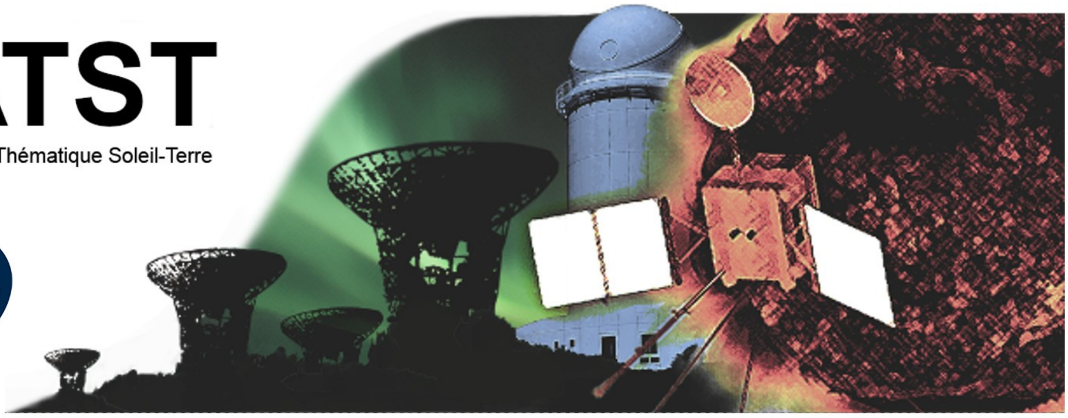

ATST : colloque scientifique

Biarritz, 1-5 juin 2026

RÉSUMÉS ET LISTE DES PARTICIPANTS

Accès Web :

Site du colloque : https://atst-2026.sciencesconf.org/

Site de l'ATST : https://atst.osups.universite-paris-saclay.fr/

Le colloque scientifique de l'Action Thématique Soleil-Terre (ATST) du CNRS aura lieu du lundi 1er juin (12h) au vendredi 5 juin (12h) 2026 au VTF Le Domaine de Françon à Biarritz.

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 de l'ATST 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).

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.

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Thème 1 : Simulations et outils numériques

PHARE - helioplasma modeling with adaptive mesh refinement

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PHARE is a multi-formalism Adaptive Mesh Refinement (AMR) numerical framework developed at LPP for the helio-plasma community. The code solves Hybrid-PIC, Hall-MHD, and resistive MHD equations on a dynamical hierarchy of uniform Cartesian grids with incrementally finer spatial and temporal resolution. Key features of the current roadmap include the coupling of these formalisms within a single AMR hierarchy and the modeling of planetary magnetospheres. This presentation outlines the code's current capabilities and development roadmap, with the goal of fostering new collaborations regarding its usage.

Whistler-mode waves in the tail of Mercury's magnetosphere : A numerical study

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Mercury hosts a small, highly dynamic magnetosphere in which magnetic reconnection plays a fundamental role in driving energy transfer and plasma dynamics. During its Mercury flybys, BepiColombo/Mio has already observed whistler-mode chorus waves, yet the underlying generation mechanisms and their global distribution remain poorly understood. We investigate these processes using a fully kinetic three-dimensional global simulation of the Hermean magnetosphere performed with the iPIC3D code, modeling the solar wind interaction under southward interplanetary magnetic field conditions, allowing to maximize magnetic coupling between the solar wind and the planet.

Our simulation reveals that magnetic reconnection in the magnetotail drives significant wave activity originating near the diffusion region and propagating at large scales across the nightside magnetosphere. We show that high-energy electrons above 1 keV remain confined to closed magnetic field line regions, while lower-energy electrons populate both open and closed topologies, establishing a clear link between magnetic topology and electron energy distribution. In the vicinity of the diffusion region, we identify narrowband whistler-mode waves propagating nearly parallel to the background magnetic field at f$\sim$0.5 fce, exhibiting both electromagnetic and electrostatic components. A strong electron temperature anisotropy is identified as the likely free energy source driving wave growth. Once generated, these whistler waves propagate along the separatrices and resonantly interact with the local electron population. Our findings are discussed in the context of BepiColombo observations, offering a physical interpretation of the detected wave signatures and providing testable predictions for future measurements by the Mercury Magnetospheric Orbiter.

Implementation and Evaluation of the 5+1 Wave MHD Solver in the Kalypsso Hybrid CPU–GPU AMR Platform

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Kalypsso (Kokkos Applicative Layer for Parallel and Scalable Solvers on Octrees) is a hybrid CPU–GPU parallel platform that can be used for 2D/3D ideal magnetohydrodynamics (MHD), written in C++ [1]. It relies on structured adaptive mesh refinement (AMR) based on octree blocks through coupling with the p4est library [2]. Performance portability across architectures is ensured using Kokkos [3], allowing efficient execution on CPUs and GPUs without major code modifications. Kalypsso includes several ideal MHD solvers, enabling both application-oriented flexibility and solver cross-validation. In this work, we focus on the latter aspect. A new ideal MHD solver was developed in La Maison de la Simulation, named 5+1 Waves [4], has been implemented in Kalypsso. We assess its behavior in the presence of AMR and compare it to a widely used reference solver in the astrophysical community :
the HLLD [5] solver combined with constrained transport (HLLD-CT) [6]. Both solvers are second-order accurate using a MUSCL–Hancock scheme [7].
The results show that both schemes exhibit similar accuracy for standard benchmark flows from the literature, while the 5+1 wave solver demonstrates better performance on both CPU and GPU.
Particular attention is given to two challenging aspects of numerical solvers for ideal MHD : the preservation of the $\nabla \cdot \mathbf{B} = 0$ constraint and the stability of the schemes in low-β regimes ($\beta = \mathrm{P}/\frac{\mathbf{B}^2}{2}$) . The two schemes exhibit relatively different properties. The HLLD–CT scheme strictly preserves $\nabla \cdot \mathbf{B} = 0$ but becomes unstable in low-β conditions, whereas the 5+1 wave solver does not exactly preserve the divergence-free condition but remains stable in low-beta regimes and naturally preserves positivity.
Finally, a dedicated study is carried out to analyze the behavior and properties of the non-zero magnetic divergence produced by the 5+1 wave scheme.

[1] P.Kestener, (2025), A performance portable platform for compressible hydrodynamics simulations using Adaptive Mesh Refinement.

[2] p4est : Scalable algorithms for parallel adaptive mesh refinement on forests of octrees

[3] C.R Trott (2022) Kokkos3 : Programming Model Extensions for the exascale era.

[4] P. Tremblin, (2024), A multi-dimensional, robust and cell-centered finite-volume scheme for the ideal MHD equations.

[5] T. Miyoshi, (2010), The HLLD approximate Riemann solver for magnetospheric simulation.
[6] S. Fromang, (2006), A high order Godunov scheme with constraint transport and adaptive mesh refinement for astrophysical magnetohydrodynamics.
[7] B. van Leer, (2003), Upwind and High-Resolution methods for compressible flow

Où sont les taches dans les simulations de dynamos solaires cycliques ?

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La présence de taches solaires à la surface du Soleil semble une évidence généralisée pour toutes les étoiles de type solaire.
Or la majorité des simulations 3-D MHD de la dynamo et convection solaire ne possèdent pas de taches bien qu'elles puissent posséder des cycles magnétiques d'environ 11 ans : c'est le paradoxe des dynamos sans tache !
Nous ferons un état des lieux de notre compréhension actuelle sur les ingrédients nécessaires à l'obtention d'une dynamo cyclique et comment l'état magnéto-rotationnel du Soleil change au cours du temps. Nous montrerons qu'en respectant des balances clés de la MHD interne solaire en accord avec les contraintes observationelless, il est possible de construire de nouvelles simulations de la dynamo solaire qui développent à la surface des structures magnétiques intenses, assimilables à des progéniteurs de taches solaires.
Nous discuterons les propriétés de ces nouvelles dynamos et l'orgine de ces précursseurs de taches ainsi que l'étape suivante qui consiste à inclure une atmosphère dans ces simulations de magnéto-convection solaire globales pour en améliorer encore plus le réalisme.

