepiColombo will orbit the planet from December 2025.

Propagation of solar energetic particles in 3D MHD simulations of the solar wind

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Lea Griton (1), Filippo Pantellini (1)

(1) LESIA, Observatoire de Paris, Sorbonne Université, CNRS, Université Paris Cité

We propagate relativistic test particles in the field of 3D ideal MHD simulations of the solar wind in the inner heliosphere. We use the MPI-AMRVAC code (https ://amrvac.org/) for the wind simulations and integrate the relativistic guiding center equations to solve the particle trajectories. To do so, following Mignone et al. (Comp. Phys. Comm., April 2023), we adopt a third order time step accurate prediction-correction method. Sample objectives are the propagation and diffusion of solar or extra-solar energetic particles in a stationary or in a CME perturbed wind.

MHD simulations in the Solar Terrestrial ObseRvations and Modeling Service (STORMS)

Mikel Indurain

IRAP, Université Toulouse III - Paul Sabatier, Observatoire Midi-Pyrénées, CNRS

As part of the Solar Terrestrial ObseRvations and Modeling Service (STORMS), an important development axis is the continual provision of heliospheric magnetohydrodynamic (MHD) simulations of solar winds and storms from the Sun to the near-Earth environment. The MHD models developed and run at STORMS exploit two different types of data-driven boundary conditions : solar surface magnetograms and direct white-light observations. We will show that the forecasting performances of these MHD models depend on the choice of boundary conditions which in turn is related to the level of solar activity. In addition to presenting the physics, the performance and the underlying assumptions of these models we will present the visualisation interfaces available to browse and download these simulations on the STORMS website. We also show how a subset of these simulations are also made available through the VSWMC Virtual Space Weather Modelling Center and can be coupled with other models (EUHFORIA). A « run on request » mode for users can help user in studying a particular event.

SciQLop : Simplifying In-Situ Space Physics Data Analysis

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The **SciQLop project**, short for the **Sci**entific **Q**t application for **L**earning from **O**bservations of **P**lasmas, addresses the challenge of analyzing in-situ space physics data stored on remote servers like the Coordinated Data Analysis Web (**CDAWeb**) or Automated Multi-Dataset Analysis (AMDA). Accessing and interpreting data from a single instrument or spacecraft mission can be technically complex, involving locating, retrieving, and understanding data. Building machine-learning pipelines that span multiple instruments and missions compounds these challenges.
The core objective of SciQLop is to alleviate these technical hurdles without compromising performance, enabling scientists to concentrate on data analysis. The SciQLop suite comprises several tools :

- Speasy : A user-friendly Python package for retrieving data from remote servers with advanced multi-layer cache support.
- Speasy_proxy : A self-hostable remote cache, designed to enhance Speasy's efficiency and flexibility.
- Broni : A Python package facilitating the identification of intersections between spacecraft trajectories and simple shapes or physical models, such as magnetosheaths.
- Orbit-viewer : A Python graphical user interface (GUI) complementing Broni, providing a user-friendly interface for trajectory visualization.
- TSCat : A Python backend for event catalog storage, crucial for organizing and managing data events.
- TSCat-GUI : A GUI for TSCat, simplifying event catalog visualization and editing.
- SciQLop-GUI : An extensible and efficient user interface equipped with an embedded IPython terminal, designed for time-series visualization and labeling.
- (py)CDFpp : A fast C++ CDF codec with Python bindings.

While certain components are production-ready and already utilized in scientific research, SciQLop remains under active development in response to the evolving landscape of space physics data analysis.
This poster presentation aims to showcase how SciQLop streamlines the analysis of extensive in-situ data, making it both accessible and rapid. We also invite collaboration and feedback from our user community to further enhance this valuable resource.

CDPP 3DView web-service for SMILE SXI synthetic X-ray observations

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The SMILE (ESA/CAS) mission is designed to investigate the dynamic response of the Earth's magnetosphere to the solar wind impact in a global manner through simultaneous X-ray and UV imaging and in situ plasma and magnetic field measurements. The UK-led Soft X-ray Imager (SXI ; Sembay et al. 2016) will measure soft X-ray emission resulting from the radiative de-excitation of the multi-charged ions (C, N, O, ...) of the solar wind which charge-exchange (SWCX) with planetary neutrals in the Earth's magnetosheath and cusps. These emissions are proportional to the solar wind ion flux and to the density of the neutral targets and are therefore sensitive to variations in these quantities. In regions of solar wind plasma pileup, such as the subsolar magnetosheath and polar cusps, the emission is enhanced, paving the way for imaging of these key regions of the Sun-Earth system. The SMILE Modeling Working Group (MWG ; https://smile.alaska.edu/) strives to collect and homogenize the parameters of various simulations and provide synthetic observations to help interpret the future SMILE data. LATMOS has been developing test-particle simulations to complement the traditional MHD approach (see talk by Xu et al.). The MWG simulation library will be integrated to the ESA SMILE L4 product database. LATMOS and IRAP have proposed a new web-service in the 3DView tool, developed and maintained by CDPP (Centre de Données de Physique des Plasmas), in order to support the scientific feedback of the SMILE mission. The service proposes the possibility to visualize an SWCX X-ray intensity/flux map for SMILE observation configurations and propose a 3D scene to facilitate the comprehension of the geometry of the observation. We present the basic functionalities of the web-service and future developments considered in order to enhance the inter-operability between the MWG simulation archive and future SXI observations.

Modélisation des environnements neutre et ionisé de Callisto

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Des quatre lunes galiléennes, **Callisto** est la plus éloignée de Jupiter, orbitant à 26,3 rayons joviens de celle-ci. Les caractéristiques de la surface de Callisto semblent indiquer un corps très peu actif géologiquement, composé de roche et de glaces en quantités égales. La lune possède une atmosphère ténue dominée par le dioxygène [Cunningham et al., 2015] et le dioxyde de carbone [Carlson et al. 1999]. La mission Galileo de la NASA a pu détecter la présence d'un champ magnétique induit qui pourrait traduire l'existence d'un océan subglaciaire sur cette lune. Le satellite possède également une ionosphère caractérisée par des densités maximales d'environ 10^4 cm^{-}3, mais uniquement lorsque l'hémisphère situé à l'opposé du mouvement de Callisto autour de Jupiter est éclairé par le Soleil [Kliore et al., 2002]. L'environnement de Callisto interagit avec la magnétosphère de Jupiter dans laquelle elle baigne, ce qui a entre autre pour conséquence l'érosion de sa surface ou encore la formation d'ailes d'Alfvén. De plus, à la distance où Callisto orbite autour de Jupiter la magnétosphère évolue en magnétodisque, ainsi au cours de son mouvement la lune traverse des environnements variés en raison de son excursion latitudinaire magnétique.
L'**interaction entre l'environnement plasma et neutre de Callisto et la magnétosphère** reste encore assez mal comprise. Ainsi dans le cadre de la **mission JUICE**, dont l'arrivée est prévue fin 2031 et dont l'un des objectifs est de survoler la lune à plusieurs reprises afin de l'étudier plus en détail, le lancement de simulations permettant de décrire les environnements neutres et ionisés est prévu. Ces simulations se feront à l'aide du **modèle 3D générique parallèle multi-espèces LatHyS** [Modolo et al., 2016 ; 2018] couplé au **modèle exosphérique 3D générique multi-espèces EGM** [Leblanc et al.,2017 ; Oza et al., 2019]. Les caractéristiques du système étudié ne permettant pas d'utiliser une approche MHD, les modèles utilisés sont basés sur le formalisme dit « hybride » dans lequel les ions sont décrits par un ensemble de particules numériques à poids ajustable, les électrons eux étant représentés par un fluide sans inertie préservant la neutralité de charge du plasma et le couplage entre ions et électrons se faisant au moyen des équations de Maxwell. Les données issues de ces simulations seront ensuite examinées au regard des données issues des précédentes missions in situ (**Galileo, Juno**) ainsi que des observations à distances (**Hubble ST**) afin de les valider, comme cela a déjà été effectué avec succès par le passé pour Mars par exemple [eg. Leblanc et al., 2017 ; Modolo et al., 2018 ; Romanelli et al., 2019]. Afin de mieux contraindre l'environnement dans lequel orbite Callisto, les données de la mission Juno seront utilisées.

Modélisation de la température de la source des vents solaires lents et rapides à l'aide d'un modèle fluide multi-espèces à 16 moments

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La compréhension des propriétés générales des différents vents solaire passe par la compréhension des phénomènes à leur source. Les propriétés du vent solaire sont influencées par les échanges d'énergie à la base de la couronne solaire. Par exemple, la vitesse du vent solaire est fortement influencée par le niveau de chauffage en dessous du point sonique. Le chauffage qui se produit dans la partie collisionnelle de l'atmosphère modifie le niveau d'ionisation des éléments lourds et donc leur état de charge. C'est pourquoi les rapports d'état de charge des ions lourds mesurés dans le vent solaire sont de bons paramètres pour distinguer les vents solaires rapides des vents solaires lents. Dans cette étude, nous exploitons le nouveau modèle atmosphérique solaire de l'Irap (ISAM) pour étudier le niveau d'ionisation des ions lourds transportés dans les vents solaires rapides et lents. ISAM est un modèle multi-espèces à 16 moments qui couple de manière auto-consistante les équations de transport des particules neutres et ionisées (H, p, e, He, O et Mg) de la basse chromosphère au vent solaire en passant par la couronne solaire. La basse couronne est une région fortement couplée à la région de transition par le flux de chaleur descendant.
En résolvant d'abord pour H, p et e, nous retrouvons les résultats des modélisations antérieures montrant que les variations de la température de la source modifient la pression de la région de transition qui, à son tour, module le flux de masse du vent solaire. En utilisant une fonction de chauffage ad-hoc caracterisée par une hauteur d'échelle inversement proportionnelle au facteur d'expansion des lignes de champ magnétique canalisant le vent solaire, nous retrouvons d'abord les propriétés générales du vent solaire rapide et lent ainsi que l'observation connue que la température de la source du vent lent est plus élevée que celle du vent rapide. Nous résolvons ensuite explicitement les processus d'ionisation et le transport couplé de l'oxygène avec les espèces majoritaires (H, p, e) afin d'isoler les différents processus qui contribuent au niveau d'ionisation des ions lourds. Nous comparons les résultats de notre modélisation avec des données spectroscopiques et in situ. Ce travail a été financé par l'ERC SLOW SOURCE - DLV - 819189.

Numerical study of ionospheric diamagnetic cavities

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Various phenomena naturally occur in the ionosphere, as aurorae, striations or equatorial spread F and can affect human space activities. A few decades ago, baryum releases were performed to study these perturbations and the instabilities induced. These can be modelled as the expansion of an energetic plasma in the ambient geomagnetic field.
One of the first stages observed is the birth and growth of a diamagnetic cavity, inside which the magnetic field almost vanishes, due to fast ions going through the magnetic field lines. Once the diamagnetic cavity is formed, several boundary instabilities are allowed to rise, like the Rayleigh-Taylor instability or the large Larmor radius instability. These instabilities lead to a structuration of the plasma, appearing mainly as striations or flutes at the interface.
These phenomena have been studied with full particle, hybrid or non-ideal magnetohydrodynamics (MHD) codes but also through laser experiments that are able to mimic the physical conditions and allow a better understanding of the physical process. We propose to use an adapted version of the 3D multi-fluid MHD code CLOVIS, specially developed to investigate ionospheric natural disturbances. The model is based on Euler equations for the neutral fluid and Euler-Maxwell equations with ideal MHD assumptions for the charged fluid.
Our simulation results were already able to reproduce features of a diamagnetic cavity observed in baryum releases experiments. Further advances in the development of CLOVIS allow us to explore conditions closer to laser experiments, and compare our measurements of the cavity radius to those found in experimental studies and hybrid codes. Other key features will be exploited such as the emergence of striations at the plasma edge or the size of these structures, as they provide valuable insights on the growth of instabilities.

Energetic Neutral Atoms at Ganymede and Europa : preparation to the JUICE mission

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The JUICE (JUpiter ICy moon Explorer) mission, launched by the European Space Agency in April 2023, the first large mission within the Cosmic Vision Program 2015–2025, will arrive in the jovian system in 2031 and it will provide the most comprehensive exploration to date of the Jovian system in all its complexity, with particular emphasis on Ganymede as a planetary body and potential habitat (JUICE Red Book, 2014). The Galilean satellites are known to have thin atmospheres, technically exospheres (McGrath et al., 2004), produced by ion-induced sputtering and sublimation of the surface materials. These moons and tenuous atmosphere are embedded in the flowing plasma of the jovian. The interaction between the neutral environments of the Galilean satellites and the jovian plasma changes the plasma momentum, the temperature and generates strong electrical currents.

A modeling effort has been carried out at LATMOS (PhD R. Allioux, IRAP, 2012 ; L. Leclercq, LATMOS, 2015 ; O. Apurva, LATMOS, 2017, PhD C. Baskevitch, 2023). A 3D parallel multi-species hybrid model (Latmos Hybrid Simulation, LatHyS) has been developed to model and characterize the plasma environment of Ganymede (Leclercq et al, 2016 ; Modolo et al, 2016) and Europa (Baskevitch et al, 2023, in prep) and a 3D parallel multi-species exospheric model (Exospheric Global Model, EGM) to pattern the dynamic of the neutral envelopes of Ganymede (Turc et al, 2014 ; Leblanc et al, 2017) and Europa (Oza et al, 2019 ; Leblanc et al, 2023). A first attempt to couple 3D exospheric and magnetospheric descriptions to characterize Ganymede's ionosphere has been achieved by Carnielli et al, (2019, 2020a,2020b).

Among the measurements that will be performed by JUICE, the Particle Environmental Package will be able to monitor the interaction with the ENA imaging technique. We use the same approach than Holmström et al (2002) to calculate the ENA fluxes, applied to LatHyS and EGM results. We present some possible ENA images that could be obtained for different configurations.

Gyrofluid models for turbulence and reconnection in space plasmas

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The description of turbulence and reconnection in collisionless space plasma such as the solar wind or planetary magnetospheres is challenging, especially when a wide range of scales is to be retained, or parametric studies are to be performed. It is then of great interest to use a reduced description of the low-frequency dynamics, such as provided by gyrofluid models which capture some important kinetic effects. The aim of this talk is to present a short review of three recent results obtained by simulation of a two-field Hamiltonian gyrofluid model retaining ion finite Larmor radius corrections, parallel magnetic field fluctuations and electron inertia [1,2]. This model describes the quasi-perpendicular dynamics of Alfvén and kinetic Alfvén waves, as well as inertial kinetic Alfvén waves (such as detected by MMS in the Earth's magnetosheath) and is suitable for studies of collisionless reconnection. We first demonstrate the development of a reconnection mediated regime in the three-dimensional reduced MHD turbulence that develops from collisions of counter propagating Alfvén-wave packets at various levels of the nonlinearity parameter [3]. We then discuss Alfvenic turbulent cascades, from the MHD to the sub-ion scales [4], when there is a strong imbalance between the energies of the co- and contra-propagating waves (such as observed by Parker Solar Probe close to the Sun). In this regime, we will show that a so-called "helicity barrier" emerges between the MHD and the kinetic scales, which causes the development of a transition range in the magnetic-field spectrum across the ion scales. We also briefly discuss, as a function of the ratio of ion to electron temperatures, the development of turbulence that results from secondary instabilities in the nonlinear phase of 2D collisionless reconnection [5]. The nature of this turbulence, which transfers energy to sub-electron scales, is affected by the presence of electron finite Larmor radius effects. We conclude by presenting a new 4-field model that captures these effects, as well as the coupling between Alfvén- and slow-magnetosonic waves.

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Impact of far-side structures observed by Solar Orbiter on wind simulations

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Solar Orbiter is a new space observatory that provides unique capabilities to understand the heliosphere. In particular, it has made several observations of the far-side of the Sun, unobservable from the Earth. This data could be very useful to improve space weather forecasting, especially at maximum of activity when magnetic structures emerge and fade very fast. In this study, we aim at quantifying how this far-side data will affect simulations of the corona and the interplanetary medium, which are essential to space weather forecasting. To do so, we focus on a case with a single sunspot on the far-side in February 2021. We use two different input magnetic maps for our models, one that includes the far-side active region, and one that does not. We first use a semi-empirical model (Potential Field Source Surface) to evaluate its impact on coronal synthetic observations. Then, we use two different magnetohydrodynamics coronal wind models : Wind Predict and Wind-Predict-AW. To assess the impact of the far-side active region, we compare both models with both remote sensing and in situ observations. We find that the inclusion of the far-side active region in the various models has a small local impact due to the limited amount of flux of the sunspot and the fact that the region had a previous emergence. Interestingly, there is a more global impact on connectivity, with clear differences in the coronal hole boundaries on the Earth-facing side when the active region is included. The region also seems to disrupt the shape of coronal streamers, leading to a more challenging comparison with the observations. The PFSS and Wind Predict models failed to reproduce the observed 3-fold structure with the active region, while the inclusion of far-side data clearly improves the Wind Predict-AW results.

Investigating the role of diffusion effects in the separation of heavy elements in solar loops, using a multi-specie high-order 1-D model

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We investigate several mechanisms that may produce abundance variations in solar loops, called as the First Ionization Potential (FIP) effect. We develop and exploit a multi-specie 1-D model of the solar atmosphere (called IRAP's Solar Atmospheric Model : ISAM) that solves, along a given magnetic field line, the transport of neutrals, electrons and charged particles from the chromosphere to the corona. We follow a high-order approach that allows to solve additional coupled transport equations for the heat flux, and that includes both friction and thermal diffusion effects self-consistently. Thanks to a comprehensive treatment of collisions, we can analyzse in detail the collisional coupling of heavy elements to e.g. protons. We found that depending of the nature of the interaction with protons, a fractionation between low and high FIP elements settles rapidly in the upper chromosphere up to the typical observed levels. However, under constant heating conditions we observed that this fractionation can take much longer (up to a few days) to propagate further into the corona, and hence also depends on the history of the loop. This study further shows the importance of such model to better understand abundance diagnostics and how they are connected to plasma heating. This work has been funded by the European Research Council (grant DLV-819189) and the Research Council of Norway (grant 324523).

Solar sources and expansion properties of Alfvénic slow wind streams

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Alfvénic slow wind is a strange beast. First observed by Helios, it has only been confirmed within the last decade and has challenged our usual understanding and classification of solar wind streams. With a high absolute cross-helicity, indicating an imbalanced proportion of outward Alfvén waves, it resembles the coronal hole fast wind. It could thus find its origin in the core of very rapidly expanding small coronal holes that are known to give birth to slower and denser wind streams. Close to the Sun, Parker Solar Probe and Solar Orbiter have found many examples of such streams that seem less likely to survive up to 1 AU. In this work, we focus on a series of slow Alfvénic wind streams followed by a fast wind stream observed by Solar Orbiter between March and April 2022. We study the sources of the solar wind through PFSS extrapolations of the photospheric magnetic field observed from different sources, and with a full MHD model, driven by Alfvén wave turbulence. We compare the sources and expansion properties provided by the two models and find similar results, although the expansion given by the PFSS is generally overestimated. Then, we study the heating and acceleration profile in the MHD model. We compare the Alfvénic turbulence heating with expansion dependent heating function and show that atypical non-monotonic acceleration profile can be the source of slow alfvénic streams. Finally, we examine the quasi-sepatrix network and try to assess whether it can also be a source of slow Alfvénic streams during this interval.

Reconstruction of electron precipitation spectra at the top of the upper atmosphere using 427.8 nm auroral images

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We present an method to reconstruct the characteristics of precipitated electrons in auroral regions from optical measurements. This method is based on an optimization implemented between numerical simulations of the Transsolo code and tomographic maps made from the Auroral Large Imaging System (ALIS) network. We focus on the Volume Emission Rate (VER) of the blue line N+2 1NG 427.8 nm, which is the most representative line of the energy deposition by electrons. The optimization is tested with the ALIS measurements carried out on March 05, 2008, at 18 :41 :30 UT and 18 :42 :40 UT. The reconstruction is performed by extracting the energy flux and the mean energy of the precipitating particles. Both Maxwellian and quasi-monoenergetic energy distributions are considered. Calculations performed with a Maxwellian energy distribution yielded a mean energy ranging from 1.8 to 5.2 keV with energy flux from 0.1 to 44.3 erg.cm^{-2}.s^{-1} for 18 :41 :30 UT, and a mean energy from 2.2 to 9.5 keV with energy flux from 2.1 to 136.7 erg.cm^{-2}.s^{-1} for 18 :42 :40 UT. Assuming a quasi-monoenergetic energy distribution, we find a mean energy of 4.2 to 11.8 keV with energy flux ranging from 0.1 to 45 erg.cm^{-2}.s^{-1} for 18 :41 :30 UT, and 8 to 17.1 keV with energy flux ranging from 2.2 to 110.1 erg.cm^{-2}.s^{-1} for 18 :42 :40 UT. Moreover, we show this method allows to reconstruct the energy characteristic of the precipitating electrons on a large region covering approximately 150 km by 150 km. It appears clearly that the energy flux is linked to the column integrated intensity, the mean energy is linked with the peak altitude of the emission and the width of the energy distribution with the altitude thickness of the emissions.

Characterising a flaring active region through data-driven MHD simulations

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The first results of the STORMGENESIS project will be introduced in this presentation. This project aims to characterize the initiation, propagation and connectivity of solar storms using innovative and ambitious numerical simulations based on the PLUTO code combined with the latest space weather observations. In this presentation, I will focus on the first part of the project which is the characterisation of the eruptive properties of an active region. Considering that estimating the magnetic field above the photosphere is one of the big uncertainties for our understanding of solar eruptions, we use different extrapolation techniques (potential, non-linear force-free, and non-force-free fields) based on an HMI magnetogram. We study how these different configurations influence the dynamics of the magnetic structure when considered very close to the onset of the observed eruption and how the energy is repartitioned for each extrapolation strategy. We also reproduce synthetic EUV emission out of these models. This work takes us a step closer to understanding the eruptivity of a given AR, as well as the energy channelling during the eruption, and hence, it improves our predictive and forecasting abilities for space weather purposes.

Modeling Soft X-ray emissions at the dayside magnetopause

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Magnetopause is the boundary of the Earth's magnetosphere that separates the magnetospheric plasma from solar wind. Investigating the location of magnetopause can improve our understanding on the interaction between solar wind and the Earth's magnetic field. However, it is difficult to obtain large-scale magnetopause motion from the current in situ spacecraft measurements due to the sparse observation points. X-ray imaging is an appropriate technique to study the large-scale motion of magnetopause in response to solar wind variations. Indeed, at the magnetopause, X-ray emissions are generated by charge exchange reactions between multiply charged heavy solar wind ions (O^{7+}, O^{6+}, C^{5+}, ...) and the hydrogen geocorona. Recently, the Solar Wind-Magnetosphere-Ionosphere Link Explorer (SMILE) mission has been proposed to remotely image the magnetopause with the onboard Soft X-ray Imager (SXI). In this study, we simulate the soft X-ray emission around the Earth by using the Test-Particles (TP) model, with the electric and magnetic field from OpenGGCM and PPMLR MHD approaches as its input. The soft X-ray emissivity maps derived from TP model with two different MHD inputs are presented. The X-ray maps derived from a pure MHD approach is proportional to proton fluxes and is based on an average coefficient to describe the heavy ion distribution. These results are compared with our TP results which calculates individual contribution for ion species allowing to study the kinetic effects and the individual spectral characteristics.

Thème 2 : Nouvelles missions et instrumentation (sol et espace)

Instruments optiques pour l'observation des aurores polaires

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Depuis plus de 15 ans, nous développons des instruments optiques pour l'observation de différents paramètres des aurores polaires, l'idée globale étant de reconstituer la dynamique des zones aurorales et les précipitations de particules. Cela passe à la fois par des imageurs, des spectromètres, ainsi que des polarimètres (Non abordés ici). Si les imageurs permettent d'obtenir des structures spatiales des aurores, les spectromètres ajoutent des informations spectrales qui sont particulièrement riches. Plus récemment, il a été démontré que des reconstructions tomographiques des volumes d'émissions étaient particulièrement riches notamment en termes de précipitations de particules.
Dans les prochains temps, nous envisageons de développer des instruments dédiés à l'observation des vents (ATISE-Winds), des aurores australes, des protons, à l'observation hyperspectrale qui permet de conjuguer les informations spatiales et spectrales (WFAI) et à des mesures tomographiques depuis le sol (Tomorora) ou l'espace (SATIS). L'ensemble de ces mesures se couplent avec les codes de modélisation de l'ionosphère, tels Transsolo. Nous présenterons donc au cours de cette intervention, les différents instruments qui sont développés à Grenoble ainsi que dans le cadre de collaborations et les mesures qui ont pu etre prises. Nous aborderons également ceux qui sont projetés dans les prochaines années ainsi que les méthodes d'interprétation en terme de conditions ionosphériques et thermosphériques.

NenuFAR solar radio observations : a complement to space missions

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NenuFAR is a recent ground-based facility dedicated to decameter radio observations. It is opened to the international community since December 2022. Owing to its high spectral and temporal resolution in spectral observations (down to 0.1 kHz and 0.30 ms, respectively - but not simultaneously) and the polarimetric measurements in four Stokes parameters, it provides clues to study the electron propagation at the base of the corona (observations between 10 to 85 MHz). The beam size of the instrument in the "Time-frequency" mode does not allow the identification of the emission site (0.5° to 4° beam size). However, imaging is systematically performed simultaneously with the spectral mode, enabling the location of the emissions.
This presentation highlights results regarding spikes and Type II emissions. Also, NenuFAR was dedicated to solar observations for a large part of the day during SPS and Solar Orbiter's passages in front of the Earth-directed solar surface. We will present some preliminary results concerning these ground-based & space coordinated observations.

UVSQ-SAT NG : A Pioneering CubeSat Mission for Climate Monitoring, Greenhouse Gas Assessment, and Sun-Earth Relations

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UVSQ-SAT NG is a 6-unit CubeSat (111.3 x 36.6 x 38.8 cm) designed by LATMOS to address critical climate challenges in the 21st century. Its primary scientific objective is to monitor and understand climate change by studying the Earth's Energy Imbalance (EEI) at the top of the atmosphere. Additionally, it aims to provide a monitoring of greenhouse gases like CO_2 and CH_4 with high spatial (a few kilometers) for emission tracking.
Scheduled for launch in 2025/2026, UVSQ-SAT NG will complement the existing French constellation consisting of UVSQ-SAT and INSPIRE-SAT 7, collectively dedicated to studying Earth's radiation balance. To accomplish its mission, UVSQ SAT NG is equipped with a suite of payloads. UVSQ-SAT NG features multiple nadir-pointing radiometers to quantify outgoing radiative fluxes at the top of the atmosphere. Additionally, the satellite is equipped with a near-infrared spectrometer, enabling the measurement of atmospheric columns containing essential greenhouse gases like CO_2 and CH_4. Alongside these scientific instruments, UVSQ-SAT NG also boasts a cutting-edge nano-camera, which functions as an imaging and geolocation device, providing remarkable capabilities for high-resolution Earth observation. The purpose of this presentation is to outline the scientific objectives of the mission, introduce the satellite and its instruments, and elucidate the methods to be employed for data inversion.

Quantifying the diffusion of suprathermal electrons by whistler waves between 0.2 and 1 AU with Solar Orbiter and Parker Solar Probe

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The evolution of the solar wind electron distribution function with heliocentric distance exhibits different features that are still unexplained, in particular, the fast decrease of the electron heat flux and the increase of the Strahl pitch angle width. Wave-particle interactions between electrons and whistler waves are often proposed to explain these phenomena.
We aim at quantifying the effect of whistler waves on suprathermal electrons as a function of heliocentric distance.
We first perform a statistical analysis of whistler waves (occurrence and properties) observed by Solar Orbiter and Parker Solar Probe between 0.2 and 1 AU. The wave characteristics are then used to compute the diffusion coefficients for solar wind suprathermal electrons in the framework of quasi-linear theory. These coefficients are integrated in order to deduce the overall effect of whistler waves on electrons along their propagation.
About 110,000 whistler wave packets are detected and characterized in the plasma frame, including their direction of propagation with respect to the background magnetic field and their radial direction of propagation. Most waves are aligned with the magnetic field and only 0.5% of them have a propagation angle greater than 45°. Beyond 0.3 AU, almost exclusively quasi-parallel waves propagating anti-sunward (some of them are found sunward but are within switchbacks with a change of sign of the radial component of the background magnetic) are observed. These waves are therefore Strahl-aligned and not counter-streaming. At 0.2 AU we find both Strahl-aligned and counter-streaming quasi-parallel whistler waves.
Beyond 0.3 AU, the integrated diffusion coefficients show that the observed waves can explain the measured Strahl pitch angle evolution and are effective in isotropizing the halo. Strahl diffusion is mainly due to whistler waves with an angle of propagation between 15 and 45° (the origin of which has not yet been fully determined). Near 0.2 AU, counter-streaming whistler waves can diffuse the Strahl electrons more efficiently than the Strahl-aligned waves by two orders of magnitude.

Modeling of mutual impedance experiments and quasi-thermal noise spectroscopy in magnetized plasma

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Mutual impedance experiments and quasi-thermal noise spectroscopy are two in situ plasma diagnostic techniques. They both rely on electric antennas in contact with the plasma, and both measure electron properties, notably electron density and temperature. They differ in that mutual impedance is an active technique, while quasi-thermal noise is a passive technique. Mutual impedance experiments measure the mutual impedance spectrum between two antennas. This measurement is performed by generating an electric perturbation within the plasma using one antenna, while another antenna simultaneously measures the electric field. Quasi-thermal noise spectroscopy uses one dipolar antenna, connected to a sensitive radio receiver, that measures the electric field fluctuations produced by the thermal motion of the ambient particles of the plasma.
Both techniques are included in the scientific payload of past, current, and future NASA, ESA, and JAXA space missions, such as Rosetta, Parker Solar Probe, BepiColombo, JUICE, and Comet Interceptor.
Instrumental models for both techniques are needed to interpret the instrumental output and derive measurements of the electron properties. They take into account both the electron plasma dispersion function and the geometry of the instrument. The modelling current state-of-the-art is largely focused on the limit of an unmagnetized plasma, that in this context identifies a plasma where the ratio of plasma to electron cyclotron frequency is much larger than one. We highlight here that the magnetized plasma regime will be of interest for future planetary space missions, including BepiColombo and JUICE, and to prepare future mission in the Earth's magnetosphere.
In this context, we provide for the first time a complete diagnostic, in magnetized plasmas, of the plasma electron density and temperature, and the magnetic field magnitude and direction, based on mutual impedance experiments and quasi-thermal noise spectroscopy.
For this purpose, we developed numerical models for both mutual impedance experiments and quasi-thermal noise spectroscopy in a magnetized plasma. A diagnostic is derived for the plasma density, the electron temperature, and the magnetic field. We validated these instrumental models against both laboratory and space measurements. The dependency of this diagnostic on the antenna shape and size is investigated, as well as the expected precision of these techniques as plasma diagnostic.

THEMIS current performances and perspectives

Bernard Gelly (1)

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The THEMIS solar telescope has undergone extensive changes since 2018. Thanks to a new optical system that include a state-of-the-art solar adaptive optics, diffraction limit imaging is now available a large fraction of the time. Benefits of higher spatial resolution in spectroscopy is also extremely appreciated and has already allowed publications. Our new polarimetric analysis is currently under commissionning and we shall present our firsts observing results in spectropolarimetry using our long slit spectrograph. THEMIS is also planning to host a new instrumental mode for bidimensional (Fabry-Perot) spectropolarimetry in 2024.

Energy transfer rate estimation by an HelioSwarm-like constellation in a Hall-MHD simulation

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The energy transfer rate ε, or dissipation rate, is an essential parameter to assess turbulent processes in plasmas/fluids. Indeed, at intermediate scales, in the inertial range, Kolmogorov's law expresses the energy spectrum as a function of ε (and k). Estimating this parameter can be done globally in a simulation. In space, multi-point measurements are usually too scarce in the studied range of scales and over-simplifying assumptions must be done. Here we employ a technique proposed by Pecora et al., 2023 to derive an estimate from the future HelioSwarm magnetic field/plasma observations. HelioSwarm is a NASA mission that will fly in 2029 to study turbulent plasma processes primarily in the pristine solar wind and foreshock regions of the Earth's magnetosphere. It is composed of one main hub surrounded by eight nodes ; they are all equally instrumented (low and high frequency magnetometers, Faraday cups) with the hub holding an extra ion instrument (iESA) tailored to measure distribution functions in the solar wind. We use HelioSwarm preliminary orbit configuration (Klein et al., 2023) to estimate the energy transfer rate from the Yaglom law. This law requires the computation of divergences in lag space (inter-spacecraft separation space) of the third order structure functions of Elsässer variables (the Yaglom flux). These variables derive from the magnetic and velocity fields obtained with a new Hall-MHD code (Foldes et al., 2023). The interest of this code lies in its ability to simulate plasma down to sub-ion scales. In the solar wind, the typical ion scale, the ion inertial length or gyroradius, is about 100 km, whereas HelioSwarm separation scales vary between 20 km and 2000 km. These scales fall into the turbulent inertial range where the Yaglom law may be applied. The dissipation rate estimates, obtained by computing the divergence over all tetrahedral configurations (58905, with 9 spacecraft and 36 baselines), are compared with a global estimation. We discuss the variability induced by the large parameter space that includes the trajectory orientation (within the simulation box), the lags, the temporal variation (inherent to the orbit phase), or the spatial averaging procedure. Finally, our analysis shows that HelioSwarm will have the ability to perform novel computations/diagnostics in turbulent space plasmas by exploiting the use of multi-point techniques in a statistical manner.

Observations décamétriques du système solaire à Nançay

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Des observations décamétriques (DAM, 10-80 MHz) de la magnétosphère de Jupiter (et de ses émissions aurorales) et de la couronne solaire (notamment des sursauts solaires de type II, III, IV) sont menées au long cours depuis la forêt de Sologne grâce à deux radiotélescopes complémentaires de l'Observatoire radio de Nançay (ORN) au bénéfice des communauté PNST et PNP en France. Le Réseau Décamétrique de Nançay (NDA pour Nançay Decameter Array) observe quotidiennement le Soleil et Jupiter depuis 1978, utilisant des récepteurs numériques récents à haute résolution, avec une mission de soutien sol aux sondes spatiales Parker Solar Probe, Solar Orbiter et Juno/JUICE. NenuFAR, dont le troisième appel à observations est en cours, est utilisé par deux programmes au long cours d'observation ponctuelles du Soleil et de Jupiter à haute sensibilité. Dans cette contribution, nous reviendrons sur des chantiers importants menés par les équipes de ces deux instruments (numérisation d'archives, jouvence/construction, travail sur l'accessibilité des données) et ferons un bilan des résultats récents obtenus à l'aide de ces observations.

NDA : https://www.obs-nancay.fr/reseau-decametrique/ et
http://archives-decametriques.obspm.fr
NenuFAR : https://www.obs-nancay.fr/nenufar/

Re-exploring the radio spectrum of Uranus in orbit : science case and digital high frequency receiver

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Among the known planetary magnetospheres, those of Uranus and Neptune dis- play very similar radio environments so that they were referred to as radio twins. Their pioneering exploration by the Voyager 2 Planetary Radio Astronomy (PRA) and Plasma Wave Science (PWS) experiments revealed a variety of electromagnetic radio waves ranging from a few kHz to a few tens of MHz similar to - although more complex than - those of Saturn or the Earth. The asymmetric magnetosphere of Uranus is highly atypical with a large obliquity, magnetic tilt and fast rotation period, so that the magnetosphere undergoes perpetual geometric reconfiguration. Hereafter, we review the rich zoo of Uranian radio emissions, including the auroral Uranian Kilometric Radiation (UKR) between a few kHz and 1 MHz, the Uranian Electrostatic Discharges (UED) observed up to 40 MHz, and low frequency waves (continuum, plasma wave emissions) at a few kHz. We then emphasize the interest of re-exploring this atypical radio source and present a modern concept of a digi- tal High Frequency Receiver (HFR) in the framework of a Radio and Plasma Wave (RPW) experiment to be proposed to any future NASA/ESA orbital mission toward Uranus. This HFR concept, updated from the heritage of Cassini/RPWS/HFR, STEREO/Waves, Bepi-Colombo/PWI/Sorbet or Solar Orbiter/RPW is aimed at providing a light, robust, low-consumption versatile instrument capable of goniopo- larimetric (polarization and direction-finding capabilities) and waveform measure- ments from a few kHz to ∼40MHz, devoted to the study of radio emissions, plasma waves and dust impacts.

The ion ElectroStatic Analyzer for NASA's HelioSwarm mission

Benoit Lavraud

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The HelioSwarm mission is a NASA MIDEX mission selected in February 2022 and planned for launch in 2029. Its main objectives are to reveal the 3D spatial structure and dynamics of plasma turbulence in a weakly collisional plasma and to investigate the mutual impact of turbulence near boundaries and large-scale structures evolving in the solar wind. HelioSwarm consists of a main platform (Hub) and eight smaller satellites (nodes) evolving along an elliptical orbit with an apogee 60 and a perigee ∼15 Earth radii. The 9 nodes are three axis-stabilised and provide 36 pair combinations and 126 tetrahedral configurations, which is to be compared to only 6 pairs and 1 tetrahedral configuration for 4-spacecraft missions such as Cluster or MMS. The swarm has variable inter-spacecraft separations ranging from 50 to 2000 km. The nodes and the Hub spacecraft all accommodate three instruments : AC and DC magnetometers as well as Faraday cups for ion measurements. Because the Faraday cups do not measure full ion distribution functions, a dedicated ion ElectroStatic Analyzer (iESA) is accommodated on the Hub spacecraft only, and provides unprecedented combinations of energy, angular and temporal resolutions for ion measurements in the solar wind. This instrument is designed and built by a consortium led by IRAP and LAB (France), with contributions from UNH (USA) and MSSL (UK). We will present details of both the mission and the iESA instrument designs.

The M-MATISSE mission : Mars Magnetosphere Atmosphere Ionosphere and Space Weather Science. An ESA Medium Class (M7) candidate

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M-MATISSE est dédiée à la caractérisation de l'interaction de Mars avec notre Soleil. Avec deux points de mesure simultanée et coordonnée, cette mission est à l'exploration de Mars, ce qu'ont amené les premières missions multi-points pour la compréhension de l'environnement de la Terre. M-MATISSE se propose de développer les outils nécessaires à l'exploration robotique et humaine de Mars des prochaines décennies. Cette mission permettra de caractériser pour la première fois la météorologie de l'espace pour Mars de sa magnétosphère jusqu'à sa surface mais aussi de contraindre l'environnement radiatif de cette planète. M-MATISSE propose pour la première fois une approche originale en associant deux mesures orbitales qui permettront non seulement de découpler variabilités temporelles et variabilités spatiales mais aussi de cartographier l'ionosphère et la basse atmosphère simultanément. Comme montré par la mission InSight, les perturbations solaires se propagent jusqu'à sa surface. Comprendre la propagation du forçage solaire depuis le vent solaire jusqu'à la basse atmosphère de Mars est tout l'enjeu de M-MATISSE.

The SCM for the NASA HelioSwarm mission

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The HelioSwarm mission was selected as a MIDEX mission by NASA in February 2022 for launch in 2029 with a nominal duration of 15 months. Its main objectives are to reveal the 3D spatial structure and dynamics of turbulence in a weakly collisional plasma and to investigate the mutual impact of turbulence near boundaries (e. g., Earth's bow shock and magnetopause) and large-scale structures evolving in the solar wind (e. g., Coronal mass ejection, corotating interaction region). Therefore the HelioSwarm mission will strongly contribute to the space weather science and to a better understanding of the Sun-Earth relationship. It consists of a platform (Hub) and eight smaller satellites (nodes) evolving along an elliptical orbit with an apogee $\sim$ 60 and a perigee $\sim$15 Earth radii. These 9 satellites, three axis-stabilised, will provide 36 pair combinations and 126 tetrahedral configurations covering the scale scales from 50 km (subion scale) to 3000 km (MHD scale). It will be the first mission able to investigate the physical processes related to cross-scale couplings between ion and MHD scales by measuring, simultaneously at these two scales, the magnetic field, ion density and velocity variations. Thus each satellite is equipped with the same instrument suite. A fluxgate magnetometer (MAG from Imperial College, UK) and a search-coil magnetometer (SCM) provide the 3D measurements of the magnetic field fluctuations whereas a Faraday cup (FC, SAO, USA) performs the ion density and velocity measurements. In addition, the ion distribution function is measured at a single point onboard the Hub by the iESA instrument, allowing to investigate the ion heating in particular. The SCM for HelioSwarm provided by LPP and LPC2E is strongly inherited of the SCM designed for the ESA JUICE mission. It will be mounted at the tip of a 3m boom and will cover the frequency range associated with the ion and subion scales in the near-Earth environment [0.1-16Hz] with the following sensitivities [15pT/$\sqrt{\text{Hz}}$ at 1 Hz and 1.5 pT/$\sqrt{\text{Hz}}$ at 10 Hz]. The recent SCM developments of this on going project will be described.