Open solar data, data products, and tools at MEDOC

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Stéphane Caminade (1), Susanna Parenti (2), Barbara Perri (2), Frédéric Auchère (1), Salim Hachemaoui (3), Khalil Ashkar (1), Martine Chane-Yook (1), Dominica Leung (4)

(1) IAS, CNRS, Université Paris-Saclay (2) AIM, CNRS, CEA, Université Paris-Saclay, Université Paris Cité (3) DSI Global Services (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).

Exploration du système solaire : mesures in situ dans les environnements ionisés planétaires par la méthode de l'impédance mutuelle

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Les plasmas spatiaux sont omniprésents dans l'univers, des étoiles aux nébuleuses interstellaires, en passant par notre système solaire. Ils se manifestent à travers le Soleil et son flux continu de particules chargées, mais aussi au sein des ionosphères et magnétosphères planétaires. Ces environnements constituent des laboratoires naturels uniques pour l'étude des plasmas, mais leur accessibilité reste un défi majeur. Des missions spatiales comme BepiColombo (ESA/JAXA) et JUICE (ESA) embarquent des instruments avancés, dont les sondes à impédance mutuelle, capables de mesurer la densité et la température des plasmas. Cependant, l'exploitation optimale de ces données nécessite une meilleure compréhension de la réponse instrumentale et des modèles adaptés aux environnements ionisés complexes.

Cette étude repose sur une approche combinant modélisation permettant de simuler la réponse instrumentale des sondes d'impédance mutuelle, en tenant compte de leur géométrie et des caractéristiques de l'environnement plasma attendu, afin d'anticiper leur comportement dans des conditions spatiales variées. Mais aussi analyse des spectres d'impédance mutuelle pour la détermination des caractéristiques du plasma étudié. Enfin, une campagne expérimentale en chambre à plasma, reproduisant les conditions spatiales, permet de valider les instruments et d'affiner les modèles, assurant ainsi la robustesse des diagnostics développés.

Ces travaux visent à affiner les diagnostics des plasmas rencontrés par les missions spatiales BepiColombo et JUICE, en fournissant les outils nécessaires à l'interprétation des données. Ils ont également pour objectif d'améliorer les modèles de réponse instrumentale et les méthodes d'analyse.

PHARE : Modeling planetary magnetospheres with Adaptive Mesh and Model Refinement

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Understanding the global dynamics of a magnetosphere and its coupling with its environment is challenging due to the multi-scale nature of the problem. Kinetic models are computationally expensive, while fluid models lack realism.
We present progress on a next-generation simulation framework using the open-source PHARE code, with Adaptive Mesh Refinement (AMR) solvers for two complementary formalisms : Hall-MHD (fluid) and Hybrid Particle In Cell (kinetic). These solvers have been validated and used for large scale simulations of magnetic reconnection.
The next step is Adaptive Mesh and Model Refinement (AM2R), which enables both descriptions to run simultaneously within a single global magnetospheric simulation, refining the mesh and the physical model only where needed. We show current progress toward this fluid–kinetic coupling and discuss its application to planetary magnetosphere modeling.

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

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Nous présentons deux des familles d'outils numériques mis à disposition, documentés et maintenus sur la plateforme MEDOC de l'Observatoire des Sciences de l'Univers de l'Université Paris-Saclay, et destinés à l'interprétation des observations solaires et stellaires issues des missions spatiales telles que SoHO, Hinode, SDO, IRIS et Solar Orbiter, ainsi que des futures observations à haute résolution.

(1) Codes de transfert radiatif hors ETL (NLTE).
https://idoc.osups.universite-paris-saclay.fr/medoc/tools-2/radiative-transfer-codes/

Ces outils modélisent diverses structures solaires (protubérances, filaments, chromosphères, etc.) et stellaires en géométries 1D et 2D.
Les développements réalisés à Institut d'Astrophysique Spatiale reposent notamment sur la méthode de Feautrier et permettent le traitement simultané du continu et de nombreuses raies spectrales (H, He, Mg, Ca, Fe, Ni), avec prise en compte des champs de vitesse.
Les codes en géométries 1D et 2D cartésiennes, développés à Institut de Recherche en Astrophysique et Planétologie, utilisent des schémas numériques éprouvés à l'instar de MALI (Multi-level Accelerated Lambda Iteration). Une version 2D hors ETL incluant l'équilibre d'ionisation de l'hydrogène et le transfert du continu de Lyman est également disponible.

(2) Algorithme « Coherent Structure Tracking (CST) ».
https://idoc.osups.universite-paris-saclay.fr/medoc/tools-2/cst-codes/

Cet ensemble de codes (IDL et Fortran 90) détermine les champs de vitesses horizontales à la surface du Soleil en se servant de granules comme traceurs. Il utilise en entrée des images d'intensité SDO/HMI (série de données "hmi.Ic_45s"), avec un pas temporel de 45s.

Development of a particle tracing algorithm for electrons at Mercury and comparison with Bepicolombo data during its first three Mercury flybys

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The planetary system of Mercury will be intensively explored in the coming years. BepiColombo is an interdisciplinary mission carried out by the European Space Agency (ESA) and the Japanese Aerospace Exploration Agency (JAXA), that will perform a comprehensive orbital exploration of Mercury starting at the end of 2026. From dedicated orbits, two spacecraft will be studying the origin and evolution of the planet, its interior and surface, as well as its surrounding environment. With their powerful and unique suite of particle and wave instruments, they will return an unprecedently large amount of data on the fundamental plasma processes down to the electron scale that affect the planetary system as a whole. BepiColombo will allow a major leap forward in our understanding of the interactions between the Sun and planetary environments in our Solar System, and beyond, including habitability conditions against strong stellar winds, provided we properly interpret particle and electromagnetic data in terms of the micro- and macro-scale physical processes that took place in the magnetosphere of Mercury. To do so, we developed a particle tracing algorithm, based on the Boris pusher, for electrons at Mercury. Using the data of the first three BepiColombo's flybys, we caracterize electron precipitation at Mercury.

Modelling of space plasma from Vlasov to fluid : machine learning approach to the closure problem

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Addressing many fundamental questions in space plasma physics requires numerical modelling. The most physically complete description is the kinetic approach, which tracks the full six-dimensional particle distribution function in phase space. While faithful, kinetic simulations are computationally expensive. An alternative is the fluid approach, where the distribution function is integrated over velocity space, reducing the dimensionality of the problem. However, this reduction introduces an additional problem : the resulting hierarchy of fluid equations is not closed, the evolution of lower order moments depend on the higher order ones. Thus, one has to introduce a closure relation.

We propose a data-driven solution to the closure problem, combining kinetic simulations with machine learning techniques. We perform an ensemble of two-dimensional, fully-developed plasma turbulence simulations using the hybrid particle-in-cell code Menura, varying two parameters (the ion parallel beta and the amplitude of initial magnetic field perturbations) to explore the variability of the Earth's (turbulent) magnetosheath. These kinetic simulations serve as ground truth for training three classes of machine learning architectures : Convolutional Neural Networks (CNN), Generative Adversarial Networks (GAN), and Fourier Neural Operators (FNO). Each model is tasked with learning an approximation of the pressure tensor closure from the plasma density, velocity, and electromagnetic fields on a two-dimensional grid.

The ultimate objective is a learned closure relation that captures the kinetic physics of the magnetosheath turbulence within a computationally efficient fluid framework. The generalization capability of the trained models is explicitly tested on plasma regimes not seen during training, to provide an independent (out-of-distribution) benchmark.