Installation d'une ionosonde au Centre de Recherche Atmosphérique de Lannemezan

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Dans le cadre de l'ANR ASTRID PRISMS, nous avons obtenu des financements pour construire une ionosonde que nous avons choisi d'installer au Centre de Recherche Atmosphérique (CRA) de l'Observatoire Midi-Pyrénées à Lannemezan, en raison de sa proximité de Toulouse et des équipements déjà disponibles sur ce site instrumenté. En collaboration avec des collègues de l'ONERA Palaiseau, nous avons identifié la configuration la mieux adaptée au site, nous avons acheté le matériel et l'installation a eu lieu la première semaine d'Octobre 2023. Les premiers tests ont montré un environnement électromagnétique relativement bruité mais gérable et ne montrant pas d'interférence notable avec les instruments déjà existant au CRA (profileurs de vent). Le poster présentera les premiers sondages réalisés, les modes de fonctionnement envisagés et les pistes de travail prévues pour son utilisation (propagation HF, ingestion dans le modèle IPIM, enseignement : TP).
Une mise à jour rapide concernant le radar SuperDARN de Kerguelen sera également indiquée.

INSPIRE : From Pedagogical Object to Earth and Sun Observation Satellites

Mustapha Meftah

LATMOS, CNRS, Université de Versailles Saint-Quentin-en-Yvelines, Sorbonne Université

The International Satellite Program in Research and Education (INSPIRE) is a consortium of global space universities formed to advance space science and engineering. Each INSPIRE small satellite will proceed from concept to flight in three years, providing the opportunity for undergraduate and graduate student involvement in small-¬satellite design, building, testing, and operations. INSPIRE brings science, engineering, and management to campuses across the globe. The INSPIRE program aims to provide a constellation of Earth and space weather observing satellites. To date, 8 satellites are part of this program. The main purpose of this presentation is to showcase the three space-based missions placed under the direct responsibility of LATMOS. We will present the scientific objectives of tthe three satellites : Uvsq-Sat (Earth Radiation Budget, solar observations, Earth magnetic field), Inspire-Sat (Earth Radiation Budget, ionospheric observations, Earth magnetic field) and Uvsq-Sat NG that is dedicated to monitor Earth Outgoing Energy and Greenhouse Gases. Two satellites have already been placed in orbit (Uvsq-Sat in January 2021 and Inspire-Sat in April 2023). Through this presentation, we will present the results of observations made from space.

Coronal Composition Measurement : A multi-instrumental analysis including Solar Orbiter/SPICE

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Plasma composition plays an important role in coronal physics and in tracing the connection between the corona and solar wind. Due to the First Ionization Potential (FIP) effect, low-FIP elements typically show an increased abundance in specific coronal structures.
We study the evolution of plasma composition in a decaying active region, which was observed continuously for more than 2 weeks in 2022-10 by Solar Orbiter and then by SDO and Hinode. We analyse EUV spectroscopic data from Solar Orbiter/SPICE using the Linear Combination Ratio (LCR) method, after careful selection of the lines to be used. We interpret our results in the context of the overall plasma configuration obtained from EUI and PHI on Solar Orbiter and AIA and HMI on SDO. Furthermore, comparison with results from EIS/Hinode allows us to distinguish between the coronal plasma composition at different temperatures and altitudes in the corona.
Ultimately, we want to measure the coronal composition during transient events and detect their signatures in the inner heliosphere using in-situ instruments from Solar Orbiter, PSP, or BepiColombo.

The Fast Gamma ray Spectrometer (FGS) : a Multi-mission Instrument to Detect TGFs and Astrophysical Gamma ray Events

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Following Taranis' failure during its launch in 2020, an R&T development program has been started in 2021 by the team that developed the XGRE gamma-ray spectrometer onboard Taranis, at the Astroparticle and Cosmology (APC) laboratory (Paris, France). This program, funded by the French Space Agency (CNES), aims to develop a new gamma-ray spectrometer for space applications, and especially for the detection of Terrestrial Gamma ray Flashes (TGFs) from space. Aimed to be a multi-mission detector, Fast Gamma ray Spectrometer (FGS) can be adapted to different scientific objectives, using the same technology, namely a GaGG scintillator coupled with a Silicon Photo-Multiplier (SiPM) and an ASIC to read the signal. It is now based on 16 crystal pixels of 2 cm $\times$ 2 cm $\times$ 1 cm, but can be optimized to fit the mission purposes, FGS being used for different scientific objectives such as Gamma Ray Bursts (GRBs) and solar flares. In that sense, the GaGG scintillator type, the size of the scintillator pixels, and the number of pixels can be thus different for each mission. During the development, we consider TGFs, which are the most constraining events that we aim at, to define the detector characteristics : rapidity, energy range, timetag of photons. GaGG scintillators are newly developed non-hygroscopic scintillators, with a high light-yield and a fast decay time. We studied three different GaGG versions in the present work : a mean, a high spectral resolution, and a fast GaGG crystals. In order to validate the choice of the scintillator used, we show in the present work a comparison of their performances, and measurements within the ARRONAX proton accelerator to simulate the degradation due to the South Atlantic Anomaly (SAA) passages. FGS performances concerning TGF detection are also presented.

First fully observed vector magnetogram of a solar active region from stereoscopic observations of PHI/Solar Orbiter & HMI/SDO

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Magnetic field measurement in the solar atmosphere based on the Zeeman effect is plagued by a major caveat. The orientation of the transverse (to the line-of-sight) component is fundamentally ambiguous : two equally intense oppositely directed transverse field produce the very same spectropolarimetric signal. So far, the removal of such ambiguity has required assumptions about the properties of the photospheric field, making disambiguation methods model-dependent.
However, Solar Orbiter, embarking PHI, the first solar spectro-polarimetric telescope observing away from the Earth vicinity, has made the removal of the 180°-ambiguity possible solely using observations.The basic idea is that the unambiguous line-of-sight component of the field measured from one vantage point will generally have a non-zero projection on the ambiguous transverse component measured by a second telescope observing from a different point of view, thereby determining the "true" orientation of the transverse field. In this presentation, I will introduce the Stereoscopic Disambiguation Method (SDM) which was developed, implemented and first tested using numerical simulations. I will then present the successfully application to observational data from synergic observations of PHI/SolO and HMI/SDO obtained on March 2022 of active region NOAA 12965. I will present the first ever magnetogram of an active region in which the 180°-ambiguity has been resolved solely thanks to observational data. I will conclude on the possible importance of such milestone on our understanding of solar active region, their energetic and their capacity to produce solar eruptions.

Energisation du plasma et transport d'énergie dans le système magnétosphérique terrestre dévoilés : la mission multi-échelles Plasma Observatory

Alessandro Retinò (1)

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L'énergisation des particules et le transport d'énergie sont des problèmes scientifiques clés de la physique des plasmas spatiaux qui ont des implications majeures dans des domaines allant de la météorologie de l'Espace aux plasmas astrophysiques lointains. Ces phénomènes sont pilotés par des processus fondamentaux tels que les chocs, la reconnexion, la turbulence/ondes, les jets plasma, ainsi que leur combinaison. Les aspects clés du transport d'énergie sont les courants alignés, les instabilités et la répartition du flux d'énergie. Le système magnétosphérique est l'environnement plasma fortement dynamique où se produisent l'énergisation et le transport d'énergie les plus intenses autour de la Terre. Les observations multipoints par Cluster et MMS ont considérablement amélioré notre compréhension des processus plasma mais seulement à une échelle donnée. Cependant, des mesures simultanées aux grandes échelles fluides et aux petites échelles cinétiques sont indispensables. Des telles mesures ne sont actuellement pas disponibles. Nous présentons ici la mission multi-échelles Plasma Observatory (PO) conçue pour étudier l'énergisation du plasma et le transport d'énergie dans le système magnétosphérique terrestre à travers des mesures simultanées aux échelles fluides et ioniques. Ce sont les échelles auxquelles la plus grande quantité d'énergie électromagnétique est convertie en particules énergétiques. La mission PO comprend un satellite mère (MSC) et six petits satellites

filles identiques (DSC) sur une orbite couvrant toutes les régions clés du système magnétosphérique. Les séparations entre les satellites vont des échelles fluides aux échelles ioniques. La charge utile de la MSC fournit une caractérisation complète en un seul point aux échelles sub-ioniques tandis que celle des DSC, malgré beaucoup plus simple, donne une caractérisation suffisante aux échelles ioniques et fluides. PO est la prochaine étape logique après Cluster et MMS. Il cible les deux thèmes de Voyage 2050 ESA “Magnetospheric Systems” et “Plasma Cross-scale Coupling” et nous permettra de résoudre pour la première fois le couplage d'échelles dans le système magnétosphérique terrestre. PO est l'un des trois candidats M7 de l'ESA actuellement en phase A compétitive, avec une sélection prévue en 2026. La communauté française PNST est fortement impliquée dans PO, avec des responsabilités scientifiques et techniques majeures.

Premières mesures des moments électroniques à Mercure

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BepiColombo est une mission conjointe de l'ESA et de la JAXA actuellement en route vers Mercure. Durant sa phase de transfert, les trois modules composant Bepicolombo demeurent solidaires : le Mercury Transfer Module (MTM), Mercury Planetary Orbiter (MPO) et le Mercury Magnetospheric Orbiter (MMO or Mio). Afin de protéger Mio des rayonnements solaire, ce dernier est protégé par le Magnetospheric Orbiter Sunshield and Interface Structure (MOSIF). Bien que BepiColombo arrivera à destination fin décembre 2025, les instruments du consortium plasma ont été allumés à plusieurs reprises. Contrairement aux instruments ions, les Mercury Electron Analyzers (MEA) 1 et 2 permettant de déduire les moments électroniques tels que la densité et la température au prix de quelques approximations. En effet, MOSIF limitant fortement le champ de vision des instruments, nous assumons l'isotropie du cœur des électrons dans le vent solaire. Aussi , les détecteurs MEA 1 et 2 se trouvant proches de MPO et de MOSIF, ceux-ci vont mesurer une forte contamination dû à de l'émission secondaire électronique, qu'il convient de supprimer.
Nous montrerons durant la première partie de cette présentation, comment nous supprimons l'effet de l'émission secondaire afin de déterminer les moments électroniques. Durant la seconde partie, nous présenterons les mesures de densité et température électronique enregistrées, durant les trois survols de Mercure, les premières depuis la mission Mariner 10.

NOIRE : an instrumental concept to monitor the sky at very low radio frequency

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Inside the solar system multiple phenomenons can be studied through the analysis of their radio emissions. It is especially true when plasma undergoes deceleration : planetary magnetospheres, solar bursts, radiation belts, planetary atmospheres,...
They are already studied by ground-based radio interferometer like LOFAR, NenuFAR and SKA in the future. They provide images of the sky but are limited by the ionospheric cutoff at about 10-50MHz [de Gasperin et al 2018].
On the other hand, space probes provide in-situ measurements without this limitation. Yet, their direction finding is restricted and they are not able to generates images [Cecconi 2011].
NOIRE (Nanosatellite pour un Observatoire Interferometric Radio dans l'Espace)[Cecconi et al 2016] is an instrumental concept that aims to provides interferometric measurements from space in the range 30kHz-100MHz. The instrument constists of a swarm of about 50 nanosatellites in orbit around the Moon clustered in about 100km.
This presentation depicts the scientific objectives that can be covered by such an instrument and its advantages. It highlights the physical constraints and the technical challenges that have to be overcome in order to make this mission successful. Then, I will present the current status of the mission and its complementary mission concepts.

Thème 3 : Couplages entre enveloppes de plasma

Time and space variability of the electron environment at the orbit of Ganymede as observed by Juno

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The thermal and energetic electrons along Ganymede's orbit not only weather the surface of the icy moon, but also represent a major threat to artificial satellites. In this article, we rely on Juno plasma measurements to characterize the time and space variability of the electron environment upstream of Ganymede. In particular, we find that electron spectra observed by Juno are persistently harder than what was measured two decades earlier by Galileo, as high-energy electron fluxes are on average a factor of 2 to 9 higher than previously estimated. This result will advance our understanding of the surface weathering and may be a concern for the radiation safety of the JUICE mission. Furthermore, the June 2021 close fly-by of Ganymede reveals that the open field line regions of its magnetosphere attenuate electron fluxes at all energies by a factor of 2 to 5, thereby offering a natural shelter to visiting spacecraft. This research holds as part of the project FACOM (ANR-22-CE49-0005-01 ACT) and has benefited from a funding provided by l'Agence Nationale de la Recherche (ANR) under the Generic Call for Proposals 2022 as well as from the European Union's Horizon 2020 programme under grant agreement No 871149 for Europlanet 2024 RI.

La magnétopause et la théorie des discontinuités

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Déterminer où la magnétosphère est ouverte ou fermée est une question persistante en physique spatiale, qui continue d'intéresser la recherche actuelle. Dans le contexte de la magnétopause, la question clé se pose : cette limite est-elle parfois une discontinuité tangentielle ou non ? La théorie des discontinuités, dans sa plus simple approximation, c'est à dire lorsque les effets du rayon de Larmor fini sont ignorés, impose que les caractéristiques de compression et de rotation s'excluent mutuellement, sauf dans ce cas particulier de "discontinuité tangentielle".

Les observations à la magnétopause de la Terre révèlent en fait des propriétés mixtes de compression et de rotation. Cela signifie-t-il que cette frontière est toujours "tangentielle", c'est-à-dire complètement imperméable, avec des composantes normales du champ magnétique et de la vitesse du plasma strictement nulles ? Ou bien que les seules exceptions sont localisées en de petites régions où les effets 2D sont importants et où cette théorie ne s'applique donc pas (reconnexion) ?

Dans cette étude, nous abordons l'inadéquation des théories classiques des discontinuités pour expliquer les caractéristiques observées de la magnétopause, en raison de sa faible épaisseur. Nous introduisons le concept de discontinuités "quasi-tangentielles", dans lesquelles les propriétés de compression et de rotation coexistent, sans que les flux normaux soient strictement nuls. Cette transition ressemble au passage d'une onde d'Alfvén à une onde d'Alfvén cinétique dans le contexte des modes linéaires.

Nous présentons ensuite des données de franchissement de la magnétopause terrestre en utilisant la mission Magnetospheric Multiscale (MMS). Grâce à cette analyse, nous démontrons que les effets de rayon de Larmor fini, et les tenseur de pression non-gyrotropes qui en découlent, jouent effectivement un rôle important dans l'équilibre de la magnétopause.

Energy mapping of the Jupiter's auroral electrons from the Juno/UVS data

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The Juno probe, which studies the Jupiter system, continues to increase our knowledge of the Jovian magnetosphere and environment. Thanks to onboard instruments such as JEDI and JADE, measurements of the energy spectra of charged particles precipitating in the auroral regions enabled us to establish the most realistic energy distributions for these precipitating electrons. These distributions can be fitted by a phenomenological function (as the example of Coumans et al. 2002) defined by a characteristic energy E0 and a kappa parameter describing its broadness over high energies.
Considering the distance between the probe's measurement altitude and the impact position of charged particles, particularly electrons, where auroral emissions are produced, these energetic distributions of magnetospheric particles are influenced by various phenomena such as Alfvén wave-particle interaction. These processes can accelerate or decelerate these particles, altering their average energy. Therefore, particle energy distributions measured at the Juno probe may differ from those observed at auroral altitudes.
In this study, we developed a UV emission model, which we combined with an electron transport model to simulate the auroral spectral emission of H2 molecules in the UV range. Based on observations of the Jovian aurora by the UVS instrument on board Juno, we derived the characteristic energies of the electrons precipitating in the auroral regions during PJ32. For this, we modeled the relationship between the color ratio (CR) and the average energy of precipitated electrons. In a first step, we consider monoenergetic electron flux. In a second step, we consider fluxes following a kappa energy distribution with kappa = 2.5.
Finally, we were able to establish characteristic energy maps for electrons precipitated in Jupiter's auroral regions. In comparison with previous similar studies, and based on HST observations, we found that modeling the CR with a monoenergetic distribution led to an underestimation of the average energy of electrons precipitating in the auroral regions by a factor of 3 to 5.
In conclusion, we have established a more realistic estimation of electron energy flux distributions at auroral altitudes. We now have the possibility of deriving maps of the mean energy of precipitating electrons from UVS observations for other Juno perijoves.

Simulation of deuterium and hydrogen loss on Mars by thermal, photochemical and solar wind processes

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The D/H ratio is a key parameter to understand the atmospheric evolution of a planet. On Mars a D/H $\sim$ 5 times larger than the ratio on Earth is measured. This large ratio can be explained by a preferential escape of the hydrogen compared to the deuterium due to its lower mass. However, while the thermal escape (Jeans escape) is strongly mass dependent other non-thermal processes are less mass dependent and would impact the time needed to fractionate the water from the terrestrial value to the current value.
In this work, we will present new simulations obtained by coupling 3 models to estimate the hydrogen and deuterium escape. The 3D Martian Planetary Climate Model (PCM-Mars) is used to compute the Jeans escape rate of D, H, H_2 and HD, as well as the ion and neutral densities below the exobase are computed using at spring equinox. A 3D exospheric model is used to compute the escape rate of H and D due to photochemical reactions in the ionosphere and the escape rates of H, D, H_2 and H_2 induced by the collisions between the hot oxygen and these atmospheric species. Finally, a 3D hybrid model of the Martian induced magnetosphere is used to compute the escape of H^+ and D^+ produced by photoionization and charge exchange with the solar wind protons. The contribution of each process and the derived fractionation factor will be presented and discussed.

A self-consistent model of radial transport in the magnetodisks of gas giants including interhemispheric asymmetries

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The magnetospheres of gas giants are dominated by the presence near their centrifugal equator of a plasmasheet/magnetodisk filled with thermal plasmas originating from active moons : Io at Jupiter, Enceladus at Saturn. These plasmas are transported from their region of generation in the inner magnetosphere to the outer magnetosphere where they are lost through magnetospheric boundaries or downtail. Their transport is believed to be controlled by a balance between the centrifugal force acting on cororating plasmas trapped in the planetary magnetic field, plasma pressure gradients and magnetic forces. In turn, this balance determines the rate of outward transport of mass, angular momentum and energy in these plasmasheets and has a strong influence on the global configuration and dynamics of these magnetospheres.

Until now, description of this transport has followed two different lines in the literature. "Corotation enforcement" models focus on the description of angular momentum transport in a disk exchanging momentum with the planetary thermosphere/ionosphere via electric current systems transferring magnetic torques. They assume mass conservation but do not explicitly describe the transport of energy. On the contrary, radial diffusion models do not explicitly take into account angular momentum transport, but they describe radial transport of mass and energy assuming a certain state of turbulence in the plasmasheet.

We present a unifying approach of the radial transport of mass, angular momentum and energy, using turbulent diffusion acting on sources and sinks of plasma of arbitrary radial distribution throughout the disk. Our set of coupled equations independently describes momentum exchange with the two conjugate ionospheres, thus allowing for the study of interhemispheric asymmetries in this coupling. We will show solutions of our coupled set of transport equations that explore the different possible causes and effects of interhemispheric asymmetries in plasmasheet/planet coupling, with emphasis on the cases of latitudinally thin and thick disks corresponding respectively to the magnetosheres of Jupiter and Saturn.

Detection of a steep height gradient of the rotational velocity in the low photosphere of the Sun

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We present a new method to measure the rotational height gradient in the solar photosphere. The method is inspired from differential interferometric techniques, it is applied to spectroscopic observations in the FeI 630.15 nm obtained at the solar telescope THEMIS equipped with an efficient adaptative optics system.
At the center of the solar disk, we measured systematic retrograde equatorward shifts between images of the granulation pattern obtained at different line cords that are formed at different heights.
The same technic was used to measure the formation height difference of the images at different line cords using their perspective shift when they are observed away from the disk center. The retrograte equatorward shift varies linearly with height. We interprete this as the signature of a steep decrease of the rotational velocity in the low photosphere.

Thermal non-equilibrium cycles in solar coronal null points - implications for the solar wind

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In the solar atmosphere, thermal non-equilibrium (TNE) is a global thermodynamical state of atmospheric structures that is set by specific heating conditions - a stratified and quasi-steady heating. TNE is commonly observed in active region coronal loops. It manifests as evaporation-condensation cycles that will show up as long-period intensity pulsations in coronal channels and as coronal rain showers in transition region/chromospheric emission.
Coronal rain has also been reported in topologies involving open-field, such as coronal null-points. However, the exact relationship of these events with TNE remains to be investigated. In particular, the periodicity of their cycles, if any.
In our study, we report the detection of combined long-period EUV pulsations and coronal rain events in open-close boundaries observed off limb with SDO/AIA. We analyze the thermal properties of these events to confirm these are indeed TNE events.
These observations lead to many questions on the interplay of TNE with interchange reconnection at coronal null-points and draw interesting perspectives on linking mass and energy transport in the solar atmosphere to solar wind release mechanisms.

Classer les facteurs d'influence des frontières plasma planétaires

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L'interaction des environnements planétaires avec le vent solaire conduit à la formation de structures plasma à grande échelle, les frontières plasma. Étudier leur dynamique en identifiant les facteurs d'influence est crucial pour mieux comprendre l'interaction globale en jeu. Dans les cas de Mars et Vénus, la dynamique des frontières plasmas est complexe, en raison de l'influence combinée de facteurs externes (photons solaires, plasma et champs du vent solaire) et internes (atmosphère ionisée, sources crustales de champ magnétiques pour Mars), dont les échelles temporelles sont variées.
Nous présenterons ici une méthodologie visant à identifier et quantifier les facteurs d'influence des frontières plasmas, en s'appuyant sur le cas du choc d'étrave de Mars et Vénus. Nous nous appuierons sur les données fournies par Mars Express et MAVEN dans le cas martien et Venus Express dans le cas vénusien, ainsi que sur un ensemble de méthodes complémentaires permettant d'étudier des facteurs d'influence minoritaires, et de classer les facteurs d'influence des chocs martien et vénusien : corrélations partielles, critère d'information d'Akaike, LASSO.

Mercury's ion plasma environment : New findings from BepiColombo/Mio

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On June 23rd 2022 and 19th 2023, BepiColombo performed its second (MFB2) and third (MFB3) gravity assist maneuvers at Mercury. The two flybys had similar trajectory, where the spacecraft approached the planet from dusk-nightside toward dawn-dayside, traveling down to an extremely close distances (at 198 km and $\sim$ 235 km altitudes above the planet's surface for MFB2 and MFB3 respectively). Even though BepiColombo is in a so-called "stacked configuration" during cruise (meaning that most of the instruments cannot be fully operated yet), the instruments can still make interesting observations. Particularly, despite their limited field-of-view, the particle sensors allow us to get a hint on the plasma composition and dynamics very close to the planet.

In this presentation, we will show the first ion composition observations of the Mass Spectrum Analyzer (MSA) at Mercury during the two flybys. MSA is part of the Mercury Plasma Particle Experiment (MPPE, PI : Y. Saito) consortium that is a comprehensive instrumental suite for plasma, high-energy particle and energetic neutral atom measurements onboard Mio (Saito et al. 2021). MSA is a time-of-flight spectrometer that provides information on the plasma composition and the three-dimensional ion distribution functions in the $\sim$ 10 eV/q-38 keV/q energy range and in the $\sim$ 1-60 amu mass range (Delcourt et al. 2016). We will focus on the third Mercury flyby, during which MSA revealed the presence of energetic ($>$ 10 keV) and cold ($<$ 100 eV) heavy ions inside the magnetosphere around closest approach. Moreover, we will show major features of the Mercury magnetosphere highlighting different regions : 1) plasma sheet, 2) nightside bounday-layer and the 3) magnetosheath.

Solar wind interactions with the Earth, planets and comets : is the solar wind turbulent ?

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We aim to understand whether and how the turbulent nature of the solar wind affects the structure and dynamics of the solar wind interaction with the Earth and other solar system bodies. We focus here more specifically on the interaction between a turbulent solar wind and different kinds of objects : (i) a comet and (ii) a magnetised planet. We aim in this way at shedding light on the macroscopic effect of the upstream solar wind turbulence on (i) the structure and dynamics of the induced magnetosphere of a comet, as well as (ii) the dynamics of the bow shock, the magnetosheath and the magnetopause of an intrinsic magnetosphere.

For this purpose, we use the newly developed kinetic hybrid code Menura. Menura is built around a hybrid Particle-In-Cell solver, treating electrons as a massless charge-neutralising fluid, and ions as massive charged particles. It solves iteratively the particles' dynamics, gathers particle moments at the nodes of a grid, at which the magnetic field is also computed, and then solves Maxwell's equations. The solver uses the popular Current Advance Method (CAM) in the solar wind reference frame. Menura simulates the global interaction between a fully turbulent solar wind and various bodies of the solar system using a two-step approach. First, a fully developed turbulent hybrid simulation is used to "prepare" a periodic turbulent solar wind. Second, a solar system object (e.g. planet, comet) is injected onto this self-consistent turbulent plasma.

Using this numerical model, we perform direct comparisons using both turbulent and laminar solar wind inputs. We show and discuss how the turbulent nature of the solar wind controls the dynamics of various frontiers, modifies the magnetosheath dynamics (in an intrinsic magnetosphere), and affects the inner plasma dynamics and plasma escape (in an induced magnetosphere).

The satellite auroral footprints at Jupiter : A Juno perspective

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Jupiter's satellite auroral footprints are a consequence of the interaction between the co-rotating iogenic plasma and the Galilean moons. Since the disturbance caused by the presence of the moons in the plasma flow propagates along the field lines in the form of Alfvén waves, the physical positions of the moons are magnetically connected to their respective footprint. The accurate determination of the footprint positions therefore provides an important physical reference point in Jupiter's auroral regions with respect to where they map in the magnetosphere. It also depends on the physical conditions near each of the moons (plasma conditions, variation in magnetic field amplitude, and magnetodisc topology). Juno's elliptical polar orbit around Jupiter allows Juno-UVS to produce a comprehensive satellite footprint dataset. We present an extensive analysis of the Io, Europa and Ganymede satellite footprints, and estimate observationally for the first time the corresponding Alfvén travel time at all system III longitudes, constraining the Alfvénic interaction at the 3 innermost Galilean moons.

The peak frequency source of Saturn's Kilometric Radiation

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Before to ultimately plunge into Saturn's atmosphere, the Cassini spacecraft explored between 2016 and 2017 the auroral regions of Saturn's magnetosphere, where rises the Saturn's Kilometric Radiation (SKR). This powerful, nonthermal, radio emission analog to Earth's Auroral Kilometric Radiation, is radiated through the Cyclotron Maser Instability (CMI) by mildly relativistic electrons at frequencies close to the local electron gyrofrequency. The typical SKR spectrum, which ranges from a few kHz to ∼1MHz, thus corresponds to auroral magnetic flux tubes populated by radiosources at altitudes ranging from ∼4 kronian radii (RS) down to the planetary ionosphere. During the F-ring orbital sequence, Cassini probed the outer part of both northern and southern auroral regions, ranging from ∼2.5 to ∼4 RS altitudes, and crossed several SKR low frequency sources (∼10-30 kHz). Their analysis showed that the radiosources strongly vary with time and local time, with the lowest frequencies reached on the dawn sector. They were additionally colocated with the UV auroral oval and controlled by local time-variable magnetospheric electron densities, with importants consequences for the use SKR low frequency extensions as a proxy of magnetospheric dynamics. Along the proximal orbits, Cassini then explored auroral altitudes below ∼2.5 RS and crossed numerous, deeper, SKR sources at frequencies close to, or within the emission peak frequency (∼80-200 kHz). Here, we present preliminary results of their survey analysis, taking advantage of HST remote UV observations coordinated with Cassini in situ radio and magnetic measurements. Understanding how the CMI operates in the widely different environments of solar system magnetized planets has direct implications for the ongoing search of radio emissions from exoplanets, ultracool dwarves or stars.

Application du modèle IPIM aux événements intenses : éjections de masse coronale (CME) et région d'interaction en corotation (CIR)

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Les développements récents du modèle IPIM (IRAP Plasmasphere- Ionosphere Model) permettent désormais une description avec une bonne précision des événements solaires intenses. Nous présenterons des résultats récents du modèle lors d'impact sur l'ionosphère aurorale de High Speed Streams (CIR/HSS) et de CME. Nous décrirons les stratégies suivies pour représenter la thermosphère utilisée en entrée d'IPIM (utilisation du modèle physique TIEGCM ou ajustement aux données de densité thermosphérique et de rapport O/N2 issues de satellites). Nous explorerons aussi les problématiques liées à l'électrodynamique aurorale (convection, précipitation), avant l'intégration du modèle d'électrodynamique en cours de développement dans le cadre de la thèse d'Antoine Resseguier. Nous présenterons les résultats en terme de propriétés de l'ionosphère et de courants ionosphériques.

Effect of Faraday rotation on Jovian low-frequency radio-emissions

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Studying Jovian low-frequency magnetospheric radio-emissions ($\leq$40 MHz) allows to remotely probe their generation mechanism (especially the electron Cyclotron Maser – ECM) and the acceleration processes of electrons that power it. Those emissions have different time scales : from milliseconds to hours, and are mainly polarized elliptically (both circular and linear polarization are present).
While propagating through the plasmas between the source and the observer, the linearly polarised fraction of the emissions is subject to Faraday rotation, producing spectral fringes in linear polarization. Studying these fringes allows to retrieve the Rotation Measure (RM) of the emission and remotely study the interplanetary medium, the terrestrial ionosphere and especially the Jovian magnetosphere in our case, if its contribution is strong enough. In this work, we compare the measured RM to predicted RM values for the terrestrial ionosphere and we aim at analyzing the dependence of the difference to source-observer geometry and periodicities related to the Jovian magnetosphere.
Finally, it has been convincingly argued that radio emissions from exoplanets and star-planet interactions are expected to have deep similarities with Jupiter's. Thus, the next step of this study will be to evaluate the application of this detection method to exoplanets by conducting 'Jupiter as an exoplanet' studies with data from the NenuFAR radio telescope. Combined with other tools, such as predictions on the exoplanetary magnetic field or Zeeman-Doppler Imaging (ZDI) observations, this will allow us to remotely study the interstellar medium and exoplanetary magnetospheres.

On the location of magnetic reconnection on the dayside magnetopause

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Coupling the magnetosphere with the interplanetary medium, magnetic reconnection at the magnetopause serves as the main driver of magnetospheric activity. The efficiency of this coupling is highly contingent upon the location at which reconnection occurs on the magnetopause. Although various models have been proposed to predict the location of reconnection lines, also referred to as X-lines, none of these models are consistently aligned with global MHD simulations. These models often rely on quantities whose spatial distributions at the magnetopause are obtained by analytical or numerical modeling. To study and constrain magnetic reconnection on a large scale from an observational standpoint, we used statistical learning to automatically select in-situ measurements from four missions (Cluster, Doublestar, THEMIS, MMS). This allowed for a 3D reconstruction of the magnetic field draping in the dayside magnetosheath, and the discrepancies with a commonly used magnetostatic model revealed the significance of the plasma flow in the draping mechanism. It also enabled the investigation of the impact of magnetic reconnection on the magnetic pileup in the magnetosheath, on which previous studies have not been consistent. Finally, the reconstruction of the global distribution of magnetic shear angle, current density, and asymmetric reconnection rate at the dayside magnetopause provide some constraints on the location of magnetic reconnection. The location of the X-line on the dayside magnetopause will be further discussed in relation to both global and local modeling.

Observations and modelling of the solar wind composition variations

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The physical mechanisms that regulate the abundance of heavy ions in the solar wind are not well understood. Variations in composition are measured in the charge state of heavy ions as well as the abundance of alpha particles and of elements with low first ionisation potential (FIP). The ionisation state and the abundance of heavy ions remain frozen once they escape the solar corona. Since the slow and fast solar winds have very different compositions, the slow wind being enriched in low-FIP elements, it has been argued that they must form through different processes in the solar corona. In this study, we present the analysis of solar wind data taken in situ at different points in the inner heliosphere using Solar Orbiter, Parker Solar Probe, Wind and ACE to study the relation between abundance variations and solar wind properties (plasma moments, cross-helicity and non-thermal particles). This allows us to classify the different solar wind types according their composition and Alfvénicity. We then compare this classification with recent results of a new multi-species model of the solar corona and solar wind to study the various mechanisms potentially operating, including diffusion processes and wave-particle interactions, to regulate heavy ion abundances. This work was funded by the ERC SLOW SOURCE project.

Parametric simulations of the propagation of solar jets : Investigating the origin of switchbacks

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The recent discovery of switchbacks, localized magnetic deflections in the solar wind, by Parker Solar Probe has spurred investigations into their origin. One prominent theory suggests their formation in the lower corona through a process of magnetic reconnection akin to solar jet formation. To explore this hypothesis, I will present parametric simulations using a three-dimensional numerical magnetohydrodynamic (MHD) model of solar-jet-like events. Within the MHD framework, I examine the influence of varying atmospheric plasma beta on the dynamics of solar-like jets.
Across simulations representing distinct solar atmospheres, similar temporal energy variations were observed. Notably, magnetic energy injection exhibited consistency, with a partial conversion into kinetic energy during jet generation. The parametric study validates this model for initial plasma beta values ranging from 10^{-3} to 1, corresponding to different magnetic environments within the solar atmosphere. Common structural characteristics in solar jets, including a dense bulk flow of plasma and a magnetic wavefront propagating at an Alfvénic speed in the atmosphere, were identified. However, the propagation ratio of these structures varied among simulations, revealing intricate influences of atmospheric stratification on jet dynamics.
Overall these simulations unveiled the propagation of magnetic deflections thanks to jet-like events, shedding light on the possible formation processes of switchbacks.

Preliminary results from a new model of the Io torus fed by the two Juno Io flybys

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In December 2023 and January 2024, two Juno orbits around Jupiter will result in a close fly-by of Io and a crossing of its plasma torus. Taking advantage of these first Io fly-bys since Galileo, we will present a new simplified mathematical model of the Io torus aimed at describing the links between generation and loss mechanisms of the atmosphere and neutral cloud, chemical processes, torus ions pickup and plasma exchange with the magneto disk, which will assimilate observational data in the model. We will discuss our preliminary modeling results and their implications on the role of the Io source on Jovian magnetosphere dynamics.

Connecter SPICE à HIS à travers l'effet FIP

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Relier l'activité solaire dans la photosphère et la couronne à l'héliosphère interne est l'un des principaux objectifs de la mission Solar Orbiter de l'ESA et de la NASA. Établir un lien entre un événement au Soleil et ses répercussions dans l'héliosphère n'est pas une affaire triviale, surtout dans le cas des petites structures qui sont souvent en dessous de la résolution des imageurs héliosphériques actuels. Heureusement, pour ces petits événements, il est possible de trouver un lien entre le Soleil et l'héliosphère en diagnostiquant la composition élémentaire du plasma grâce à l'effet FIP (pour premier potentiel d'ionization en anglais), une augmentation de l'abondance des éléments à faible FIP présents habituellement dans les zones de champ magnétique fermé.
Solar Orbiter a été conçu pour réduire l'écart entre les mesures in situ et les mesures de télédétection, en s'approchant du Soleil jusqu'à 0,28 UA. Sa combinaison unique d'instruments in situ et de télédétection peut être utilisée pour éclaircir cette tâche difficile.
Nous présentons une analyse dans laquelle nous avons établi une telle connexion par le biais d'observations et de modélisation. Le spectromètre EUV SPICE peut observer les régions sources du Soleil qui seront échantillonnées quelques jours plus tard par l'instrument in-situ SWA-HIS. Grâce à la modélisation, nous avons déterminé la trajectoire suivie par le vent solaire et établi d'où proviennent les différents paquets de plasma mesurés in situ.
Nous avons analysé un événement qui a eu lieu en mars 2022 où la composition in situ a montré une diminution globale du rapport Fe/O avec des structures périodiques dans la composition et nous avons déterminé si la tendance générale que nous avons observée in situ se reflétait dans les données de télédétection lors de la mesure de l'abondance relative souffre/azote.

Thème 4 : Transport d’énergie multi-échelles et turbulence

Two Classes of Equatorial Magnetotail Dipolarization Fronts Observed by Magnetospheric Multiscale Mission : A Statistical Overview

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We carried out a statistical study of equatorial dipolarization fronts (DFs) detected by the Magnetospheric Multiscale mission during the full 2017 Earth's magnetotail season. We found that two DF classes are distinguished : class I (74.4%) corresponds to the standard DF properties and energy dissipation and a new class II (25.6%). This new class includes the six DF discussed in Alqeeq et al. (2022,) and corresponds to a bump of the magnetic field associated with a minimum in the ion and electron pressures and a reversal of the energy conversion process. The possible origin of this second class is discussed. Both DF classes show that the energy conversion process in the spacecraft frame is driven by the diamagnetic current dominated by the ion pressure gradient. In the fluid frame, it is driven by the electron pressure gradient. In addition, we have shown that the energy conversion processes are not homogeneous at the electron scale mostly due to the variations of the electric fields for both DF classes.

Study of a dayside magnetopause reconnection event detected by MMS related to a large-scale solar wind perturbation and magnetospheric cold ions

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Magnetic reconnection is a fundamental process that is ubiquitous in the universe and allows the conversion of magnetic field energy into heating and acceleration of plasma. It is responsible for the dominant transport of plasma, momentum, and energy across the magnetopause from the solar wind into the Earth's magnetosphere. The present study reports on a magnetic reconnection event detected by the Magnetospheric Multiscale mission (MMS) on 21 October 2015 around 04 :40 UT far from the diffusion regions and related to a large-scale solar wind (SW) disturbance impacting the Earth's magnetosphere. Based on OMNI data, the event impacting the Earth's magnetosphere is ahead of the weak Stream Interacting Region (SIR) (SW beta≈7 and Alfvénic Mach number≈15) where the averaged density of solar wind is about ∼20 cm^{-3} (compared with average SW density ∼ 3 to 10 cm^{-3}). On one hand, the magnetosheath (MSH) density measured by MMS just after the crossing of the magnetosphere separatrix layer (identified by the large decrease of energetic electron fluxes) is very large ∼95 cm^{-3} (compared with average MSH density ∼20 cm^{-3}). In such a condition, we show that the current density at this separatrix is dominated by the ion diamagnetic current. On the other hand, cold ions are detected close to the magnetic reconnection separatrix layer on the magnetosphere side. Their origin and impact on the ongoing reconnection process and the energy conversion at the separatrix are investigated/discussed. The drifting cold ions and the presence of a guide field have significant effects on the orientation of the electric field normal to the magnetopause.

Characterizing space plasmas through the data analysis of multi point space missions

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The interplanetary medium around the earth is in the form of plasma and it is this medium that principally governs energization processes of both particles and waves in space. Measurements of the fields in space plasmas show temporal and spatial variations on all observed scales. Single satellite measurements only provide a partial picture as they do not allow deltaing of these variations. Multipoint missions, in particular the 4-satellite tetrahedron configuration of CLUSTER (2000) and MMS (2004), have been launched to overcome this difficulty. For example, the wave field characterization from the data of CLUSTER have been done by using the k-filtering technique and Phase Differencing technique. These missions and techniques have advanced our understanding of space plasmas. However using only 4 spacecrafts allows us to take 3D measurements at only one spatial scale at a time. The existing methods employed are also severely limited due to spatial aliasing and important uncertainties. Specifically, the investigation of a turbulent cascade, from the injection to the dissipation scale, requires a much broader coverage of scales. To relate the injection range to the dissipation scale, three nested tetrahedron are needed. The first step towards this Cross-Scale Mission concept is the planned HELIOSWARM mission (2029), which will be a multipoint mission consisting of 9 satellites with its maximum operating frequency being 16 Hz. HELIOSWARM will focus on understanding turbulent cascading from the MHD to Sub -Ionic scales.

Magnetospheric MultiScale Measurements of Energy Balance in Collisionless Plasma

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The study of energy conversion in collisionless plasmas has remained largely inaccessible until recently thanks to the high-resolution, multi-spacecraft Magnetospheric MutliScale (MMS) observations. Direct derivation from the Vlasov-Maxwell equation provides a set of equations that describe the temporal evolution of the kinetic and internal energies. In this work, we investigate, in a multifluid framework, the terms that quantify the transfer to and from kinetic energy, i.e., pressure-gradient force term, and the electromagnetic energy term. The former accounts for plasma acceleration/deceleration from a pressure-gradient, while the latter accounts for plasma acceleration/deceleration from an electric field. We use in-situ observations from MMS to understand the relationship between the pressure-gradient force term and the electromagnetic energy term. We perform a statistical analysis of those parameters in different regions, i.e., regular magnetosheath regions, electron diffusion regions and bow shock crossings. The analysis reveals a weak but observable anti-correlation between the two terms for ions, implying energy balance. However, the expected relationship is less clear for electrons. Overall, the signs of the two terms are opposite, as expected. Possible explanations lie in the uncertainty associated with gradient measurements in pressure-gradient terms. In an approach aimed at understanding errors arising directly from gradient measurements, we modeled a pressure gradient from a regular magnetopause crossing. We measured the gradient using a 4 spacecraft technique and compared it to the analytical derivative. The analysis indicates that gradient values are underestimated when spacecraft separation is either comparable to the gradient scale or greater than the gradient scale. A more comprehensive analysis is underway to investigate the factors influencing gradient measurements, particularly the impact of signal noise on these measurements.