Un seuil magnétique pour l'émergence des taches : faire un lien entre les courbes de lumière et les simulations MHD globales

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Comprendre l'origine et le fonctionnement des mécanismes de la dynamo solaire fait partie des enjeux majeurs de la physique solaire. Ces mécanismes sont à l'origine du cycle magnétique du Soleil et de l'activité magnétique observée à sa surface, depuis les taches solaires jusqu'aux éruptions et éjections de masse coronale dans l'atmosphère solaire. Ces phénomènes peuvent se propager à travers l'héliosphère et influencer l'environnement spatial terrestre.

Si les simulations MHD globales permettent aujourd'hui d'explorer la génération et l'organisation du champ magnétique dans l'intérieur solaire, les observations directes du magnétisme restent surtout limitées aux manifestations de surface, en particulier les régions actives et les taches solaires. Établir un lien entre ces signatures observables et les propriétés du champ magnétique interne est donc essentiel pour mieux comprendre le fonctionnement de la dynamo.

Du côté observationnel, une approche consiste à étudier des étoiles de type solaire afin de mieux comprendre le passé comme le futur de la dynamo du Soleil par analogie. La photométrie constitue un outil privilégié pour cela : les courbes de lumière révèlent les signatures laissées par les taches à la surface des étoiles et sont aujourd'hui disponibles en très grand nombre grâce aux missions spatiales de haute précision comme CoRoT, Kepler, TESS et bientôt PLATO).

Dans ce contexte, j'ai développé un outil d'analyse visant à relier signatures photométriques et simulations MHD globales. Une difficulté majeure est que ces simulations ne reproduisent pas directement les taches ni la photosphère, car elles ne résolvent pas les petites échelles et ne possèdent pas de traitement du transfert radiatif, ce qui empêche la production directe de courbes de lumière synthétiques.

Pour surmonter cette limitation, j'ai adopté une approche Sun-as-a-star reposant sur la base de données solaire multi-instruments de la HFC, comprenant des informations sur plusieurs centaines de milliers de taches et de régions actives. L'analyse statistique de ces données, ainsi que l'utilisation d'images HMI et AIA, a permis la mise en évidence un seuil de champ magnétique associé à l'émergence de taches dans les régions actives.

Ce seuil peut ensuite être appliqué aux cartes de champ magnétique issues de simulations MHD globales dont la résolution est comparable à celle des régions actives solaires.

À partir de cette approche, j'ai développé un pipeline permettant d'identifier des régions potentielles d'émergence de taches et de produire des courbes de lumière synthétiques à partir de simulations globales (ASH, MaGIC). Je discuterai de ce seuil magnétique, de son application aux simulations globales et des premières courbes de lumière synthétiques obtenues.

Étude des modes d'une simulation solaire globale à l'aide d'un code hydrodynamique compressible

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Bien que la convection solaire soit étudiée depuis longtemps dans des simulations locales compressibles, construire un modèle global compressible réaliste du Soleil entier, couplant de façon consistante l'enveloppe convective et l'intérieur radiatif stable, reste un défi numérique majeur.
En utilisant le code Dyablo-Whole Sun, un solveur volumes finis pour les équations compressibles de la dynamique des fluides et de la MHD, j'ai développé et appliqué une extension géométrique permettant de simuler la convection solaire depuis le centre r=0 jusqu'à la proche surface. Le code a été adapté à des maillages non cartésiens via des projections entre grille logique (cartésienne) et grille physique [Calhoun 2008], et j'ai implémenté un schéma well-balanced adaptés à ces grilles [Berberich 2019].
À partir d'un profil de vitesse du son calibré sismiquement [Brun et al. 2002], j'ai construit un modèle solaire en couplant enveloppe de convection et zone interne radiative sans magnétisme montrant l'excitation et la propagation simultanées d'ondes acoustiques (p-modes), d'ondes de gravité internes (g-modes) et du mode f, l'analyse spectrale et la comparaison au code linéaire GYRE confirment un bon accord avec la théorie. Les résultats sont une première mondiale : nous avons maintenant à la fois des modes acoustiques et gravitationnels auto-excités et se propageant de manière cohérente dans les deux cavités délimitées par les fréquences Lamb et Brunt-Vaissala. Le modèle est suffisamment polyvalent pour que nous puissions l'adapter à d'autres étoiles.

Numerical Modelling of Spacecraft Charging and Sheath Formation Around BepiColombo Mio Using SPIS

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The interpretation of plasma waves and electric field measurements acquired in planetary plasmas requires careful consideration of spacecraft–plasma interactions, particularly spacecraft charging and sheath formation in the vicinity of the sensors. In preparation for the analysis of observations from the PWI/AM2P experiment onboard BepiColombo Mercury Magnetospheric Orbiter (Mio), this work investigates the electrostatic environment of the spacecraft through numerical simulations performed with SPIS.

The study focuses on the formation of the plasma sheath, the evolution of spacecraft potential, and the contribution of photoelectron emission under plasma conditions representative of Mio's orbit around Mercury, used as input for the SPIS simulations. This allows us to investigate the influence of variations in plasma density and temperature along the Mio orbit on the spatial structure of the sheath and the charging state of the spacecraft. Particular attention is given to the near-spacecraft environment relevant to AM2P, with the objective of improving the interpretation of future in-flight measurements and identifying the principal plasma and charging processes that may influence the instrument response.

In parallel, a numerical model of the PEPSO plasma chamber at LPC2E in Orléans is being developed in SPIS to reproduce the laboratory configuration used for instrument development and tests related investigations. The chamber geometry, plasma source, and internal instrument elements are incorporated to study the plasma conditions established in the plasma chamber facility and to assess its influence on instrumental measurements.

Taken together, these two complementary modelling efforts aim to establish a coherent link between controlled ground-based experiments and the expected in-flight environment of Mio, thereby supporting the preparation and physical interpretation of AM2P observations.

Velocirap, a python library for advanced analysis of ion velocity distribution functions

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Velocirap is a Python library designed to facilitate the advanced analysis of ion velocity distribution functions (VDFs) from space missions such as Solar Orbiter, Parker Solar Probe, and the future HelioSwarm mission. It is developped at the Institut de Recherche en Astrophysique et Planétologie (IRAP) by the Proton and Alpha Sensor (PAS) team of the Solar Orbiter mission. It provides a wide range of tools for loading, processing, and visualizing VDF data.

Fokker-Planck Modelling of Solar Wind Electron Velocity Distributions : Diffusive Transport vs. Ballistic Effects

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In this work, we model electron transport in the interplanetary medium using the Focused Transport Equation (FTE), a gyrophase-averaged kinetic equation which takes the form of a Fokker-Planck equation. Our model accounts for magnetic focussing in a Parker-spiral magnetic field, the interplanetary ambipolar electric potential, and angular diffusion by Coulomb collisions and/or other turbulent mechanisms associated with magnetic field fluctuations. Motivated by measurements of non-thermal features by Parker Solar Probe and Solar Orbiter, such as the sunward electron deficit, we solve the FTE using the newly developed Solar Wind Electron Energisation and Transport (SWEET) code and reconstruct the radial evolution of the electron Velocity Distribution Functions (VDFs). We compare different transport regimes of solar wind electrons subject to a Parker-spiral magnetic field and an ambipolar electric potential. First, we study a collisionless regime and cross-check our simulation results with the Liouville analytical solutions typical of the exospheric approach. Second, we introduce pitch-angle diffusion driven by Coulomb collisions and show how they modify the VDFs, isotropising the thermal core and smoothing the sunward electron deficit with respect to the collisionless solution. Finally, we introduce turbulent scattering caused by magnetic field fluctuations and show how it is responsible for the appearance of an isotropic electron halo population at high energies.

PHARE for Global Magnetospheric Simulations

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PHARE is an open-source framework for simulating space plasmas. Currently, it is capable of solving either a hybrid or a fully fluid model on patch-based AMR grids. The main target of future developments is to couple both models during a single run, with the hybrid model only solved in the refined parts of the grid where physical accuracy is paramount. This approach is expected to enable computationally affordable yet accurate large-scale simulations.