Energy transport and conversion in the heart of magnetic reconnection regions

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The electron diffusion region (EDR) is believed to be a key region to the energy conversion associated with magnetic reconnection, from magnetic to kinetic and thermal, but the nature of energy transport and conversion in EDRs is still misunderstood.
In this work, we capitalise on recent studies that have increased the number of referenced EDRs observed by MMS, and perform a statistical study of 71 near X-line events previously identified in the literature. Upon detailed analysis, MMS was found to be located within the inner EDR for 32 of these events, while others correspond to outer EDR or IDR crossings.
We investigate energy partition in their vicinity and find that the electron enthalpy flux dominates within the EDRs compared to the kinetic and heat fluxes. We then evaluate the stationary terms of the energy conservation equation and find that large fluctuations of the electron enthalpy flux divergence tend to occur in the EDRs, showing for a complex energy transfer process dominated by the internal energy flux contribution. Most of the studied EDRs occur at relatively high shear and low guide field conditions, and thus no clear influence of these parameters on the energy conversion rate stands out, though this may also be due to MMS sampling the EDRs at different distances from the X-line. In future work, comparing these results to magnetotail- (symmetric) and magnetosheath- (low shear) EDR will bring insights on how the magnetic reconnection regime can impact the energy conversion and transport.

The Cross-Scale Energy Transfer in turbulent plasmas - Insight from the Terrestrial Magnetosheath

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Astrophysical processes inject energy at large scales into turbulent motion and electromagnetic fields, this energy then cascades to progressively smaller scales and it's eventually thermalized by the plasma. In this work, for the first time using in-situ data, we bring direct evidence that the energy cascade feeds the energy dissipation via the pressure-strain interaction.
Applying the coarse-graining method to MMS spacecraft's data we are able to measure simultaneously the cross-scale energy transfer and the scale-dependent dissipation showing that the cascade rate, constant in the MHD range, weakens progressively as we move into the sub-ion range. The decrease in the cascade rate is counterbalanced at each scale by the increase in dissipation via the pressure-strain interaction.
This novel method opens new pathways to investigate turbulent energy conversion in space plasmas.

Impact of the Nusselt number in global models of solar turbulent convection

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Global models of solar turbulent convection have recently shown some success to explain the origin of the observed differential rotation (DR) and surface magnetic flux, at the origin of the 11-years activity cycle. However, the amplitude of giant convective cells needed to reproduce these solar patterns is currently too high when compared to observational constraints coming from helioseismology. This over-estimation of convective velocities can even result in a global reversal of the DR profile when the turbulence of models is increased to reproduce the solar small convective scales, which is known as the Convective Conundrum. It then important to better understand how energy is transported by the solar convection and distributed among the different scales of the turbulence.
In this talk, we will present our current understanding of this paradox and its possible origin, resulting from a parametric study using high-performance numerical simulations. In particular, we propose a method to control the amplitude of convective transport, while maintaining the overall transport of solar luminosity at the solar rotation rate and being closer to what is expected from current solar surface observations. We further study scale by scale force and energy balances in different models, showing how the different balances vary with the Nusselt number.

Polarization of type III solar radio burst emissions : Particle-In-Cell numerical simulations

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Electromagnetic waves emitted during type III solar radio bursts are studied owing to data provided by PIC simulations computed using the 2D/3V version of the code SMILIE. Nowadays, there is a growing interest in the polarization characteristics of such emissions, which are crucial for understanding the processes generating them and diagnosing the solar wind and coronal plasmas. The conducted research consists in modeling virtual satellites moving in a 2D simulation box and recording waveforms of fields and particle densities. Several methods to analyze the waveforms recorded have been implemented, tested, used and compared, enabling us to identify the wave modes emitted (in particular, the electromagnetic waves emitted at frequencies wp and 2wp) and to determine their polarization characteristics (sense and ellipticity). Statistical studies using 256 virtual satellites have been performed to determine the distributions of ellipticity as a function of time as well as of magnetic field amplitude and average level of density fluctuations of the ambient plasma. Results obtained show a good agreement with space observations.

Thème 5 : Mécanismes d'accélération des particules et chauffage du plasma

Evolution of the Heliospheric Current Sheet during a PSP-SolO radial alignment

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Helios 1 & 2 opened a new era as they allowed for synergistic observations of the solar wind. In particular, there have been studies about the radial evolution of what can be considered the same solar wind parcel passing through both spacecraft when they were radially aligned during so called "plasma line-ups". The recently launched Parker Solar Probe (PSP) and Solar Orbiter (SolO) are great new opportunities for such studies. Results of plasma line-ups studies are however strongly dependent on the considered time intervals. We propose here a new solar wind propagation method allowing to identify what we believe to be the same plasma passing through PSP (∼0.075 au) & SolO (∼0.9 au) during a radial alignment. We show the matching of two density structures (with radial lengths of $\sim 10^7$ km), corresponding to crossings of the Heliospheric Current Sheet on both spacecraft. Data also indicate the development of Stream Interaction Region during the plasma propagation. The unperturbed slow wind observed at PSP has indeed been caught up by a faster wind, creating a propagating shock and trailing compression region, eventually engulfing the Heliospheric Current Sheet.

Are Switchback Boundaries Observed by Parker Solar Probe Closed ?

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Switchbacks are sudden and large deflections in the magnetic field that Parker Solar Probe frequently observes in the inner heliosphere. Their ubiquitous occurrence has prompted numerous studies to determine their nature and origin. Our goal is to describe the boundary of these switchbacks using a series of events detected during the spacecraft's first encounter with the Sun. Using FIELDS and SWEAP data, we investigate different methods for determining the boundary normal. The observed boundaries are arc-polarized structures with a rotation that is always contained in a plane. Classical minimum variance analysis (MVA) gives misleading results and overestimates the number of rotational discontinuities. We propose a robust geometric method to identify the nature of these discontinuities, which involves determining whether or not the plane that contains them also includes the origin ($\boldsymbol{B} = 0$). Most boundaries appear to have the same characteristics as tangential discontinuities in the context of switchbacks, with little evidence for having rotational discontinuities. We find no effect of the size of the Parker spiral deviation. Furthermore, the thickness of the boundary is within MHD scales. We conclude that most of the switchback boundaries observed by Parker Solar Probe are likely to be closed, in contrast to previous studies. Our results suggest that their erosion may be much slower than expected.

Connecting in situ measurements and solar EUV images to investigate the sources of magnetic switchbacks

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The origin of the sudden deflections of the magnetic field, known as magnetic switchbacks, is still hotly debated. These structures, which are omnipresent in the observations made by Parker Solar Probe (PSP), are likely to have their source in the lower corona. We investigate this hypothesis by using both in situ and remote-sensing observations, an approach that has remained largely unexplored so far.
We analyze different types of sources and relate them to the properties of switchbacks during the solar encounters of PSP, including corotation periods when the spacecraft was connected to one single coronal hole.
We analyze the connectivity of the switchbacks probed in situ by PSP/FIELDS and PSP/SWEAP with the events detected by solar imagers. We first rely on extrapolations of the photospheric magnetic field (using PFSS) to constraint the identification of the sources. We then study whether the events detected in situ by PSP could be statistically connected to eruptive events seen in EUV images taken by SDO/AIA and PROBA2/SWAP. The events investigated include topological boundaries that are known to favor interchange reconnection, such as small-scale loop systems in coronal holes that can erupt and produce coronal jets.

Caractérisation statistiques des sources joviennes hectometriques par des mesures electrons et radio in situ

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Dans des zones d'accélération magnétiquement connectées aux aurores UV diffuses de Jupiter, des émissions radio aurorales sont produites à la fréquence cyclotron électronique locale (entre 100 kHz à 40 MHz) par l'Instabilité Maser Cyclotron. Cette instabilité requiert une inversion de population électronique, qui apparaît naturellement pour une population d'électron accélérée. La sonde polaire Juno explore depuis 2016, ces régions d'accélération et d'émission radio aurorale in situ et permet des mesures radio, électroniques et magnétiques. Dans ce travail, nous avons analysé les radiosources hectométriques (f qq MHz, où pique le spectre radio jovien) traversées lors des 45 premiers périjoves. Nous avons caractérisé les régions d'émission et identifié 3 types de distributions électroniques instables : deux déjà connues à Jupiter (loss cone et conics) et une nouvelle (shell). Les distributions de type coquille (shell) ont été identifiées sur Terre dans des régions d'accélération mono énergétiques (inverted V) que l'on retrouve peu à Jupiter. Nous menons donc une étude comparative des mécanismes de génération des émissions radio aurorales hectométriques joviennes au cas de références des émissions kilométriques terrestres.
Cette méthode pourra être appliquée au rayonnement kilométrique jovien (b KOM) ainsi qu'aux émissions aurorales de Mercure.

Statistical Analysis of the Radial Evolution of the Solar Winds between 0.1 and 1 au, and their Semi-empirical Iso-poly Fluid Modeling

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Classifying solar wind observations by HELIOS in several populations sorted by bulk speed, has revealed slight accelerations of the wind as it expands away from the Sun in the 0.3 - 1 au radial range (Maksimovic et al. 2020). The faster the wind is, the smaller is this acceleration. Recent measurements from Parker Solar Probe, which have been added closer to the Sun, show that the HELIOS populations can be extended smoothly back to the Sun. Moreover, the well established bulk speed/proton temperature (u, Tp) correlation, together with the acceleration of the slowest winds, are clearly visible in the PSP data (Dakeyo et al. 2022, Halekas et al. 2022), and in the Solar Orbiter data at larger distance.

Based on the previous classifications, we present results of semi-empirical Parker-like models (Iso-poly) for which the solar wind is modeled as isothermal in the corona, then polytropic well after the sonic point, with polytropic indices corresponding to the observed temperature gradients. Such models allow to establish a differentiated energy balance for the heating of the wind and for the acceleration separately. We also present an estimate of the heating rates radial evolution required to coherently reproduce the solar wind observations.

Advancing Solar Wind Microstream Modeling through 3D MHD Simulations : Unraveling Formation and Evolution Dynamics

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We investigate the origin of mesoscale structures in the solar wind called microstreams defined as enhancements in solar wind speed and temperature that last several hours. They were first clearly detected in Helios and Ulysses solar wind data and are now omnipresent in the 'young' solar wind measured by Parker Solar Probe and Solar Orbiter. These recent data reveal that microstreams transport a profusion of Alfvénic perturbations in the form of velocity spikes and magnetic switchbacks. In this study, we use a very high-resolution 3D MHD and 2.5D model of the corona and the solar wind to simulate the emergence of magnetic bipoles interacting with the pre-existing ambient corona and the creation of jets that become microstreams propagating in the solar wind.

Temporal correlations between solar energetic particles events properties and coronal shock waves parameters

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Solar energetic particle (SEP) events, particularly those of significant magnitude, are commonly associated with fast and wide coronal mass ejections (CMEs). These CMEs generate and drive shock waves in the solar corona, proving to be highly efficient in particle acceleration to high energies. Understanding the intricate connections between shock wave properties and SEP characteristics is crucial for advancing Space Weather forecasting.

To achieve this objective, we employ a methodology to analyze a SEP event involving a coronal shock wave, observed by several spacecraft well distributed around the Sun. Initially, we reconstruct the 3D ellipsoidal shape of the expanding shock, enabling the extraction of its geometry and kinematic properties. Using magneto-hydrodynamics (MHD) cubes, we then reconstruct the magnetic connectivity of spacecrafts and retrieve the MHD properties of the shock wave at the intersections with these magnetic field lines. The temporal correlations between the shock properties and the SEPs recorded by individual spacecraft can finally be compared.

Through the application of this methodology, we identify enhanced correlation coefficients between SEPs and shock parameters, such as speed, Alfvénic Mach Number, and theta_BN (the angle between the shock's normal and the magnetic field line).

Investigation of solar wind kinetic properties and velocity distribution function during Parker Solar Probe and Solar Orbiter radial alignments

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The new space missions recently launched to the Sun – Parker Solar Probe (PSP) and Solar Orbiter (SO) – prompt us to a new era of solar wind studies. Particularly, there are several opportunities where PSP and SO align in the radial direction, allowing us to study the evolution of solar wind properties and structures as a function of distance from the Sun. I investigate the plasma properties of the solar wind major ions during PSP-SO radial alignments. Using a measure for global dependence of two time series, I identified plasma parcels that are plausibly intercepted by both spacecraft. By considering the kinetic properties of the ion observations at PSP and SO, it is found that the ion temperature anisotropy decreases while the ion beta increases away from the Sun. Using the linear instability analysis, it is found that a larger proportion of the data points are unstable to the proton cyclotron instability closer to the Sun. Moreover, the ion distributions in the velocity space, or the ion velocity distribution function (VDF), at PSP and SO for the same plasma parcel show different kinetic (non-Maxwellian) features. Using linear and quasi-linear instability analyses, I will discuss ion-kinetic activities and possible wave-particle interactions observed at PSP and SO with a focus on their effects on the production of non-Maxwellian features of VDF and the local energy transfer. This work contributes to the understanding of the solar wind ion energization, and the production of non-Maxwellian ion VDF features that in turn provide sources of free energy in the driving of the solar wind heating and acceleration.

Comparative visibility of planetary auroral radio emissions and implications for the search for exoplanets

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The auroral regions of the so-called radio planets are the source of powerful, non-thermal, radio emissions amplified by an electron-wave resonant instabil- ity. These emissions are produced near the planetary magnetic poles along high latitude magnetic flux tubes at altitudes ranging from above the atmosphere up to a few planetary radii, and over variable ranges of local time and longitude. The radiated waves are also beamed at large angles from the local magnetic field vector, along a hollow cone, and further affected by refraction along the ray path. As a result, the final visibility of planetary auroral radio emissions strongly depends on the position of the observer. The underlying electron acceleration mecha- nisms depending on the considered magnetosphere, understanding the overall visibility of radiated waves is important to assess the diagnostic brought by remote radio observations onto auroral and magnetospheric dynamics. This topic has been widely studied in the literature, taking advantage of space-based radio exploration, generally on a planet-by-planet basis. In this work, we present an updated view of the visibility of Saturn's kilometric radiation from the full set of Cassini/RPWS observations obtained over 2004-2017. We then review comparatively recent parallel studies of the visibility of Terrestrial kilometric radiation and of Jovian broadband kilometric, hectometric and decametric emissions. We finally discuss the implica- tions for the search for exoplanetary auroral radio emissions.

Détection et interprétation de structures fines dans des sursauts radio de la naine rouge AD Leo

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Les sursauts radio provenant de naines M actives proches ont été fréquemment signalés et étudiés. En revanche, leurs sous-structures ou structures fines restent rarement explorées malgré leur importance potentielle pour diagnostiquer les propriétés du plasma et du champ magnétique de l'étoile. Dans le passé, ces études ont été limitées par la sensibilité des radiotélescopes. Nous présentons ici les résultats d'observation à haute résolution de la naine rouge AD Leonis (étoile éruptive), à l'aide du radiotélescope chinois FAST (Zhang, Tian, Zarka, Louis et al., 2023). Dans les trois observations effectuées (en décembre 2021 et mars 2022), de nombreuses émissions radio ont pu être détectées, composées de structures fines sous la forme de sursauts millisecondes. Les sursauts millisecondes observées sont de deux types, s'apparentant très fortement (i) aux sursauts solaires (émission plasma), et (ii) aux sursauts "S-burst" joviens (instabilité maser cyclotron). Nous nous focaliserons ici sur les émissions de type S-burst. La pente de ces émissions dans le plan temps-fréquence nous renseigne directement sur le mouvement des électrons provoquant ces émissions, et nous permet de remonter à leur énergie. Par le biais de simulations, nous montrons que ces émissions sont compatibles avec l'Instabilité Maser Cyclotron, et déclenchées par un couplage de l'étoile avec son environnement plasma, des éruptions solaires, ou une interaction avec un compagnon planétaire.

Source des émissions radio induites par les lunes galiléennes Io, Europa et Ganymède : mesures in situ par Juno

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Sur Jupiter, une partie des émissions radio aurorales est induite par les lunes galiléennes Io, Europa et Ganymède. Jusqu'à présent, à l'exception de Ganymède, elles n'ont été détectées qu'à distance, à l'aide de radiotélescopes au sol ou d'antennes électriques à bord des engins spatiaux. La trajectoire polaire de l'orbiteur Juno permet de traverser la gamme des tubes de flux magnétiques qui soutiennent les diverses interactions Jupiter-satellite, et d'échantillonner in situ les régions d'émission radio associées. Dans cette étude, nous nous concentrons sur la détection et la caractérisation des sources radio associées à Io, Europa et Ganymède. En utilisant des mesures d'ondes électriques ou des observations radio (Juno/Waves), des mesures d'électrons in situ (Juno/JADE-E), et des mesures de champ magnétique (Juno/MAG), nous démontrons que l'instabilité Cyclotron Maser (CMI), déclenchée par une fonction de distribution d'électrons de type cône de perte, est responsable des sources radio rencontrées. Nous confirmons que les émissions radio sont associées au spot UV "Main Alfvén Wing" (MAW) ou au spot UV "Reflected Alfvén Wing" (RAW), mais nous avons également montré que pour Europe et Ganymède, les émissions radio induites sont associées au faisceau d'électrons transhémisphérique ("Transhemispheric Electron Beam", ou TEB). Pour chaque source radio traversée, nous déterminons l'extension latitudinale, l'énergie des électrons résonnants CMI, et la bande passante de l'émission. Nous montrons que la présence de perturbations Alfvénique et de courants alignés descendant est nécessaire pour que les émissions radio soient amplifiées.

Discovery of Jovian radio bursts related to Ganymede and the main aurora, and implications on Alfvénic electron acceleration

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Radio detection, especially at high time-frequency (t-f) resolutions, is a powerful means of remotely studying electron acceleration processes, provided that the radio generation process is well identified and understood. Low radio frequencies (typically $\leq$ 100-200 MHz) are likely to be a preferred spectral domain to detect exoplanetary magnetospheres and star-planet interactions. Detection of radio bursts is also a means to overcome the hindering presence of interference and of ionospheric propagation effects at these low frequencies. In planetary solar system magnetospheres, the occurrence of radio bursts drifting in the t-f plane is common. The best documented case concerns the Jovian "S-bursts" induced by the Io-Jupiter interaction, the generation of which has been modelled, from the acceleration of electrons by Alfvén waves (themselves amplified by the ionospheric Alfvén resonator to the growth rate of radio emissions). We have developed a detection method of drifting radio bursts in massive high t-f resolution data, and have applied it to Jupiter observations with the Nancay Decameter Array. Beyond the expected many Io-Jupiter S-bursts, we present the first detection of decameter S-bursts related to the Ganymede-Jupiter interaction and to the main Jovian aurora. This reveals the ubiquitous character of Alfvénic electron acceleration and of the Alfvén resonator in Jupiter's high-latitude regions. We estimate the Alfvén wave periods and the energy of accelerated electrons. Two populations are found to co-exist, with different energies (a few keV and a few hundred eV). The technique developed for achieving these detections may become important for characterizing inaccessible astrophysical sources such as exoplanets.

Pitch Angle Distribution of MeV Electrons in the Magnetosphere of Jupiter

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The magnetosphere of Jupiter harbors the most extreme fluxes of MeV electrons in the solar system and therefore provides a testbed of choice to understand the origin, transport, acceleration, and loss of energetic electrons in planetary magnetospheres. Along this objective, the Pitch Angle Distribution (PAD) of energetic electrons may reveal signatures of the dominant physical processes. Furthermore, studying the anisotropy of energetic electrons at Jupiter is important for (1) surface weathering of the icy moons, and (2) radiation hazard for artificial satellites.
Here, we analyze for the first time the PAD of MeV electrons observed by the Galileo-Energetic Particle Detector (EPD) experiment in orbit around Jupiter from 1995 to 2003. Galileo-EPD reveals persistent pancake distributions at the M-shell of M = 9 (where Europa orbits). Outward of this distance, at M = 15 (Ganymede) and M = 20–60 (Callisto), MeV electron distributions have pancake, isotropic, and scattered beam field-aligned distributions. The scattered beam distributions indicate that high-latitude auroral acceleration may be a dominant source of trapped electrons for the Jovian radiation belts.
The impact of these results on JUICE science and radiation hazard will be presented.

Poynting flux injection by magneto-convection in the chromosphere of coronal holes

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Diverse dynamical processes contribute to the heating of the solar atmosphere. Recent observations and simulations have highlighted the importance of waves and magnetic reconnection in the chromosphere, providing energy to balance the radiative cooling. However, the precise amount of energy and the relative roles of these processes in different solar regions (e.g., coronal hole, quiet sun) are still under debate.
The community agrees that magnetic fields play a major role for the atmospheric heating. Numerical simulations have especially demonstrated that the braiding of magnetic field lines by photospheric convection can sustain a million-degree corona by injecting energy through Poynting flux (Gudiksen and Nordlund 2005, Finley et al. 2022). However, the initial magnetic field in such models remains a free parameter, and limited resolution may dampen velocity dispersions, impacting the accuracy of the simulations. In that context, how does the energy injected by magneto-convection into the chromosphere impact its dynamics and the subsequent heating ?
We present a parametric study using the Bifrost code, focusing on high-resolution simulations of coronal holes. By varying the amount of upwardly advected magnetic field at the bottom boundary, we simulate different configurations of flux emergence. Analysis of the internal energy balance confirms an increase of the mass loading and Ohmic atmospheric heating, related to the amplitude of the injected Poynting flux. We are then interested on understanding the dynamics of magnetic events leading to such loading and heating. Future comparisons of these models with observations, and in particular the out-of the-ecliptic exploration of polar caps by Solar Orbiter, make us envision the possibility for better constrains on the dynamics of coronal holes, and the injection of energy into the solar wind.

Observing delayed emissions of Interplanetary Type III bursts during the comissioning phase of Solar Orbiter

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The Sun is a magnetic and active star as well as an efficient particle accelerator. Particle acceleration and transport in the corona and in the heliosphere is an important and challenging topic, not only from the point of view of understanding fundamental processes in our star but also from the point of view of understanding and potentially forecasting the effects of solar energetic particles on the terrestrial environment (space weather applications). The most direct diagnostics of energetic electrons in the solar atmosphere are the X-ray and radio emissions they produce. The launch of the Solar Orbiter in early 2020 marked a significant milestone, as it equipped us with the capability to simultaneously capture both types of emissions. This unique vantage point enables us to investigate the acceleration mechanisms of energetic electrons during solar flares, their subsequent transport, and radiative processes as they propagate from the corona into the interplanetary medium. Our study focuses on 16 Interplanetary Type III radio bursts (IT3s) associated with HXR emission peaks, observed by the instruments RPW and STIX during the commissioning phase of the Solar Orbiter mission from November 17 to 21, 2020. We have observed changes in the X-ray source morphology coinciding with the occurrence of IT3 emissions, and our combined observations with the EUI instrument suggest the presence of open magnetic field lines within the active region, which could potentially enhance IT3 production.

About the nature of sustained kink oscillations in coronal loops : combining coronal and chromospheric diagnostics

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We investigate the nature of sustained kink oscillations in coronal loops, by looking at their properties and potential drivers in multiple observational datasets, including both imagers and spectrographs. Kink oscillations have been observed for many years in SDO/AIA, where a majority of them has been seen to dissipate quickly and to be associated with impulsive heating events (as during e.g. magnetic reconnection events). That until recently, when long-lived (decayless) kink oscillations have started to be observed more frequently with the advent of the high-resolution EUV imager on board Solar Orbiter (SolO-EUI). Their sustainability shows significant potential for coronal heating but their energy source still remains to be identified. A scenario of coronal loops seen as self-oscillatory systems where their footpoints are excited by quasi-steady granular or super-granular flows has received positive support recently. We investigate further this scenario by combining typical coronal diagnostics with chromospheric diagnostics given by the Swedish 1-m Solar Telescope (SST). In this contribution I will show preliminary results and future perspectives to this work, which has been funded by the Research Council of Norway (grant 324523).

Caractérisation in-situ des propriétés des électrons dans les circuits lunes-Jupiter et mécanismes d'accélération associés

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Dans la magnétosphère de Jupiter, les lunes galiléennes perturbent l'écoulement du plasma du magnétodisque entraîné en quasi-corotation par le champ magnétique de la planète. Cette interaction donne lieu à divers processus physiques, y compris la génération d'ondes d'Alfvén pouvant se propager le long des lignes de champ magnétiques et accélérer des particules chargées. L'une des manifestations de ces phénomènes est l'accélération parallèle des électrons qui précipitent dans l'atmosphère de Jupiter et déclenchent des émissions aurorales visibles dans les domaines ultraviolet et infrarouge.
La mission Juno, en orbite depuis 2016, permet actuellement de caractériser in-situ les interactions lune-magnétosphère. Plusieurs traversées à haute latitude des lignes de champ magnétique reliant les orbites des lunes galiléennes à Jupiter ont été rapportées. Les mesures de particules de l'instrument JADE et les observations d'ondes (Waves) révèlent alors une diversité de propriétés de particules et d'ondes, reflétant les processus d'accélération sous-jacents.
Nous présentons ici une comparaison des propriétés des électrons mesurés dans les circuits Io-Jupiter, Europe-Jupiter et Ganymède-Jupiter. En étudiant les distributions en énergie de ces particules accélérées, nous montrons qu'en aval des lunes l'accélération des électrons est liée à des processus d'interaction entre des ondes d'Alfvén et les particules. En revanche, des observations d'électron plus énergétique en amont des lunes montrent des distributions bien différentes, avec notamment un maximum dans les spectres en énergie indiquant des processus d'accélérations se substituant ou s'ajoutant aux processus alfvéniques.

Using the IRAP Solar Atmosphere Model & Solar Orbiter to Investigate Helium Abundance in the Inner Heliosphere

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Helium is a major constituent of the corona and solar wind that plays an important role in the energy budget of the corona and in the acceleration of the solar wind. Helium abundance varies significantly with the solar cycle and between the different types of fast and slow solar winds. We present the newly-developed multi-species IRAP Solar Atmospheric Model (ISAM) which solves for the coupled transport of both neutral and charged particles between the chromosphere and the corona, including a self-consistent treatment of collisional and ionisation processes. We exploit ISAM to study the mechanisms that regulate helium abundance in the source region of the fast and slow solar winds and contrast numerical results with and without helium included in the model. We compare our model outputs with Parker Solar Probe and Solar Orbiter data, in particular from the Proton and Alpha particle Sensor (SWA-PAS).

Electrons énergétiques dans la couronne solaire : Emissions X et radio observées lors de l'événement de longue durée du 9 Mai 2021

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Nous présenterons ici les résultats d'une analyse de l'éruption de longue durée du 9 Mai 2021. Cette éruption est associée à la production de rayonnements X thermique et non thermique observés par Fermi/GBM dans la direction terrestre et STIX sur Solar Orbiter (97° de la direction soleit-terre). Cette éruption est également observée en radio avec les instruments de Nançay (NRH, ORFEES, NDA) et dans le milieu interplanétaire avec WAVES sur WIND et RPW sur Solar Orbiter. L'événement X présente une phase impulsive observée jusqu'à 25 keV par STIX et FERMI ainsi qu'une phase graduelle observée jusqu'à 15 keV. Dans le domaine décimétrique/métrique, l'événement est associé à un groupe de types III se prolongeant dans le milieu interplanétaire et à un continuum de type IV dans la phase graduelle. Nous discuterons ici de la comparaison des émissions X et radio (de différents types) et de l'évolution spatiale comparée des différentes sources X et radio au cours de l'événement. Nous étudierons également les caractéristiques des électrons non-thermiques dans l'atmopshère solaire pendant la phase impulsive et graduelle de l'événement et présenterons brièvement le lien avec les électrons détectés dans le mileiu interplanétaire.

Thème 6 : Activité éruptive ou impulsive dans les plasmas

The impact of the observer's position on solar radio observations

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A large arsenal of space-based and ground-based instruments is dedicated to the observation of radio emissions, whether they originate within our solar system or not. Radio photons interact with anisotropic density fluctuations in the heliosphere, which can alter their trajectory and influence properties deduced from observations. This is particularly evident in solar radio observations, where anisotropic scattering leads to highly-directional radio emissions. Consequently, observers at varying locations will measure different properties, including different source sizes, source positions, and intensities. However, it is not known if measurements of the decay time of solar radio bursts are also affected by the observer's position. Decay times are dominated by scattering effects and so are frequently used to estimate the level of density fluctuations in the heliosphere, making any necessary location-related correction crucial. We use multi-spacecraft observations of interplanetary Type III bursts to investigate the dependence of both the decay- and rise-time measurements on the separation of the observer from the source. Using an improved fitting of the radio light curves, we determine that the decay and rise times are independent of the observer's position, identifying them as the only properties to remain unaffected. Moreover, we examine the ratio between the rise and decay times, finding that it does not depend on the frequency. Therefore, we provide the first evidence that the rise time is also dominated by scattering effects, adding to our understanding of the plasma emission process.

Spectrographic imaging of solar radio bursts with the Nancay Radioheliograph and the ORFEES spectrograph

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Since November 2020 the Nancay Radioheliograph resumed scientific observations, after five years of technical work. The NRH and the ORFEES spectrograph are providing observations relevant to particle acceleration in support of the SolarOrbiter and other space missions. We give a brief status report on the instrument and illustrate this research with studies of the origin of relativistic solar particle events and the trappig and escape of non-thermal electrons from an erupting flux rope during a coronal mass ejection. The unique contribution of radio spectral imaging is the tracking of elementary acceleration processes and of the magnetic structures that guide energetic particles from eruptive active regions at the Sun to remote places in the solar atmosphere and the Heliosphere. Earth-bound radio observations are therefore an essential element in the chain between X and gamma-ray observations of non-thermal to relativistic particles at the Sun and the detection in situ.

Solar jets : SDO and IRIS observations in the perspective of new MHD simulations

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In the last decade coordinated observations of the Interface Region Imaging Spectrograph (IRIS) with the instruments on board the Solar Dynamics Observatory (SDO) allow to make a step forward for understanding the trigger of jets and the relationship between hot jets and cool surges. We observe at the same time the development of 2D and 3D MHD numerical simulations to interpret the results.
We review a few jet studies based on IRIS spectra and SDO observations and show that with the same observations, different theoretical interpretations are possible based on different approaches, e.g. non-linear force-free field extrapolation, 3D MHD data driven simulations.

Que peut-on apprendre de la reconnection magnétique dans les plasma à haute densité d'énergie ?

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La première expérience sur la reconnexion magnétique a été menée en 2006 au Rutherfore Appleton Laboratory. Depuis, d'autre expériences on été faite permettant soit de confirmer les observations in-situ, soit de les compléter. Cette présentation souligne les paramètres des plasmas à haute densité d'énergie induit par laser de haute puissance, afin de comprendre comment appliquer les observations aux plasma spatiaux. Après une revue de ces expériences les plus significatives, nous verrons plus précisement celles menées par la communauté francaise du PNST ainsi que les avancées qu'elles ont permit.

Thème 7 : Relations Soleil-Terre et météorologie de l'espace

PNST
Programme National Soleil-Terre

Investigation of the Impact of Interplanetary Coronal Mass Ejections (ICME) on the geomagnetic tail by THEMIS observations

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We focus on a well defined interplanetary coronal mass ejection (ICME) with a dynamic pressure Pdyn $>$ 20 nPa, in December 2015. ACE observations and OMNI data allowed to identify ahead of Earth the expected features with shock and sheath regions preceding a magnetic cloud. This ICME triggered a storm in the magnetosphere with a storm sudden commencement (SSC) phase (SYM-H $\sim$ +50 nT) followed by a growth phase (SYM-H $<$ -150 nT at the minimum) and a long recovery phase lasting several days.
We investigate the impact of this ICME on the Earth's magnetotail from observations by the NASA mission THEMIS. Indeed we estimate the total pressure exerted on magnetotail current sheet. We find that the current sheet is compressed to $>$2nP in the main phase, i.e. 4 times more than in the quiet phase before the event, while in the recovery phase, the pressure gradually decreases and approximately comes back towowards quiet phase values. According to the tracking of magnetic field lines using the Tsyganenko T96 magnetic field model, the current sheet appears very stretched right from the SSC phase, and even more than during the main phase, before coming back very progressively to a shape comparable to the quiet phase. We quantify and discuss these effects.

Prévision d'indices géomagnétiques pilotée par les données sous la forme de scénarios physiquement crédibles

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Le projet Horizon Europe FARBES (Forecast of Actionable Radiation Belt Scenarios) a pour but le développement de méthodes de prévision de la dynamique des flux de particules piégées dans les ceintures de radiations dans un contexte opérationnel. Contrairement à l'approche consistant à prédire un événement dans les ceintures de radiations à partir de son origine solaire, ou bien à partir de paramètres du vent solaire mesurés en amont, nous cherchons ici à prédire, sous forme de scénarios, l'évolution d'un événement sur plusieurs jours à partir du moment où son début a été observé (par exemple, via des indices géomagnétiques). Toujours dans une optique opérationnelle, nous nous restreignons ici à l'utilisation de données et proxys mesurés depuis le sol, en excluant les données obtenues depuis des instruments embarqués.

Dans ce poster, nous présentons les travaux effectués jusqu'ici pour développer une méthode de prévision à plusieurs jours d'avance des indices et paramètres pilotant le modèle Salammbô de restitution de l'état des ceintures de radiation. Cette méthode s'appuie notamment sur une technique dite d'Analogs Ensemble, qui consiste à retrouver dans le passé les périodes les plus « similaires » à l'état (perturbé) actuel et à utiliser les différents déroulements futurs de ces événements passés comme membres d'une prévision ensembliste. Cette méthode, simple, a pour avantage de produire des scenarios physiquement réalistes (ce qui n'est pas nécessairement le cas par exemple des méthodes d'apprentissage automatique), et de pouvoir être mise à jour dès que des données plus récentes sont disponibles.

Pour commencer, nous présentons une méthodologie automatique de catalogage de périodes passées correspondant à des intensifications dans les ceintures à partir d'un proxy sol unidimensionnel. Puis nous comparons différentes méthodologies pour définir « l'état actuel », ainsi que des mesures de similarité de cet état avec des états passés. Enfin, nous évaluons notre modèle et présentons des pistes de développements futurs.

IMCPEA : Connecting Space Weather along the 30° E - 150° W Great Meridian Circle over Europe, Africa and the central Pacific

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In this talk we will provide an update to the PNST community about the progress and perspectives the IMCPEA project, whose aim is to deploy, connect and jointly operate a chain of space weather research and monitorng instruments along the 30° E - 150° W Great Meridian Circle, which runs over Europe, Africa and the central Pacific, following presentations of this "Internatonal Meriian Circle Program for Europe and Africa" at the ISWI and CEDAR workshops in June 2023, at the IMCP International Workshop in Beijing in Septermber 2023, and its discussion at the ESSW2023 in Toulouse in November 2023. Based on a synthesis of the feedback from these different meetings, which provides a fair understanding of the interests and potential contributions of the different regional communities to this project, we will :

- identify its key added values for interdisciplinary research and monitoring of the different types of natural hazards affecting our upper atmosphere and our space environment at large : disturbances propagating along the Sun-Interplanetary Space-Magnetosphere chain ; upward propagation of the effects of tropospheric weather and climate change through the atmosphere ; effects of secular variations of the geomagnetic field, impacts of Solid Earth disturbances (earthquakes, volcanic eruptions,...).
- present a premilinary assessment of the most urgent needs of this project in terms of suppport to the equipments and of development of collaborative tools ;
- open the discussion with the PNST community on the eminent role that this community, ground-based and space-based alike, can play in the development and implementation of this project ;
- propose a "Road Map" for its development.

Développement d'un nouveau modèle électrodynamique : Application à l'électrodynamique équatoriale

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Dans le cadre des évolutions du modèle IPIM, nous avons entrepris le développement d'un modèle électrodynamique en utilisant le nouveau système orthogonal de coordonnées magnétiques (Dipôle Excentré Généralisé, voir poster dédié), qui permet de prendre en compte les « anomalies » liées au champ magnétiques IGRF. Dans une première étape, ce modèle est focalisé sur la région de l'électrojet équatorial afin de le tester sur les spécificités de cette région : anomalie d'ionisation, fontaine équatoriale, électrojet... Nous présenterons ce modèle et les premiers résultats sur la dynamique de la région équatoriale. Ensuite, nous présenterons les extensions prévues pour ce modèle, notamment en terme de perturbations magnétiques au sol et de couverture électrodynamique jusqu'aux latitudes aurorales. Nous aborderons enfin les extensions que nous envisageons pour utiliser ce modèle dans un cadre « Météorologie de l'Espace » avec assimilation de données.

Analysis of cosmic radiation measurements on-board airplanes with Citizen Science gaseous detector : an insight on the calibration

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As part of various citizen science projects aimed at assessing radiation doses in the environment, some measurements have been taken on board airliners. Research activities aimed at gaining a better understanding of transient radiative phenomena in the atmosphere, such as the impact of solar energetic proton events, could potentially benefit from these data. In fact, as these phenomena cannot be predicted, very little data measured at the flight altitude could be taken. In addition to radiation monitoring programs on board aircraft, which are in fact very few in number and very complicated to maintain over time, analysis of the data provided by these citizen science projects could be of interest to research activities if efforts are made to characterize detectors, particularly with regard to radiation for which they were not designed, such as secondary cosmic rays. Even if this detector is not suitable and is far from being the best for this type of measurement, if data is available, why not use this new data ? Especially if no other new data is available. In this poster, we present an analysis of data measured with SAFECAST detectors on board aircraft. SAFECAST detectors were designed following the Fukushima accident to help the public monitor their contaminated environment. It consists of a pancake gaseous detector equipped with a GPS chip and an autonomous data logger. These detectors are designed for beta and gamma counting, not for neutrons or high-energy particles. The Safecast database contains a large amount of data measured in flight. In this work, we are seeking to determine the detector's sensitivity to the various components of secondary galactic cosmic radiation (protons, neutrons, electrons, muons, etc.) using these available data. The definition of these response functions will make it possible to estimate, from the raw Safecast count data, the additional exposure during a transient exposure to an energetic solar proton. To do this, we have compared the measured data with calculations of fluxes and ambient dose equivalents of the various components of secondary cosmic radiation along flight using the CARI-7 software. This work will help to provide a better estimation of the secondary cosmic radiation measured by passengers by implementing new calibration functions in the different citizen science projects using the SAFECAST detector such as SAFECAST of Cosmic-on-air projects.

VNET4IONS

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The ionospheric D-layer (60 and 90km) is also called the "ignorosphere", clearly indicating the level of knowledge on this atmospheric layer. Its electron content follows a daily cycle, but also the seasonal cycle of the solar UV flux radiation. In addition to these long-period variations, the D-layer electron density is submitted to much faster forcing, like geomagnetic storms and solar eruptions (hours) or lightning and Transient Luminous Events (seconds or less). The project VNET4IONS aims to study the D-layer electron density disturbances during eruptive solar events and electric events over stormy regions. It has a societal objective : providing real-time alerts on communication degradations for civil aviation during solar flares. It is thus part of research on the Sun-Earth relationship and space weather (natural hazards).
The D-layer is too high for balloons and too low for satellites. Therefore, it is inaccessible to continuous in situ measurements (few measurements were carried out by sounding rockets during rapid crossings of this layer). The most widely used technique to study the D-layer consists of measuring the VLF emissions from man-made or natural origin. VLF modes propagate in the waveguide formed by the Earth and the ionosphere, with reduced loss (2 dB/Mm), thus propagating very long distances. An increase in electron density alters the modes : the amplitude and phase are then affected, which provides an efficient way to detect, in real-time, electron density variations. The project aims to build a worldwide VLF network to complete the French assets for Space Weather.
The VLF network is based on the AWESOME instrument, developed by the Georgia Institute of Technology. It provides broadband (1 - 450kHz) waveforms @1MHz and 100kHz with an absolute timing accuracy of 20 ns and narrowband time profiles (amplitude and phase) around several VLF-transmitter's frequencies. Measurements are performed along (geomagnetic) North-South and East-West directions simultaneously.
We will present the project in details and some examples of data analysis and modeling performed from the instrument located in Nançay.