In parallel with these developments, this work focuses on incorporating the features required to simulate, at large scales, the interaction between the solar wind plasma and an Earth-like planet located within the computational domain. Namely, these components include the description of the solar wind at the inflow, the planetary magnetic dipole, as well as ionospheric boundary conditions around the planetary surface. This poster will describe these elements in terms of physical modeling and numerical methods, and will showcase preliminary simulations based on them.

The SciQLop Ecosystem : Open-Source Tools for Interactive Multi-Mission In-Situ Plasma Data Exploration and Analysis

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Our community benefits from decades of in situ measurements stored across international public archives. Exploring these databases and searching for plasma process signatures remains a bottleneck — not only due to the massive amount of data, but also its intrinsic complexity. Even accessing a single instrument raises technical hurdles : finding where to get data, how to download it, and how to read it. These compound for multi-mission studies across archives.

We present SciQLop, an open-source ecosystem of interoperable tools that removes these barriers.

Speasy provides a unified Python API to access over 65,000 products from AMDA, CDAWeb, CSA, SSCWeb, and CDPP 3DView through a single get_data() call, with transparent multi-level caching (local and shared community proxy), automatic inventory discovery with auto-completion, and native NumPy/SciPy/Pandas interoperability. It is also available in Julia.

CDFpp/PyCDFpp is a modern, thread-safe C++ CDF implementation with Python bindings, achieving up to 4 GB/s read speeds– addressing the legacy NASA library's lack of thread safety and licensing issues. Combined with PyISTP for ISTP-compliant access, it forms the ecosystem's data I/O foundation.

SciQLop is an interactive application built on a custom C++ plotting engine (SciQLopPlots) optimized for large non-uniform datasets. Researchers can browse and label multivariate time series with fluid interaction on gigabyte-scale data. Features include drag-and-drop discovery from all supported archives, user-defined virtual products recomputed on-the-fly, graphical event cataloging (tscat), and JupyterLab integration for hybrid workflows. Upcoming : CRDT-based collaborative catalog co-editing (cocat) and a community plugin marketplace.

These tools directly serve the ATST community : multi-spacecraft comparison for plasma envelope coupling studies, rapid event identification for eruptive activity, and streamlined multi-archive access for Sun-Earth and space weather investigations. All tools are open-source, pip-installable, and supported by CDPP and Plas@Par.

Comparaison de méthodes de modélisation de la propagation trans-ionosphérique des signaux radio

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La modélisation de la propagation des signaux radio trans-ionosphériques en bande HF est cruciale pour la prédiction et l'optimisation des portées des systèmes de télécommunication ou radars. Les exigences de précision croissantes rendent ce problème difficile, notamment parce que la performance des outils de modélisation dépend fortement des hypothèses adoptées sur la propagation radioélectrique ainsi que sur le milieu ionosphérique. En effet lors de la modélisation de la propagation dans le plasma ionosphérique, la prise en compte du champ magnétique terrestre, des collisions entre particules et des variations de densité électronique complexifie considérablement la résolution des équations de propagation. Dans le cadre de nos travaux, deux approches ont été comparées :

- La résolution numérique des équations de Haselgrove : une formulation hamiltonienne de l'équation d'onde qui conduit à un système de six équations décrivant la trajectoire d'un rayon et l'évolution du vecteur d'onde le long de celle-ci. Ces équations sont classiquement résolues avec l'algorithme de Runge-Kutta-Tsitouras.
- Une méthode analytique nommée MQP (pour "Multiple Quasi-Parabolic") : la variation de densité électronique est localement approchée par une succession de segments paraboliques. Cette représentation rend possible la résolution analytique des trajectoires des rayons propagés sous l'hypothèse d'un milieu non collisionnel et sans champ magnétique terrestre.

Les deux modèles ont été comparés dans différentes configurations canoniques. Le modèle MQP, totalement analytique, sert de référence sous hypothèse d'un indice de réfraction sans influence du champ magnétique terrestre, ni collisions particulaires. L'erreur introduite par la résolution numérique des équations de Haselgrove est ainsi estimée. Les résultats montrent que, dans des conditions nominales, le modèle numérique reproduit fidèlement les solutions analytiques. En revanche, à proximité du rayon de Pedersen, de très petites approximations numériques entraînent des écarts significatifs, révélant les limites de la méthode numérique dans ces zones sensibles.

Cette étude fournit une base solide pour de futures comparaisons avec des mesures réelles obtenues à partir de sondages ionosphériques obliques et verticaux, ouvrant la voie à une validation expérimentale des deux approches.

Réseaux de neurones informés par la physique appliqués à la ceinture de radiation d'électron externe de la Terre : évaluation dans le cadre d'une expérience-jumelle

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Les réseaux de neurones informés par la physique (PINNs) sont apparus comme un outil puissant pour la modélisation directe et inverse des systèmes physiques. Des travaux récents (Camporeale et al., 2022) ont démontré leur potentiel pour reconstruire les coefficients de diffusion et de perte à partir d'observations in situ du flux de particules dans les ceintures de radiation terrestres. Le problème est toutefois mal posé et l'inférence précise de ces coefficients est rendue difficile par l'hétérogénéité et l'anisotropie des coefficients de transports ainsi que par les échelles de temps étendues qui caractérisent les ceintures de radiation.

Dans cette étude, nous évaluons quantitativement la capacité des PINNs à reconstruire le coefficient de diffusion radiale et de perte gouvernant la dynamique des électrons dans les ceintures de radiation. L'approche repose sur le cas unidimensionnel de l'équation de Fokker-Planck, qui décrit l'évolution radiale de la densité de particule d'électron sous l'effet des processus de diffusion et de perte induits par les variations de l'activité géomagnétique. Dans le cadre d'une expérience-jumelle, des données synthétiques de densité de particule d'électron sont générées puis échantillonnées le long d'une trajectoire satellitaire afin d'entraîner le PINN et d'évaluer sa capacité à récupérer les paramètres physiques de transport sous-jacents.

Nos résultats montrent que les PINNs peuvent estimer les paramètres clés gouvernant la diffusion radiale dans les ceintures de radiation et capturer leur variabilité temporelle et radiale globale. Cependant, les pics localisés prononcés et les variations rapides sont lissés, probablement en raison de la disposition des observations et de la régularisation du réseau de neurone.
Malgré ces limitations, le modèle reconstruit de manière cohérente le rapport entre les termes de diffusion et de perte, préservant ainsi l'équilibre global du transport.

The Auroral Planetary Imaging and Spectroscopy (APIS) service : a facilitated access to UV observations of solar system planets

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Remote Ultraviolet (UV) auroral observations of the outer planets provide highly valuable constraints on the auroral processes at work and the underlying coupling between the solar wind, the magnetosphere, the ionosphere and the moons. APIS stands for Auroral Planetary Imaging and Spectroscopy. This french CNRS national observation service has been available online at https://apis.obspm.fr since 2012, and aims at facilitating the use of complex UV planetary auroral observations. APIS provides an open and interactive access to high level data, dealing with UV observations from various UV observatories (HST, Hisaki, Cassini, Juno), through a dedicated search interface and standard VO tools. APIS is additionnally interfaced with other VO services of the community such as VESPA, CDPP/AMDA, CDPP/3dView and CDPP/PropTool. Recently, we extended the HST database to observations of Jupiter in support to Juno, developed high level products for the Cassini/UVIS dataset and worked on prototypes of Juno/UVS observations of Jupiter and JWST/NIRSPEC observations of the giant planets.