RB-FAN2 : « Radiation Belt Forecast And Nowcast », un nouvel environnement basé sur le code d'assimilation de données Salammbô

Antoine Ferlin (1)

Vincent Maget (1), Stefaan Poedts (2), Constantinos Papadimitriou (3), Ingmar Sandberg (3), Sigiava Aminalragia-Giamini (3), Zafar Iqbal (3), Mark Dierckxsens (4), Natalia Ganushkina (5), Stepan Dubyagin (5), Kaspar Schiess (6), Joep Neijt (6), Janos Lichtenberger (7), Balazs Heilig (8), Ioannis Daglis (9), Christos Katsavrias (9), Alexey Isavnin (10), Alexi Glover (11), Ralf Keil (11), Hugh Evans (12)

(1) DPHY, ONERA (2) KULeuven (3) SPARC (4) Belgian Institute for Space Aeronomy (5) Finnish Meteorological Institute (6) SOLENIX (7) Eötvös Loránd University (8) Space Science and Engineering Ltd (9) Institute of Accelerating Systems and Applications, Athens (10) A. ISAVNIN (11) ESA - ESOC/OPS-SW (12) ESA - ESTEC, Netherlands

Le projet Radiation Belt Forecast And Nowcast 2 (RB-FAN2, programme ESA Space Safety Program S2P) vise à fournir, l'état des ceintures de radiation terrestres, en temps quasi-réel sur un horizon de 3 jours.
Découlant directement de RBFAN (programme ESA Space Situational Awareness), RB-FAN2 proposera de nouveaux indicateurs de risques par orbite, pour améliorer les prévisions des conditions spatiales, via une version enrichie du site web RBFAN actuellement accessible depuis le réseau de services SWE via le portail SWE de l'ESA (SSA SWE Service Network).
Avec dix partenaires (BIRA-IASB, KU Leuven, FMI, SPARC, A. Isavnin, IASA, SSE Ltd., ELTE, Solenix, et l'ONERA) et RBFAN2 s'attache tant à la conception de l'architecture qu'à la prise en compte des besoins des utilisateurs, que ce soit pour les aspects modélisation/simulations ou pour la distribution des produits via l'interface web.
L'environnement actuel de simulation RB-FAN est composé de plusieurs modèles chainés via le Virtual Space Weather Modelling Centre (VSWMC), depuis les modèles EUHFORIA pour le vent solaire à IMPTAM qui modélise la dynamique des particules de basse énergie de la magnétosphère terrestre. Le code Salammbô, qui couvre les ceintures de radiation terrestres, utilise en entrée ces sorties de modèles, pour les électrons (100 keV – 8 MeV) et les protons (1 - 400 MeV). Un processus d'assimilation de données enrichit et corrige la dynamique des ceintures de radiation, via l'utilisation de données mesurées en vol des bases de données de l'ONERA (IPODE) et de nos partenaires (BIRA-IASB et SPARC).
Trois nouveaux modèles seront intégrés à l'environnement RBFAN2. Le modèle PLASMA fournira des informations sur la prévision des densités plasmasphériques, la position et la forme de la plasmapause. EMERALD, fournira à Salammbô-DA les coefficients de

diffusion radiale dans les ceintures de radiation, pour les électrons et les protons. Enfin, le modèle SPE (Solar Proton Event) sera dédié à la prévision d'événements de protons solaires (probabilité d'arrivée de protons solaires), et l'évolution temporelle des spectres de flux sur la durée (estimée) de l'événement en cours.
Nous retravaillerons le site web fournissant des produits et indicateurs synthétiques de météorologie de l'Espace, pour différents niveaux d'expertise. Pour rappel, le site web propose des feux tricolores pour mettre en exergue les événements importants, et des séries temporelles pour les utilisateurs avertis. Outre la définition de nouveaux indicateurs, avec l'aide des acteurs du secteur, le nouveau site web permettra le calcul à la demande de produits pour une orbite donnée.

Remerciements : Ces travaux sont financés par le programme S2P « Space Safety Program », S2P S1-SW-14.2 (RB-FAN2) sous le contrat ESA numéro 4000140076/22/D/KS.

Estimates of the global magnetic flux content of the magnetosphere during magnetic storms

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We are interested in the global magnetospheric impact of large-scale solar events, such as coronal mass ejections, which can trigger intense magnetic storms.
In the absence of continuous monitoring, the geomagnetic activity of the magnetosphere is often estimated using magnetic indices such as DST, Kp or auroral indices. Calculated from the ground-based measurements of the magnetic field deviation, they provide an integrated view of the current circulation in space from the ionosphere to the boundaries of the magnetosphere.
We use simultaneous observations from several missions including Cluster, THEMIS and MMS in the magnetosphere and we examine how such in-situ observations could add extra information to qualify and quantify the geomagnetic activity of the magnetosphere. We estimate the magnetic flux content of the magnetosphere and discuss its evolution during the different phases of a magnetic storm during the impact of a coronal mass ejection. In particular, we evaluate its diurnal and nocturnal dynamics as well as the phases of conservation or loss of magnetic flux content.

Massive extraction of magnetopause boundary layer observations from in-situ data with machine learning

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Magnetic reconnection is a key plasma process leading to the reconfiguration of magnetic field lines, during which magnetic energy is transferred to the plasma as kinetic and thermal energy. Magnetic reconnection in 3D happens along a topological line called the X line. On the Earth's magnetopause, the position and shape of the X line is known to strongly depend on solar wind and interplanetary magnetic field conditions, but this relationship is still poorly understood despite its important impact on the overall dynamics of the magnetosphere.
A way to constrain the position and shape of the X line is to build a map of the global ion flow on the Earth's magnetopause, whose source is magnetic reconnection at the X-line. This method requires extracting observations of the boundary layer from large amounts of complex time-series data. This has been made possible by the sheer volume of data collected by four missions over twenty years, from which boundary layer signatures can efficiently and automatically be extracted with machine learning algorithms.
In this work, we present an innovative method to extract the boundary layer signatures from in situ data using neural networks. First, a dataset was built by manually labeling boundary layer observations. Then, the trained algorithm was applied to all data from MMS, Themis, Double Star and Cluster to massively detect occurrences of the boundary layer. We show and discuss the resulting collection of observations, which will be used to build maps of the ion flow at the magnetopause boundary layer in order to determine how the position of the X-line changes as a function of external conditions.

A new empirical model of Saturn's plasma environment

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As part of the ESA Testbed for Radiation and Plasma Planetary Environments Development (TRAPPED) project (ESA contract 4000141429/23/NL/CRS), we are developing an empirical model of the plasma environment at Saturn in support of researchers and industry for future mission planning at the ringed planet. In this presentation, we will present the first steps of this process including a literature review covering the determination of cold plasma moments from spacecraft observations (i.e., from Pioneer 11, Voyager 1, Voyager 2 and Cassini) as well as a review of data availability and quality in order to develop a comprehensive picture of plasma parameters throughout the magnetosphere of Saturn. We will also present the methodology and approach adopted to model the kronian plasma environment and its spatio-temporal dynamics. We also aim to expand the application of this modelling process to Uranus and Neptune, even if only Voyager 2 observations are available for the ice giants.

Neural network modeling of the ground magnetic perturbation at mid-latitude : towards future application of geomagnetic storm prediction

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Ground magnetic observatories measure the Earth's magnetic field and its coupling with the solar wind responsible for the ionospheric and magnetospheric current systems. Magnetic indices derived from ground observatories are vital in characterizing the intensity of geomagnetic storms and possible consequences. Yet, deriving magnetic indices is a very challenging task because ground magnetic measurements comprise the combination of multiple sources. To distinguish the perturbations of solar origin in the signals from other origins, establishing the so-called magnetic baseline that robustly represents quiet periods is imperative. In an effort to derive a new magnetic index with a higher resolution, Haberle et al. (2022) proposed to characterize the magnetic measurements during quiet periods by filtering the signals into the long-term (above 24 h), diurnal (24 h), and sub-diurnal variations to capture physical sources at specific time scales and combine them to determine the magnetic baseline. Nevertheless, this approach cannot robustly establish the baseline during non-quiet periods. To progress towards the future application of those filters, we develop long-term short-memory neural networks to predict the long-term and the diurnal variations focusing on magnetic data from a mid-latitude station. The main objective is to be capable of predicting the baseline for operational space weather nowcasting and to replace it when the system is perturbed and when the baseline given by the filters is not reliable. First, by excluding the quiet-day sources, i.e., in the absence of geomagnetic storms, we find that the neural networks model follows to some extent perturbations contained in the filters owing to the solar variability, the solar wind, and the interplanetary magnetic field. We will present the performance of the neural networks throughout a solar cycle and discuss a future application of this approach.

Importance de la prise en compte précise du champ électrique de convection dans la modélisation des ceintures de radiation à basse énergie

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Depuis le début de l'ère spatiale, les ceintures de radiation suscitent un vif intérêt parmi les scientifiques et les acteurs de l'exploration spatiale. En raison de leur nature énergétique et dynamique, elles induisent des risques pour les engins spatiaux et les humains. Ainsi, comprendre les processus physiques et la dynamique globale de ces ceintures est crucial. Le Département de Physique, Instrumentation, Environnement et Espace (DPHY) de l'ONERA développe depuis 1990 la suite de codes physiques Salammbô pour simuler la dynamique des protons et des électrons piégés dans les ceintures de radiation. La version 4D du code, Salammbô 4D, intègre le temps local magnétique (MLT), afin de modéliser le transport des particules de basse énergie par les champs électriques magnétosphèrique autour de la Terre.
A travers cette étude, on cherche à améliorer Salammbô 4D en affinant la description du transport des particules de basse énergie dans les ceintures de radiation à travers le choix des modèles de champ électrique de convection. Parmi les modèles dynamiques de champs électrique de convection, le modèle numérique de [H.Matsui et al. 2013] apparaît comme l'un des plus réaliste. Il s'agit d'un modèle basé sur les données du Satellite CLUSTER, piloté par l'indice géomagnétique Kp. Nous présentons ici nos résultats quant à l'apport du modèle de Matsui dans le code Salammbô-4D en comparant avec résultats de simulations et données satellites. Nous montrons en particulier l'importance de cette amélioration pour les applications en météorologie de l'Espace.

The time profile of relativistic solar particle events – a prediction tool in radiation advisories for civil aviation ?

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The most energetic particles accelerated in solar eruptive events are protons and nuclei with energies that may reach a few tens of GeV. They can be detected on the Earth through the secondaries they produce when interacting with the atmosphere. Solar energetic particle events where this happens are called Ground-Level Enhancements (GLEs). The secondary particles constitute a source of radiation in the atmosphere that may temporarily exceed the permanent dose rate from galactic cosmic rays. This makes the monitoring of radiation doses received by aircrew from GLEs one issue of space weather services for civil aviation. This study addresses the time profiles of GLEs, in the search for commonalities that can be used to constrain models of acceleration and propagation and to forecast the evolution of an ongoing event. We investigate historical GLEs (1971–2012) with the worldwide network of neutron monitors, comparing the rise and the decay as observed by the neutron monitor with the strongest response. We evaluate statistical correlations between rise times and decay times and compute a normalised median GLE time profile. An empirical correlation reported in earlier work between the observed rise times and decay times of the neutron monitor count rate profiles is confirmed. We show that the observed time profiles are in general close to the median one, while deviations from the median time profile can be attributed to the detection of particles that are reflected at a magnetic mirror beyond Earth orbit, due to a previous CME. We discuss the usefulness of our results for the prediction of the duration of an ongoing GLE and dose rates at aviation altitudes.

Observation des ceintures de radiation terrestres depuis la Lune par l'intermédiaire du rayonnement cyclo-synchrotron

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Les particules énergétiques piégées dans les ceintures de radiation de la Terre constituent une menace importante pour les satellites. Ces régions, soumises à l'influence du vent solaire et des activités géomagnétiques, sont très dynamiques. L'observation et la surveillance des particules énergétiques au sein des ceintures de radiation est cruciale. La méthode actuelle repose uniquement sur des détecteurs de particules embarqués sur des satellites, ne permettant pas d'obtenir une observation globale et une compréhension complète de la dynamique temporelle des ceintures.

Les électrons énergétiques accélérés par un champ magnétique émettent spontanément un rayonnement nommé rayonnement synchrotron. Au niveau de la Terre, ce rayonnement est émis à des fréquences comprises entre 0,01 et 10 MHz et ne peut être observé depuis la surface en raison de la coupure ionosphérique. En 2020, Hegedus, Nénon et al. ont présenté un modèle préliminaire simulant le rayonnement synchrotron émis par les ceintures de radiation de la Terre lorsqu'elles sont observées depuis la face proche de la Lune. Ce modèle a été adapté d'un précédent modèle synchrotron créé pour l'analyse des émissions radio de Jupiter (Santos Costa 2001, Sicard 2004, Nénon 2018). Pour ces modèles, les simulations ont été restreintes aux électrons d'énergie supérieure à 1 MeV, limitant le champ d'application aux électrons relativistes ou quasi-relativistes. Depuis 2022, de nouveaux travaux ont démarré à l'ONERA au travers d'une thèse pour étudier la faisabilité de remonter à la distribution des électrons des ceintures de radiation à partir de cartographies 2D (simulées) du rayonnement cyclo-synchrotron des électrons depuis la Lune. Ce travail nécessite plusieurs étapes. Tout d'abord, nous avons mis en place un nouveau modèle simulant le rayonnement cyclo-synchrotron permettant d'étendre l'étude aux électrons de plus basses énergies, essentielles dans le cas des ceintures de radiation de la Terre. Les distributions d'électrons issus du modèle Salammbô ont été utilisées comme entrées du modèle cyclo-synchrotron et des cartographies 2D du rayonnement ont été obtenues. Puis l'influence de la dynamique des ceintures de radiation sur le rayonnement cyclo-synchrotron a été étudié à travers différents orages géomagnétiques. Enfin, dans un futur proche, le but est d'inverser le signal en partant des cartographies 2D simulées pour retrouver les flux d'électrons issus de Salammbô. De ce fait, si dans le futur, des observations du rayonnement cyclo-synchrotron des électrons depuis la Lune existe, nous serons en mesures de les utiliser pour remonter à la distribution des électrons des ceintures dans le cadre de la météorologie de l'Espace.

No evidence of solar oblateness variations correlated with solar activity during cycles 24 and 25

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Solar oblateness, a fundamental parameter of the Sun, offers insights into the inner rotation profile, matter distribution, and imposes constraints on General Relativity. However, measuring it is challenging due to its minuscule value, with the solar equator-to-pole radius difference being less than 10 milli-arcseconds (mas). Magnetic activity and instrumental effects related to the space environment can impact measurements. The Helioseismic and Magnetic Imager (HMI) on the Solar Dynamics Observatory (SDO) provided precise determinations of solar oblateness from 2010 to 2023. HMI obtained solar shape measurements during spacecraft roll maneuvers, shifting by 11.25 degrees around the spacecraft-sun line. HMI executed several such roll maneuvers between October 2010 and December 2023. Analysis of HMI data seems to reveal a slight anti-correlation between solar oblateness and solar activity. Applying a new correction method, the mean solar equator-to-pole radius difference at 617.3 nm during 2010–2023 was determined to be 8.75 $\pm$ 0.49 mas, equivalent to 6.34 $\pm$ 0.35 km at one sigma. The objective of this presentation is to showcase the results obtained with the HMI instrument, which conducts observations in the absorption line of Fe I at 6173Å with a 1-arcsecond resolution. Results will be presented for the four linear polarizations of the telescope (filter sequences 10004, 10005, 10006, and 10007) as well as for the two circular polarizations (filter sequences 10008 and 10009). The evolution of the quadrupole C2 (characteristics of the Sun's gravity field that are due to its non-spherical shape) and hexadecapole C4 (higher-order term that takes into account additional deformations in the Sun's mass distribution) coefficients during a solar cycle will also be presented.

The SOLAR-HRS New High-Resolution Solar Spectra for Disk-Integrated, Disk-Center, and Intermediate Cases

Mustapha Meftah

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The solar spectrum at the top of the atmosphere contains crucial data for solar physics, astronomy, and geophysics. Accurately determining high-resolution solar reference spectra, whether they are disk-integrated, disk-center, or intermediate cases, represents a new challenge and is of primary importance for all applications where spectral solar radiation needs to be evaluated. These spectra are also essential for interpreting remote sensing measurements that rely on sunlight, such as those obtained by Earth observation satellites or spacecraft exploring other planets. We will present the implementation of multiple new solar irradiance reference spectra that have high resolution and are representative of solar minimum conditions. We developed the SOLAR high-resolution extraterrestrial reference spectra (SOLAR-HRS disk-integrated spectra) by normalizing high-spectral-resolution solar line data to the absolute irradiance scale of the SOLAR-ISS reference spectrum. The resulting one-of-a-kind SOLAR-HRS disk-integrated spectrum has a spectral resolution varying between 0.001 and 1 nm in the 0.5–4400 nm wavelength range. We also implemented a new high-resolution solar spectrum at the disk-center, covering a range of 650–4400 nm with a spectral resolution of 0.001 to 0.02 nm. We further expanded our analysis by producing several solar spectra for ten different solar view angles ranging m=0.9 to mu=0.05 (SOLAR-HRS intermediate cases). Finally, we developed new Merged Parallelised Simplified ATLAS spectra (MPS-ATLAS) based on solar modeling with Kurucz and Vald3 solar linelists for both the disk-integrated and disk-center spectra. One of the objectives of implementing all these new solar spectra is to fulfill the requirements of the MicroCarb space mission, which focuses on measuring greenhouse gas emissions. The solar data of this study are openly available.

SPODIFY : Space Plasma Object Detection Inspired From Yolo

Gautier Nguyen (1)

Guillerme Bernoux (1)

(1) ONERA / DPHY, Université de Toulouse

La capacité de reconnaissance automatique des évènements solaires les plus géoeffectifs comme les Ejections de Masse Coronale Interplanétaires (ICMEs) ou les régions d'interaction en co-rotation (CIRs) permet d'orienter les scénarios d'évolution et les conséquences possible sur l'environnement spatial terrestre ainsi que sur les systèmes technologiques humains. C'est également un moyen très simple d'élaborer rapidement et de façon reproductible des catalogues répertoriant les dates de début et fin de ces évènements les plus exhaustifs possible et utilisable dans le cadre d'études statistiques sur leurs propriétés physiques.
L'accumulation depuis presque 3 décennies, de données provenant de missions spatiales explorant le vent solaire et l'environnement terrestre proche a naturellement conduit au développement de méthodes de reconnaissance automatique de ces évènements s'appuyant sur de l'apprentissage statistique (Nguyen et al. 2019, Rudisser et al. 2022, Chen et al. 2022). Ces méthodes sont capable de produire des catalogues rapidement, de façon reproductible et aussi exhaustivement que ce qu'aurait pu faire un observateur extérieur. Bien que facilement adaptable, ces méthodes sont toutefois limitées à un seul type d'évènement sans pour autant pouvoir prendre en compte leur possible superposition.
Ici, nous adaptons l'approche adoptée par les méthodes You Only Look Once (YOLO) en détection d'objets sur images aux données OMNI entre 1995 et 2023 pour mettre en place un algorithme de reconnaissance automatique des ICMEs et des CIRs prenant en compte leur possible superposition. En plus de produire moins d'erreurs que l'état de l'art, notre méthode détermine les dates de début et de fin des évènements plus précisément. Notre méthode a de plus l'avangtage d'être facilement extensible à d'autres types d'évènements et facilement transposable à d'autres types de données d'entrée.

Etudes de particules énergétiques, d'ondes VLF, et de leurs interactions dans l'espace proche Terre

Jean-Francois Ripoll (1)

Léo Cerfolli (1), Thomas Farges (1), Olivier Le Contel (2), Alessandro Retinò (2), Aurélie Marchaudon (3), Pierre-Louis Blelly (3), Frédéric Lescouat (4), Marc Sevoz (4), Alexandre Roussel (4), Ramon Gomez (4)

(1) CEA, DAM (2) LPP, Observatoire de Paris, Ecole Polytechnique, Sorbonne Université, Université Paris-Saclay, CNRS (3) IRAP, Université Toulouse III - Paul Sabatier, Observatoire Midi-Pyrénées, CNRS (4) Airbus Defence and Space

Nous présentons des observations de l'environnement électronique ambiant, i.e. les flux d'électrons, complexe et très variable, dans des régions de l'espace proche de la Terre, dont l'évolution est fortement conditionnée par l'existence et la puissance d'ondes électromagnétiques ambiantes de très basses fréquences. Nous nous focalisons sur l'étude d'un évènement naturel particulier avec une forte injection d'électrons relativistes atteignant jusqu'à 600 keV, observée par plusieurs types de mesures simultanées, effectuées depuis plusieurs satellites. Grâce à cette vision globale, nous arrivons à distinguer l'injection de l'arrivée massive de particules associée au sous-orage magnétosphérique en cours qui remplit la zone de vide entre les ceintures de radiations. Nous remontons aussi à la source des particules (i.e. timing/localisation) dans la partie nuit de la magnétosphère interne.
Nous étudierons aussi une expérience active récente, conduite hors laboratoire, dans la haute ionosphère, qui a permis de modifier l'environnement électronique ambiant et d'amplifier ainsi des ondes électromagnétiques VLF existantes. De telles ondes ont la capacité d'interagir avec les électrons énergétiques et de causer des précipitations dans l'atmosphère qui vont réduire le flux rayonné. Nous montrerons comment des calculs de lancer de rayons peuvent aider à suivre la propagation de ces ondes et l'évolution de leur puissance afin de caractériser les zones d'interactions ondes-particules.
Ces travaux font partie du projet PACTE-ESPACE (Physique ACTivE des particules énergétiques, des ondes, et de leurs interactions dans l'ESPACE proche Terre) sélectionné par l'ANR ASTRID en 2022. Le projet a des retombées in fine pour la protection des composants électroniques en environnement spatial suite à des perturbations électromagnétiques.