Real-time detection of Solar and Jovian radio bursts with NenuFAR : a part of the EXTRACT project

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In the past decades, the increasing need for ultra-high-resolution radio observations with enhanced sensitivity has led to a surge in data volumes from next-generation radio telescopes. Efficient tools for data management, processing, and storage optimization are now crucial for helping scientific analysis. The EXTRACT project, funded by the European Commission, is developing a distributed data-mining platform for EXTReme dAta Across the Compute conTinuum. A key use case, Transient Astrophysics with a Square Kilometer Array pathfinder (TASKA), takes advantage of EXTRACT technologies to handle the massive data streams produced by NenuFAR, one of the SKA pathfinders.
This work presents two targeted projects, TASKA-A1 and A2, focusing on real-time detection of (A1) Solar radio spikes and (A2) Jupiter's fast-drifting radio bursts (S-bursts), in high resolution time-frequency dynamic spectra. TASKA-A1 employs the deep learning-based SpikeNet convolutional neural network [Murphy et al., 2024] to detect Solar spikes in real-time observations. TASKA-A2 adapts an existing detection pipeline based on Fast Fourier Transform (FFT) and Radon Transform [Mauduit et al., 2023] to enable real-time identification of Jovian S-bursts. Additionally, we are developing a novel convolutional neural network based on anomaly detection to enhance detection efficiency and robustness. Both algorithms are embedded within the MurMuRe pipeline (Modular Multicast Receiver), specifically developed for the NenuFAR real time data receiver, which allows to use either the real-time data flow from the instrument or stored data with various formats.
These advancements provide an important step toward smart data filtering for next-generation radio telescopes. Indeed, by enabling real-time decision-making, astronomers can dynamically store high-resolution data for only the most scientifically valuable events while preserving lower-resolution data for broader analysis. It also paves the way of "analog to information" processing, which would drastically reduce the storage needs. As a matter of fact, the emissions studied in this work require a high time-frequency resolution, but are often embedded within larger slowly-varying emissions that can be studied at a lower resolution. This approach helps optimizing data storage while maintaining its value for scientific analysis, thus preparing for scalable solutions in the era of the Square Kilometer Array.

Simulation et métamodélisation par apprentissage automatique des chocs non collisionnels dans les cavités diamagnétiques

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La formation de chocs dans un plasma non-collisionnel magnétisé, phénomène fréquemment rencontré en astrophysique, est largement étudié depuis plus de quarante ans à travers de multiples vecteurs. Souvent associé à la formation de cavités diamagnétiques, résultant de l'expansion d'un plasma perturbé dans un plasma ambiant magnétisé, le phénomène a été étudié expérimentalement via des expériences de lâcher de baryum dans l'ionosphère, en 1984 [1] et 1990 [2]. Par la suite, l'attention s'est portée vers des expériences de pulvérisation par laser, plus simples à réaliser et offrant un environnement plus contrôlé. Les données furent ensuite confrontées à des codes de calcul toujours plus performants simulant l'expansion de ces cavités afin de mettre en lumière la physique responsable de la formation des chocs magnétiques [3,4]. Cependant ces simulations, notamment les modèles PIC ou hybrides, sont bien souvent très coûteuses en ressources et la quantité de configurations physiques qui peut être explorée s'en voit drastiquement réduite.
L'approche présentée ici pour contourner ces limitations met en jeu un nouvel outil développé au CEA, KALYPSSO [5]. Il s'agit d'une plateforme de simulation intégrant du raffinement de maillage adaptatif et une compatibilité GPU, doté d'un solveur magnétohydrodynamique qui permet de mener rapidement des simulations d'expansion 3D de cavités d'une grande précision. Ce code a permis de simuler plus de 4000 cavités, couvrant une vaste gamme de paramètres rencontrés dans la littérature, dont nous avons extrait des coupes 2D orthogonales au champ magnétique ambiant. La base de données ainsi formée, adéquatement nettoyée et post-traitée, a été utilisée pour alimenter un modèle d'apprentissage automatique. Celui-ci prend en entrée une sélection de paramètres physiques adimensionnés, le rendant compatible avec une vaste gamme de contextes physiques, et fourni en réponse le profil radial du champ magnétique à un instant donné de la vie de la cavité, moyenné par axisymétrie. Les performances de ce métamodèle se sont révélées très satisfaisantes, et les résultats obtenus sont en bon accord avec des exemples tirés de la littérature, y compris basés sur des modèles hybrides. Cet outil pourra être exploité pour mener des études préparatoires à des simulations de grandes envergure, réaliser efficacement des études statistiques complètes, et représente une base solide pour l'extension de cette étude à des phénomènes plus complexes.

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Exploring numerical schemes and tools for the solar wind-magnetosphere-ionosphere system

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The coupling of solar wind, magnetosphere and ionosphere involes multiple physical processes, connecting kilometer to planetary scales. For instance, the interaction between the geomagnetic field and the solar wind variability has profound influence on the atmosphere dynamics, including polar outflows and Earth's magnetic activity [1]. Solar wind particle inflows also occur through the polar cusp, which configuration depends on the SW pressure and tilt angle of the geomagnetic field [2]. These dual interactions, from in- and outside, may affect the radiation belts and the particles trapped within. Understanding this complex, interconnected system heavily relies on numerical simulations to explain the observational data and validate the theoretical models.
Fortunately, the fluid approximation is mostly valid for these structures through the magnetohydrodynamic (MHD) approach, enabling the study of these interactions at a lower computational cost. However, reducing the time and ressources required to model such systems remains challenging, hence the ongoing search for efficient numerical schemes and methods [3]. For example, higher-order Riemann solvers, adaptive mesh refinement (AMR) and GPU are increasingly being chosen for large-scale astrophysical applications. Here, an original implementation of a modified HLLD Riemann solver is compared to classical schemes, including Roe-type, through both performance and physical reliability. Then, we explore a classic historical case of interaction between the solar wind and a magnetised planet [4] using a new platform called kalypsso (Kokkos Applicative LaYer for Parallel and Scalable Solvers on Octrees) [5]. The terrestrial environment is initially represented by an idealised dipolar magnetic field exposed to a homogeneous plasma inflow. Simultions are performed using an ideal MHD Riemann solver, recognised for stability and precision across shocks, with a single-fluid simplification in a three-dimensional geometry. This system naturally evolves to a steady-state, which can be altered through dynamical inflow parameters. These first results help provide valuable insights into the most efficient numerical approach for MIT coupling.

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Modeling the Solar Wind – Mars interaction under quasi-radial IMF configuration

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In absence of a global intrinsic magnetosphere, the Solar Wind plasma interacts directly with the planet's conductive ionosphere and upper atmosphere, exchanging momentum and energy. The interplanetary magnetic field (IMF) plays a crucial role as it drapes around this nearly unmagnetized planet, it induces a magnetotail with a two-lobe structure of opposite polarity as well as a dayside magnetic pileup region upstream of the ionosphere. This classical picture of the Mars-Solar wind interaction has been suggested to be largely modified when the IMF is quasi-radial leading to a so-called degenerated magnetosphere (Zhang et al, 2024). Among the main findings, MAVEN observations indicated a highly variable plasma environment near the subsolar region, which corresponds to the foreshock region associated to a quasi-parallel bow shock, a deeper penetration of solar wind ions down to MAVEN periapsis (about 230km), a magnetic barrier present at lower altitude and significant erosion of the upper ionosphere driving enhanced ion escape (Fowler et al, 2022). More recently, Dubinin et al (2026) have analyzed MAVEN data for small cone angles (below 20° or larger than 160°) and found that the main patterns of the classical Martian induced magnetosphere under Parker spiral conditions generally persist. The presence of crustal magnetic fields may support the formation of an induced magnetosphere, while a truly degenerated magnetosphere may occur only under nearly radial IMF. To investigate these different drivers, a series of hybrid simulations has been performed with the LatHyS model (Modolo et al, 2016) and we compare simulations results for cone angle of 57°, 20°, 5°, 2° and 0°, both with and without the presence of crustal magnetic fields. The results reveal a highly disturbed magnetic and plasma environment in the subsolar region, with a foreshock region that can extend to more than 10 Martian radii, a persistent bipolar tail structure, the disappearance of the plume region and increased precipitation of solar wind protons. Simulation results also emphasize the critical role of crustal fields in helping to stabilize this hybrid magnetosphere.