Extraction des caractéristiques solaires pour la prédiction de l'activité géomagnétique : Utilisation d'AutoEncodeurs pour améliorer les modèles dirigés par les données

Maria Tahtouh (1)

Angélica Sicard (1), Antoine Brunet (1), Guillerme Bernoux (1), Denis Standarovski (2)

(1) ONERA / DPHY (2) CNES

Les éjections de masse coronale (CME) sont considérées comme les principaux déclencheurs des orages géomagnétiques forts et extrêmes. De nombreux efforts ont été consacrés au développement de modèles physiques capables de prédire de manière fiable les orages associées aux CME. Cependant, actuellement, ces modèles ne sont pas suffisants pour une modélisation précise et opérationnelle, et ils sont coûteux en termes de temps de calcul. Quelques études menées au cours des dernières années ont démontré que les modèles basés sur l'apprentissage profond et les techniques associées ont le potentiel de prédire les conséquences de l'activité solaire à partir d'images solaires EUV uniquement. C'est notamment le cas du modèle SERENADE développé à l'ONERA qui fournit directement des prévisions probabilistes du maximum quotidien de l'indice géomagnétique Kp jusqu'à quelques jours à l'avance à partir de ces images. Cependant, une limitation de ces modèles est leur incapacité à prédire les orages associés aux CME, qui sont difficiles à détecter à l'aide d'images EUV. Pour cela, l'utilisation des images de résolutions spatiales et temporelles plus élevées est nécessaire. Cependant, plus la dimensionnalité augmente, plus les efforts de calcul requis pour obtenir de bonnes performances par les méthodes d'apprentissage augmentent également, ce qui pose donc des défis. Notre objectif dans cette étude est de compresser les images de dimensions plus élevées sans perdre d'informations importantes afin d'extraire les caractéristiques liées aux CME de ces images, qui serviront finalement d'entrées au modèle de prédiction SERENADE. Pour cette étude, nous avons sélectionné un jeu de données prétraité pour un usage en apprentissage profond de l'instrument Atmospheric Imaging Assembly (AIA) à bord de la mission Solar Dynamics Observatory (SDO). Nous avons développé un algorithme de réduction de dimensionnalité en utilisant les AutoEncodeurs (AE). Ce sont des réseaux de neurones qui transforment les données d'un espace de haute dimension en un espace de plus basse dimension appelé l'espace latent, qui peut ensuite être décodé pour reconstruire les données originales, dans ce cas, l'image d'entrée. Une étude statistique est réalisée sur les caractéristiques obtenues à partir de l'espace latent afin de montrer dans quelle mesure il peut représenter les données physiques qui caractérisent l'activité géomagnétique (cycle solaire, indices géomagnétiques...). Ensuite, l'AutoEncodeur est intégré dans SERENADE en tant qu'extracteur de caractéristiques, et les performances du modèle en termes de précision dans ses prédictions des indices géomagnétiques sont étudiées.

Evaluating auroral kilometric radiation observations as a geomagnetic indicator of substorm onset using binary classification

James Waters (1)

Laurent Lamy (1,2), John Coxon (3)

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Auroral kilometric radiation (AKR) is a cyclotron maser instability generated radio emission that occurs in the region above the auroral oval ; the observed intensity increases with the growth rate of the instability, indicating an active source region and the presence of accelerated electrons, while the emission frequency is inversely proportional to the altitude of a source along a field line. Remote observations can thus provide a direct insight into the spatial development of the primary coupling region between the magnetosphere and ionosphere during energetic phenomena. During substorms in particular, the auroral acceleration region has been shown to increase in altitude and increase the low-frequency power of the AKR spectrum, particularly towards dusk (Morioka et al. 2007, Waters et al. 2022). However, AKR is beamed anisotropically, which makes it difficult to observe global variability of the emission when a spacecraft is not in an ideal position, namely at dayside local times.

With an automatic extraction of AKR observations from the Wind spacecraft, we have access to nearly 30 years of data from a variety of viewing positions. The latest 20 years of observations are made from the dayside, near L1. To evaluate the efficacy of the AKR observations as an indicator of substorm dynamics and further constrain the visibility effects, we compare AKR bursts from Wind (Fogg, Jackman, Waters et al. 2022) to a published list of substorm events derived from the SuperMAG magnetometer network. We calculate the binary classification statistics in four local time sectors with more than 10 years of AKR observation. When evaluated over a 2 hour window, AKR bursts observed from the nightside and duskside have a good (> 0.6) recall of substorm events, while the duskside observations have a more favourable false alarm probability (< 0.4). Dayside observations have a high miss rate (0.8), but a high specificity (> 0.9), thus exhibiting a reliable proxy for substorm activity. Observations from all local time sectors except the nightside have positive forecast skill as determined by the Heidke skill score. Occurrence distributions of AKR burst frequencies from each local time sector and event group highlight the components present in each local time sector. This work lays the foundations for further parameterisation of the visibility of AKR sources at different locations within the inner magnetosphere by Wind when observing from L1, where the effects of the frequency, magnetic local time and magnetic latitude of the source can be examined more finely. Such work is useful for providing context for past AKR observations, as well as for the interpretation of future radio observations (with the JUICE flyby for example), observation scheduling or planning of future missions.

PNST
Programme National Soleil-Terre

Using novel multi-point observations to study the auroral acceleration region at substorm onset

James Waters (1)
Caitriona Jackman (2), Daniel Whiter (3), Alexandra Ruth Fogg (2), Laurent Lamy (1,4), Jennifer Carter (5), John Coxon (6), Laura Fryer (3), Corentin Louis (4), Larry Paxton (7), Carine Briand (4), Baptiste Cecconi (4), Karine Issautier (4), Xavier Bonnin (4), Peter Gallagher (2)

(1) LAM, Pythéas, Aix Marseille Université, CNRS (2) Dublin Institute for Advanced Studies (3) Department of Physics and Astronomy, University of Southampton (4) LESIA, Observatoire de Paris, Sorbonne Université, CNRS, Université Paris Cité (5) Planetary Sciences Group, University of Leicester (6) Department of Mathematics, Northumbria University (7) Applied Physics Laboratory, John Hopkins University

On 28th October 2021 the Sun released a large coronal mass ejection (CME) in Earth's direction. An X1.0 class solar flare and a rare ground level enhancement (GLE) were observed, along with bright solar radio bursts. We explore the inner terrestrial response to this solar event using multi-point measurements from the near-Earth space environment. These measurements include historical solar wind monitors and geomagnetic indices, UV auroral observations from the spectrograph imager SSUSI onboard the DMSP spacecraft, field-aligned current (FAC) measurements from the AMPERE project via the IRIDIUM constellation, and newly accessible auroral kilometric radiation (AKR) observations from Wind (Waters et al. 2021).

The CME and its arrival is tracked at ∼1 AU using remote radio observations from Wind, along with in-situ interplanetary magnetic field (IMF) and solar wind measurements from OMNI. Geomagnetic activity is studied with SYM-H, SuperMAG and PC indices, showing the expected presence of multiple substorm onsets. The dayside auroral response is monitored for the first time with Wind AKR observations from L1, where the highly-directed beaming of AKR from typical nightside sources is not easily observed; the radiated power exceeds the 10 year average from the same local time by 1-2 orders of magnitude and originates from discrete, substorm-associated UV aurora in the afternoon local time sector. This is supported by novel multi-point observations between Wind AKR measurements and FACs from AMPERE, which also allows the dominant acceleration mechanism to be inferred for upward currents between 1400-1800 hours magnetic local time (MLT). During a particular 12 hour period where Wind is least affected by viewing constraints, the Southern hemisphere presents enhanced upward current during multiple, repeat substorm onsets and AKR bursts, suggesting parallel electric field acceleration and Alfvénic acceleration processes are both occurring in this MLT sector. Upward current is then enhanced in both hemispheres during a single substorm onset and is well correlated with the largest observed AKR burst, suggesting dominance of double-layer potential acceleration.

Such exploration of AKR with Wind and assimilation of multiple observed phenomena provides insight into the dynamics of the magnetosphere-ionosphere coupling region via

the structure and activation of auroral current systems. This precedes statistical, parametric modelling of the visibility of substorm and similar dynamics for dayside observations from Wind, allowing the spatial distribution of active AKR sources and acceleration processes to be constrained more quantitatively for future use.

Activités en météorologie de l'espace au MinArm

Angelique Woelffle (1)

(1) Ministère des armées, Direction générale de l'Armement (DGA)

Cette présentation vise à offrir à la communauté académique du Programme National Soleil-Terre un panorama actualisé des activités au sein du MinArm, ayant rapport à la météorologie de l'espace. Notamment, les éléments suivants seront passés en revue :

- Présentation de l'outil opérationnel FéDoME : fonctionnalités actuelles et axes de développement
- Présentation des activités d'intérêt pour les besoins MinArm
- Présentation du processus de soumission de projets à l'AID et statistiques générales
- Les grandes tendances en Météorologie de l'Espace de Défense auprès des nations OTAN : organisation-type et sujets scientifiques de prédilection.

Programme du colloque

LUNDI 8 JANVIER

12h30-13h55 : Accueil des participants + pause café

14h00-14h15 : Introduction du colloque (B. Lavraud, G. Aulanier)

14h15-14h25 : Nouvelles INSU/CNRS (A. Marchaudon)

14h25-14h35 : Nouvelles CNES (K. Amsif, M. Kretzchmar)

14h35-14h45 : Nouvelles CEA (S. Mathis)

PNST Thème 3 "Couplages entre enveloppes de plasma"

14h45-15h00 : Connecter SPICE à HIS à travers l'effet FIP (N. Zambrana Prado)

15h00-15h15 : Parametric simulations of the propagation of solar jets : Investigating the origin of switchbacks (J. Touresse)

15h15-15h30 : Thermal non-equilibrium cycles in solar coronal null points - implications for the solar wind (C. Froment)

15h30-15h45 : La magnétopause et la théorie des discontinuités (G. Ballerini)

15h45-16h00 : Classer les facteurs d'influence des frontières plasma planétaires (P. Garnier)

16h00-16h45 : Pause café + posters

16h45-18h00 : TABLE RONDE & PROSPECTIVE : GT4 Prospective numérique

18h00-21h00 : Apéritif régional, dîner sur place

MARDI 9 JANVIER

PNST Thème 3 "Couplages entre enveloppes de plasma"

9h00-9h15 : On the location of magnetic reconnection on the dayside magnetopause (B. Michotte de Welle)

9h15-9h30 : Energy mapping of the Jupiter's auroral electrons from the Juno/UVS data (B. Benmahi)

9h30-9h45 : The satellite auroral footprints at Jupiter : A Juno perspective (V. Hue)

9h45-10h00 : A self-consistent model of radial transport in the magnetodisks of gas giants including interhemispheric asymmetries (M. Devinat)

PNST Thème 1 "Simulations et outils numériques"

10h00-10h15 : Solar sources and expansion properties of Alfvénic slow wind streams (V. Réville)

10h15-10h30 : Nature of Solar Wind Turbulence at Electron Scale (V. David)

10h30-11h15 : Pause café + posters

11h15-12h30 : TABLE RONDE & PROSPECTIVE : GT5 Enseignement - communication grand public

12h30-14h00 : Déjeuner sur place

PNST Thème 1 "Simulations et outils numériques" (suite)

14h00-14h15 : New insights into the consequences of different interplanetary conditions on the near-Hermean environment (E. Cazzola)

14h15-14h30 : Generation mechanism and beaming of Jovian nKOM from 3D numerical modeling of Juno/Waves observations (A. Boudouma)

14h30-14h45 : Impact of far-side structures observed by Solar Orbiter on wind simulations (B. Perri)

14h45-15h00 : IRIS : a radiative transfer simulation tool for space-based GHG observation missions - Application to the Uvsq-Sat NG mission (C. Clavier)

15h00-15h15 : Gyrofluid models for turbulence and reconnection in space plasmas (T. Passot)

15h15-15h30 : Characterising a flaring active region through data-driven MHD simulations (V. Sieyra)

15h30-15h45 : Modélisation de la température de la source des vents solaires lents et rapides à l'aide d'un modèle fluide multi-espèces à 16 moments (P.Lomazzi)

15h45-16h00 : Modeling Soft X-ray emissions at the dayside magnetopause (X. Qiuyu)

16h00-16h45 : Pause café + posters

16h45-18h00 : TABLE RONDE & PROSPECTIVE : GT 3 Prospective instrumentale

18h00-19h30 : Temps libre

19h30-21h00 : Dîner sur place

MERCREDI 10 JANVIER

Thème 5 "Mécanismes d'accélération des particules et chauffage du plasma"

9h00-9h15 : Connecting in situ measurements and solar EUV images to investigate the sources of magnetic switchbacks (N. Bizien)

9h15-9h30 : Statistical Analysis of the Radial Evolution of the Solar Winds between 0.1 and 1 au, and their Semi-empirical Iso-poly Fluid Modeling (J.-B. Dakeyo)

9h30-9h45 : Advancing Solar Wind Microstream Modeling through 3D MHD Simulations : Unraveling Formation and Evolution Dynamics (B. Gannouni)

9h45-10h00 : Caractérisation statistiques des sources joviennes hectometriques par des mesures electrons et radio in situ (B. Collet)

10h00-10h15 : About the nature of sustained kink oscillations in coronal loops : combining coronal and chromospheric diagnostics (N. Poirier)

10h15-10h30 : Observing delayed emissions of Interplanetary Type III bursts during the comissioning phase of Solar Orbiter (D. Paipa)

10h30-11h15 : Pause café + posters

11h15-11h30 : Investigation of solar wind kinetic properties and velocity distribution function during Parker Solar Probe and Solar Orbiter radial alignments (R. Kieokaew)

11h30-11h45 : Comparative visibility of planetary auroral radio emissions and implications for the search for exoplanets (L. Lamy)

11h45-12h00 : Discovery of Jovian radio bursts related to Ganymede and the main aurora, and implications on Alfvénic electron acceleration (E. Mauduit)

12h00-12h15 : Détection et interprétation de structures fines dans des sursauts radio de la naine rouge AD Leo (C. Louis)

12h15-12h30 : Pitch Angle Distribution of MeV Electrons in the Magnetosphere of Jupiter (Q. Nénon)

12h30-14h00 : Déjeuner sur place

14h00-19h30 : Temps libre

19h30-21h00 : Dîner sur place

JEUDI 11 JANVIER

PNST Thème 4 "Transport d'énergie multi-échelles et turbulence"

9h00-9h15 : The Cross-Scale Energy Transfer in turbulent plasmas - Insight from the Terrestrial Magnetosheath (D. Manzini)

9h15-9h30 : Energy transport and conversion in the heart of magnetic reconnection regions (N. Fargette)

9h30-9h45 : Magnetospheric MultiScale Measurements of Energy Balance in Collisionless Plasma (S. Dahani)

9h45-10h00 : Study of a dayside magnetopause reconnection event detected by MMS related to a large-scale solar wind perturbation and magnetospheric cold ions (M. Baraka)

10h00-10h15 : Two Classes of Equatorial Magnetotail Dipolarization Fronts Observed by Magnetospheric Multiscale Mission : A Statistical Overview (S. Alqeeq)

10h15-10h30 : Impact of the Nusselt number in global models of solar turbulent convection (Q. Noraz)

10h30-11h15 : Pause café + posters

11h15-12h30 : TABLE RONDE & PROSPECTIVE : GT1 PNST et Météo de l'espace

12h30-14h00 : Déjeuner sur place

Thème 6 "Activité éruptive ou impulsive dans les plasmas"

14h00-14h15 : Spectrographic imaging of solar radio bursts with the Nancay Radioheliograph and the ORFEES spectrograph (K.-L. Klein)

14h15-14h30 : The impact of the observer's position on solar radio observations (N. Chrysaphi)

Thème 7 "Relations Soleil-Terre et météorologie de l'espace"

14h30-14h45 : No evidence of solar oblateness variations correlated with solar activity during cycles 24 and 25 (M. Meftah)

14h45-15h00 : Développement d'un nouveau modèle électrodynamique : Application à l'électrodynamique équatoriale (P.-L. Blelly)

15h00-15h15 : Estimates of the global magnetic flux content of the magnetosphere during magnetic storms (D. Fontaine)

15h15-15h30 : VNET4IONS (C. Briand)

15h30-15h45 : Using novel multi-point observations to study the auroral acceleration region at substorm onset (J. Waters)

15h45-16h00 : Activités en météorologie de l'espace au MinArm (A. Woelffle)

16h00-16h45 : Pause café + posters

16h45-18h00 : TABLE RONDE & PROSPECTIVE : GT2 Services Nationaux d'Observation

18h00-19h30 : Temps libre

19h30-21h00 : Dîner de conférence sur place

VENDREDI 12 JANVIER

PNST Thème 2 "Nouvelles missions et instrumentation (sol et espace)"

9h00-9h15 : THEMIS current performances and perspectives (B. Gelly)

9h15-9h30 : Coronal Composition Measurement : A multi-instrumental analysis including Solar Orbiter/SPICE (S. Mzerguat)

9h30-9h45 : Premières mesures des moments électroniques à Mercure (M. Rojo)

9h45-10h00 : Modeling of mutual impedance experiments and quasi-thermal noise spectroscopy in magnetized plasma (P. Dazzi)

10h00-10h15 : Instruments optiques pour l'observation des aurores polaires (M. Barthélemy)

10h15-10h30 : The Fast Gamma ray Spectrometer (FGS) : a Multi-mission Instrument to Detect TGFs and Astrophysical Gamma ray Events (M. Pallu)

10h30-11h15 : Pause café + posters

11h15-12h30 : TABLE RONDE & PROSPECTIVE : GT6 Impact environnemental

12h30-13h30 : Déjeuner sur place

13h30 : Départ - Fin du colloque

Liste des participants

AIZAWA	Sae	LPP, Paris
ALEXANDRE	Matthieu	IRAP, Toulouse
ALEXANDROVA	Olga	LESIA, Meudon
ALQEEQ	Soboh	LPP, Paris
AMSIF	Kader	CNES, Toulouse
ANDRÉ	Nicolas	IRAP, Toulouse
AULANIER	Guillaume	LPP, Paris
AUNAI	Nicolas	LPP, Palaiseau
BALLERINI	Giulio	LPP, Palaiseau
BARAKA	Mohammed	LPP, Paris
BARTHELEMY	Mathieu	IPAG, Grenoble
BAUMANN	Xavier	ONERA, Toulouse
BELMONT	Gérard	LPP, Palaiseau
BENMAHI	Bilal	AGO, Liège, Belique
BERNOUX	Guillerme	ONERA, Toulouse
BERRIOT	ETIENNE	LESIA, Meudon
BIZIEN	Nina	LPC2E, Orléans

BLAISE	Alexis	AIM, Saclay
BLANC	Michel	IRAP, Toulouse
BLELLY	Pierre-Louis	IRAP, Toulouse
BOMMIER	Véronique	LESIA, Meudon
BOUDOUMA	Adam	LESIA, Meudon
BOURDARIE	Sébastien	ONERA, Toulouse
BRIAND	Carine	LESIA, Meudon
BRUN	Allan Sacha	AIM, Saclay
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BUCHLIN	Eric	IAS, Orsay
CAZZOLA	Emanuele	LPP, Palaiseau
CECCONI	Baptiste	LESIA, Meudon
CHAKRABORTY	Mehul	LPC2E, Orléans
CHANE-YOOK	Martine	IAS, Orsay
CHAUFRAY	Jean-Yves	LATMOS, Guyancourt
CHRYSAPHI	Nicolina	LPP, Paris
CHUST	Thomas	LPP, Palaiseau
CLAVIER	Cannelle	LATMOS, Guyancourt
COLLET	Brieuc	LAM, Marseille
DAHANI	Souhail	IRAP, Toulouse
DAKEYO	Jean-Baptiste	IRAP, Toulouse
DAVID	Vincent	Space Science Center, Durham, USA

DAZZI	Pietro	LPC2E, Orléans
DEVINAT	Marie	IRAP, Toulouse
FABBRO	Vincent	ONERA, Toulouse
FAGANELLO	MATTEO	PIIM, Marseille
FARGES	Thomas	CEA DAM, Bruyères-le-Châtel
FARGETTE	Naïs	Dept. Physics/Imperial College London, UK
FAUROBERT	Marianne	Lagrange, Nice
FONTAINE	Dominique	LPP, Palaiseau
FROMENT	Clara	LPC2E, Orléans
GANNOUNI	Bahaeddine	IRAP, Toulouse
GARNIER	Philippe	IRAP, Toulouse
GELLY	Bernard	IRL 2009, Îles Canaries, Espagne
GÉNOT	Vincent	IRAP, Toulouse
GHISALBERTI	Ambre	LPP, Palaiseau
GINISTY	François	LPP, Palaiseau
GRITON	Léa	LESIA, Meudon
HADID	Lina	LPP, Palaiseau
HENRI	Pierre	LPC2E, Orléans
HOUEIBIB	Hamed	LESIA, Meudon
HUE	Vincent	LAM, Marseille
INDURAIN	Mikel	IRAP, Toulouse
ISSAUTIER	Karine	LESIA, Meudon

JARRY	Manon	IRAP, Toulouse
JEANDET	Alexis	LPP, Palaiseau
KAMRAN	Aneesah	IRAP, Toulouse
KIEOKAEW	Rungployphan	IRAP, Toulouse
KIRAZ	Rabia	ONERA, Toulouse
KLEIN	Karl-Ludwig	LESIA, Meudon
KOUTROUMPA	Dimitra	LATMOS, Guyancourt
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