Vers le développement d'un modèle réduit des ceintures de radiation terrestres

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Le recours à des modèles d'ordre réduits établis à partir de données (ROMs) s'est répandu ces dernières années grâce à leur capacité à reproduire la dynamique de systèmes physiques complexes tout en réduisant drastiquement le temps de calcul en comparaison à des approches numériques plus classiques. Ces approches reposent notamment sur la réduction des sorties de modèles numériques à un petit ensemble de variables latentes dont la dynamique est pilotable par des paramètres externes. L'enjeu étant de s'assurer de l'indépendance et de l'interprétabilité des variables latentes ainsi obtenues.

Ici, nous présentons les différentes étapes de la chaîne menant au développement d'un modèle réduit des ceintures de radiation terrestres, de la réduction de la dimensionalité des flux d'électrons à l'aide d'auto-encodeurs au pilotage de la dynamique des variables latentes à l'aide de réseaux de neurones récurrents et de mesures d'indices géomagnétiques.

D'un point de vue climatologique, le modèle obtenu est une opportunité pour reconstruire l'état des ceintures sur des périodes de temps dépourvues de données in-situ, permettant ainsi d'étudier leur variabilité d'un point de vue climatologique et de considérer ces périodes lors de la construction de bases de réanalyse utiles au développement des modèles de spécification à destination d'industriels. D'un point de vue opérationnel, le modèle réduit permet également de rapidement donner une estimation en temps réel de l'état des ceintures et pourrait ainsi être incorporé dans des chaînes de prévision soleil-terre.

ATISE Wind : Auroral Thermosphere Ionosphere Spectrometer Experiment - Wind measurement

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Solar activity poses a critical threat to terrestrial and orbiting infrastructure, yet a lack of high-resolution dynamic data in the upper atmosphere hinders accurate mitigation. To bridge this gap, the ATISE Wind project introduces a static interferometer designed to measure thermospheric and ionospheric winds with better temporal resolution than previous wind measurement instruments.

Unlike traditional Fabry Perot devices constrained by mechanical optical path differences scanning (often exceeding one minute), the ATISE Wind instrument utilizes a Fizeau-based architecture. Eliminating moving parts enables direct interferogram measurements in just a few seconds. Successfully demonstrated during a 2026 ground-based campaign in Skibotn, the system proved its potential for near-future high efficiency even under low sky brightness conditions ($\approx$ 15 kR). Exposure time down to 1s could be used to determine such wind speeds for the red (630 nm) and green lines (557 nm). Future developments will focus on real-time velocity retrieval to ensure robust monitoring of winds from both ground and space, as well as developing a design with the lowest possible sensitivity to environmental conditions.

Parametric 3D MHD numerical simulations of switchback generation induced by coronal mass ejections

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The ubiquitous presence of switchbacks (SBs) - localized magnetic deflections - revealed by Parker Solar Probe in the inner heliosphere has spurred a growing interest in understanding their origin. One prominent theory suggests their formation in the lower corona within the context of solar jets, with magnetic reconnection involved in the generation process. However, obtaining observational evidence of a direct causal link between specific jets and in situ SB measurements remains a significant challenge, making numerical modeling particularly relevant. Two fundamental questions drive this study : Can solar jets explain the origin of SBs, and what is the sequence of physical mechanisms that drive the propagation of the jets toward the solar corona and can induce the formation of SB ?

Building upon the work of Touresse et al. (2024), which demonstrated that torsional magnetic waves driving solar jets can produce SB-like signatures, my PhD project explores the parameter space of these 3D MHD simulations using the Adaptive Refined MHD Solver (ARMS). We investigate the influence of the jet source size on the properties of the induced SB, by varying dipole dimensions, hence assessing how jets and SBs scale with each other. This is coupled with the implementation of diverse driving profiles to test the impact of different magnetic field geometry in the jet source region on the SB structure and properties. I will present early results from this parametric study, focusing on how these variations impact the trigger, onset, and ability of solar jets to induce SB-like signatures into the solar wind.

Modeling X-ray Emissions near Earth Magnetosphere During a CME and Magnetopause Extraction from X-ray Image

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We use the Dynamic LATMOS Test Particle (D-LaTeP) model to simulate soft X-ray emissions during the 19 October 2001 Coronal Mass Ejection (CME) event and compare the results with XMM-Newton observations. The simulation presents the evolution of X-ray emissions near Earth during the event and shows that multiply charged heavy ions can enter the magnetosphere, generating significant soft X-ray emission in the ring current region. Such emissions inside the magnetosphere should be physically plausible. Line of sight intensities of the simulated X-ray derived along the XMM-Newton viewing geometry agree well with the observations, indicating the reliability. To provide simulation-based support for the imaging missions, we calculate observation-like images from the simulation for the CME event, which reveal that ring current X-ray emissions may contribute substantially to global X-ray signatures. These results suggest that X-ray contributions inside the magnetosphere should be considered when interpreting soft X-ray observations and developing boundary detection techniques for imaging missions.
Furthermore, we present a method based on Tangent Fitting Analysis (TFA) and Hough transform to extract the location of magnetopause from the X-ray image. Specifically, it finds the optimum match of tangent curves of parameterized magnetopause function and brightest arc in the X-ray image.

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

Reconstruction des flux de particules auroraux à l'aide d'instrumentation optique

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Les flux de particules aurorales représentent une des entrées énérgétiques majeures dans la haute atmosphère de la Terre. Nous avons engagés depuis plusieurs années un travail de reconstruction de ces flux de particules en développant plusieurs types d'instruments couplées à des simulations basées sur le code cinétique Transsolo.

Ces instruments, spectromètres, imageurs, sont installés à la fois dans l'ovale Nord (Scandinavie) et dans l'ovale Sud (Bases Dumont 'D'Urville et Concordia). D'autres en développements seront embarqués dans la mission Aurora-D de l'ESA.
Nous avons récemment développé des méthodes permettant ces reconstructions des flux de particules sur la base de spectres, sur la base de reconstruction tomographiques, mais aussi sur la base d'images RGB.

Cette présentation synthétisera et croisera ces développements instrumentaux et ces simulations de manière à donner une image la plus complète possible des méthodes de reconstructions de ces flux de particules. Nous ferons également un lien avec de récents développements instrumentaux permettant de décrire la dynamique de la haute atmosphère.

Métrologie optique et développement du EUVST Grating Assembly pour la mission Solar-C

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La mission Solar-C, portée par la JAXA en collaboration avec plusieurs agences européennes, dont le CNES et l'ESA, a pour objectif d'étudier les processus physiques responsables du chauffage de la couronne et de la dynamique du plasma solaire à travers des observations spectroscopiques dans l'ultraviolet extrême. Son instrument principal, l'Extreme Ultraviolet High-Throughput Spectroscopic Telescope (EUVST), est un spectrographe imageur conçu pour fournir des diagnostics simultanés de la chromosphère, de la région de transition et de la couronne solaire.

La performance spectrale d'EUVST repose sur deux réseaux de diffraction asphériques de grande précision intégrés dans le EUVST Grating Assembly (EGA). La large gamme spectrale couverte par l'instrument impose l'utilisation de deux sous-réseaux gravés séparément puis collés pour former un élément diffractif unique. Cette opération étant irréversible, la métrologie joue un rôle critique en amont du collage pour s'assurer que chaque sous-réseau respecte précisément les spécifications d'orientation requises.

Un travail de métrologie optique de grande précision est mené afin de caractériser les réseaux à différentes étapes du développement. Ces activités s'appuient sur des mesures interférométriques permettant de déterminer le rayon de courbure, le basculement et l'écart à la surface nominale avec une précision nanométrique.

Cette contribution présentera l'approche de métrologie développée pour l'EGA ainsi que les défis associés à la caractérisation d'un composant diffractif asphérique avec un basculement important.

METEOSPACE : surveillance automatisée de la chromosphère solaire à l'observatoire de Calern

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METEOSPACE est un instrument d'imagerie solaire installé sur le plateau de Calern (Observatoire de la Côte d'Azur, 1270 m). Il est constitué de trois télescopes automatiques observant la chromosphère solaire dans les raies Hα et Ca II K, avec des filtres étroits permettant de sonder différentes hauteurs de l'atmosphère solaire. L'instrument fonctionne de manière entièrement robotisée et acquiert toutes les 10 s des images du disque solaire entier, avec une résolution spatiale inférieure à 1", permettant le suivi quasi continu de l'activité chromosphérique.

L'objectif scientifique principal est la surveillance des phénomènes dynamiques associés à l'activité solaire, tels que les éruptions, les instabilités de filaments, les ondes de Moreton ou les phases initiales des éjections de masse coronale. Ces observations permettent d'identifier et de suivre leurs signatures chromosphériques précoces, apportant des informations importantes pour l'étude et la prévision des perturbations de la météorologie de l'espace.

L'ensemble du système est conçu pour fonctionner sans opérateur : contrôle météorologique, acquisition, traitement et archivage des images sont automatisés, ce qui permet une production continue de données et leur diffusion rapide à la communauté scientifique.

Les données METEOSPACE sont librement accessibles via un serveur FTP et une interface web permettant la visualisation quasi temps réel des images, incluant la comparaison aux mesures du flux de rayons X solaires du satellite GOES utilisées pour la détection et la classification des éruptions. Afin de faciliter l'exploitation par la communauté internationale, un service d'accès aux données basé sur DaCHS (Data Center Helper Suite) a été mis en place, rendant l'ensemble des images interrogeables via les outils de l'Observatoire Virtuel et le protocole TAP (Table Access Protocol). Une sélection de données (une image par heure et par longueur d'onde) est également diffusée via la base de données solaire BASS2000, assurant une intégration dans les archives historiques des observations solaires.

Modelling the EUV coronagraphic observations of the Full Sun Imager on board Solar Orbiter

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Because of its mass and abundance, helium plays a fundamental role in the dynamics of the solar wind. The properties of helium are characterized in the photosphere with spectroscopic surveys and in the heliosphere with in-situ measurement thanks to previous space mission. However, very few measurements of the helium abundance exist in the corona above 1.1Rs where the solar wind is accelerated. The EUI and Metis instruments on board Solar Orbiter can map the spatial distribution of helium abundance from 1.5Rs to 7Rs by simultaneously observing the Lyman alpha lines of H0 et He+. These measurements will help constrain models of solar wind acceleration in the solar corona.

We need a comprehensive model of the coronal emission in the passband of each instrument in order to estimate helium abundance from EUI and Metis. In this work, we focus on modelling the EUV observations of the Full Sun Imager (FSI) from EUI in its two narrow passbands : the 304A Lyman alpha line of He+ and the 174A line of Fe9+. We built a state of art model of EUV emission lines to simulate the stray light-free images provided by the coronagraph mode of FSI. This allows us to quantify the relative contributions of the collisional excitation and photo-excitation processes. We present comparisons between FSI observations and MHD-based forward modelling.

From Solar Orbiter / PAS to HelioSwarm / iESA : synthetic data and operational modes

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We present current efforts among the HelioSwarm / iESA team to design synthetic ion data and how we use them to plan future operations. We start from Solar Orbiter / PAS data in the near-Earth environment and map them to iESA angular/energy resolution. This synthetic dataset help us 1/ to assess the performance of the peak tracking strategy, 2/ to evaluate the scientific relevance of the different iESA modes (core, proton, alpha, full) depending on solar wind regimes, and 3/ test compression algorithms to match telemetry constrains. Visualization of distribution functions is performed with the newly developed Velocirap library.

Reconstruction of ionospheric electron density profiles with the Lannemezan ionosonde

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The new ionosonde installed at Lannemezan (Atmospheric Research Center / Midi-Pyrénées Observatory) is now operational and has been recording ionograms nearly continuously since September 2025, with a temporal resolution of 15 minutes. An ionosonde transmits HF waves into the ionosphere, sweeping the frequency range between 1 and 20 MHz. Each wave emitted by the ionosonde is reflected by the ionosphere when its frequency matches the local plasma frequency of the ionized medium, allowing us to reconstruct the electron density profile of the lower ionosphere.

Using this ionosonde, we plan to reconstruct realistic real-time electron density profiles of the ionosphere at mid-latitudes and make them available to the scientific community for scientific and space weather purposes. In this regard, we have developed a new methodology to reconstruct these profiles at different times (night, day, terminators) as well as for different types of conditions (quiet periods, magnetic storms). At the same time, this methodology allows for the reconstruction of conventional parameters provided by an ionosonde, such as the density and altitude of the peaks in the E, F1, and F2 regions (NmE, hE, NmF1, hF1, NmF2, hF2), which are regularly used in physical and/or empirical models of the ionosphere. We present the initial results of this new method and discuss its uncertainties and robustness.

Probing the Inner Solar Corona with ASPIICS aboard the Proba-3 Formation Flying Space Mission : First Results

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We report the first results from observations of the solar corona by the ASPIICS coronagraph aboard the Proba-3 mission, launched on 5 December 2024. 2ASPIICS (Association of Spacecraft for Polarimetric and Imaging Investigation of the Corona of the Sun) is a giant coronagraph consisting of a telescope mounted aboard one mission spacecraft and an external occulter placed on the second. The two spacecraft fly in a precise formation for up to 5.5 hours at a time, which allows the solar corona to be observed in eclipse-like conditions (i.e., close to the limb) with very low straylight, typically down to 1.099 Rsun and occasionally down to 1.05 Rsun. ASPIICS observes quasi-stationary structures such as coronal loops, streamers, and quiescent prominences, as well as a variety of dynamic phenomena (e.g., erupting prominences, coronal mass ejections, jets, slow solar wind outflows, and coronal inflows). In particular, weak, widespread, and persistent small-scale outflows and inflows between 1.3 and 3 Rsun are observed for the first time at a high spatio-temporal resolution (5".6, 30 s). This expands the range of scales at which the formation of the variable slow solar wind can be observed.

The SCM instruments for the NASA HelioSwarm and the ESA Plasma Observatory missions

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The HelioSwarm (HSW) mission is constituted by a platform with 8 small satellites and aims at investigating the plasma turbulence in collisionless plasma like the solar wind. It was selected by NASA in 2022 after a competitive MIDEX phase A and its launch is planned in 2030. The two main objectives are 1/ the study of the three dimensional structure and dynamics of the plasma turbulence, 2/ the study of the mutual impact of the turbulence near boundaries (e.g. Earth's bow shock, ...) and large-scales structures (e. g., coronal mass ejection, ...). In particular the detailed mechanisms of the turbulent energy cascade will be investigated by measuring, for the first time, magnetic and plasma fluctuations (ion density and velocity) simultaneously, from the fluid to the subion scale. The Plasma Observatory (PO) mission concept was selected for a competitive phase A with two other missions in the ESA M7 call, with a selection planned in 2026 and a launch in 2037. Its main objectives are to unveil how are particles energized in space plasma and which processes dominate energy transport and drive coupling between the different regions of the terrestrial magnetospheric system ? The mission consists of 7 identical small satellites equipped by a comprehensive particle and fields payload, evolving along an HEO with an apogee ∼17 and a perigee ∼7RE. The 7 satellites will fly forming two tetraedra and allowing simultaneous measurements at both fluid and ion scales. The mission will include three key science regions : dayside (solar wind, bow shock, magnetosheath, magnetopause), nightside transition region (quasidipolar region, transient near-Earth current sheet, field-aligned currents, braking flow region) and the medium magnetotail. Plasma Observatory mission is the next logical step after the four satellite magnetospheric missions Cluster and MMS.
The search-coil magnetometer (SCM) proposed for these two missions, strongly inherited of the SCM designed for the ESA JUICE mission, is required on all satellites. For both missions, SCM will be delivered by LPP and LPC2E and will provide the three components of the magnetic field fluctuations. The nominal frequency range is [0.1Hz-16Hz]

and [1Hz-8kHz] for HSW and PO respectively. While SCM onboard HSW will provide multiple sequences of 1-hour continuous waveforms required for statistical studies of the plasma turbulence, PO-SCM will provide continuous waveforms and snapshots every 4 s, sampled at 512 Hz and 16 kHz respectively, to fully address wave-particle interactions in particle energization mechanisms. For both missions, SCM will allow to characterize the wave polarization at multi-points as well as to perform k-filtering at fluid and ion scales. These measurements are crucial to understand the role of electromagnetic waves in the energy conversion and partitioning processes, the plasma and energy transport, the acceleration and the heating of the plasma.

Modélisation de la réponse en impédance mutuelle des ondes acoustiques ioniques pour la mission Bepi Colombo

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Les sondes à impédance mutuelle sont des instruments actifs conçus pour diagnostiquer les plasmas spatiaux à l'aide de mesures électriques.
La méthode consiste à appliquer une petite tension alternative à des électrodes émettrices et à mesurer la réponse en potentiel induite sur une paire d'électrodes réceptrices.
En balayant la fréquence, le spectre d'impédance mutuelle fournit des informations sur le milieu environnant et permet de déterminer des paramètres fondamentaux du plasma, notamment la densité et la température des électrons, grâce à l'identification de résonances caractéristiques.

Cette technique de diagnostic a été mise en œuvre avec succès lors de plusieurs missions spatiales, notamment FR-1 autour de la Terre en 1969, Huygens vers la lune de Saturne Titan en 2004, et plus récemment Rosetta autour d'une comète en 2014, démontrant sa fiabilité dans une grande variété d'environnements plasma. Les mesures d'impédance mutuelle sont particulièrement précieuses car elles fournissent une estimation indépendante et robuste des propriétés du plasma, complémentaire aux détecteurs de particules.

La mission ESA–JAXA BepiColombo, qui devrait atteindre l'orbite de Mercure fin 2026, embarque également une expérience à impédance mutuelle qui fonctionnera dans un environnement très dynamique façonné par l'interaction intense avec le vent solaire.
Ces conditions motivent le développement d'outils d'interprétation améliorés pour les observations à venir.

Dans ce travail, nous présentons des efforts de simulation visant à affiner la modélisation des spectres d'impédance mutuelle dans les conditions propres à Mercure.
En particulier, nous discutons d'une extension récente du modèle de réponse afin de prendre en compte la dynamique ionique à basse fréquence ainsi que les effets de décalage Doppler dus à l'écoulement du plasma, en préparation des futures mesures de BepiColombo.

European Solar Telescope for the French heliophysics community

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The European Solar Telescope (EST, https://est-east.eu/) is a project of the next-generation large-aperture European solar telescope. with a 4.2m primary mirror, it will be optimised for studies of the magnetic coupling of the different layers of the solar atmosphere, from the deep photosphere to the upper chromosphere. EST shall become the most powerful European ground-based facility to study the Sun in the next 2-3 decades, in the visible and near-infrared bands. EST will provide diagnostics of the thermal, dynamic and magnetic properties of the plasma over many scale heights, by using multi-wavelength imaging, spectroscopy and spectropolarimetry. EST project is presently at a crucial stage, situation that is driving the need of an in-depth reflection on the relevance and implication of the French astrophysics community on the EST project. A clear strength of our community remains the production of (added-value) data for space weather. EST shall also provide new unprecedented datasets that will be of high interest for French space-weather-oriented services. In the present talk, I'll highlight some of the EST observables, which have been listed in a dedicated white paper on the pertinence of the European Solar Telescope (EST) for the French astrophysical community, that are specifically relevant for French solar physics and space-weather-oriented research axes.

THEMIS solar telescope : a new era begins

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Over the last 10 years, THEMIS, the French 1-m class solar telescope, has benefited from profound overhaul and renovations of diverse systems along its light path. Thanks to a state-of-the art solar adaptive optics, THEMIS observations can now reach its theoretical diffraction limit, at 0.15", enabling to resolve details on the scale of 100 km on the Sun. In the last two years, THEMIS spectro-polarimetric mode has also been renewed and tested. Unprecedented observations are thus now being obtained by THEMIS. Upcoming evolutions of THEMIS, such as space-weather-oriented observations, as well as the reception and commissioning in the spring of 2026, of a new synergic instrument, the upgraded Italian "Interferometric BIdimensional Spectrometer (IBIS 2.0)" will also be presented.

Quasi-Thermal Noise Spectroscopy, a powerful tool for understanding the plasma in the Heliosphere : Case study of the solar wind density variation during the solar cycle 25

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The Quasi-Thermal Noise (QTN) spectroscopy is an efficient tool to study, in the radio frequency domaine, the electrostatic fluctuations due to the thermal motion of the charged particles in a plasma that surrounds a passive antenna. This noise is ubiquitous, and most of the time, is dominant around the electronic plasma frequency.
The voltage power spectrum of the electrostatic fluctuations depends on the velocity distribution of the electrons $f_e(v)$, in addition to the antenna response function.

The shape of the QTN in a weakly magnetized plasma yields an accurate diagnostic of the electron properties, such as the total electron density n_e and the core temperature T_c. This allows to analyze the electronic populations in the solar wind with great precision.

We present the results of a semi-automatic method determining the local plasma frequency, applied to the Parker Solar Probe (PSP) and the WIND spacecraft data between late 2018 and early 2025.
It consists in a large-scale structure of the solar wind density down to 10 Solar Radii, and in its temporal variations with the Solar Cycle 25.

Finally, based on the above method, we discuss on the implementation of a full fitting on the power spectra to deduce a precise diagnostic of the thermal and non-thermal electron populations, both in the solar wind and in the hermean magnetosphere, when the BepiColombo measurements will be available in early 2027.

Statistical Noise Removal Method for the Mass Spectrum Analyzer onboard BepiColombo/Mio

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Mercury is one of the two terrestrial planets in our Solar System possessing an intrinsic magnetic field. Being the closest planet to the Sun and having a weak magnetic field, the Hermean magnetic environment is rapidly changing and forms a tightly coupled system with the planet's core and surface. Its closeness to the Sun causes Mercury's surface to undergo extreme conditions, with continuous space weathering that can eject atoms from the surface to form a tenuous atmosphere called an exosphere (Potter & Morgan 1985). As these atoms become ionized, they drift along the magnetic field lines and populate the magnetosphere of Mercury. Part of these ions can re-impact the surface and eject surface atoms, forming a strong coupling between the magnetosphere, the exosphere, and the surface (Potter & Morgan 1990, Leblanc et al. 2003). More than fifty years after the Mariner 10 mission confirmed the presence of Mercury's magnetic field (Ness et al. 1974), the structure of Mercury's magnetosphere and its ionic composition remain poorly understood. The ESA/JAXA BepiColombo mission is currently cruising towards Mercury to study the Hermean environment, from the planet's surface up to its magnetosphere (Benkhoff et al. 2021).

The Mass Spectrum Analyzer (MSA) (Delcourt et al. 2016) on board the ESA/JAXA BepiColombo mission collected some data during its cruise phase and during the different planetary swing-bys. The instrument measures the ions' energy, and the Time-Of-Flight (TOF) of the ions entering MSA TOF chamber. A striking feature observed in the data is a large band of detection counts present at similar energies than protons, when a large number of protons are detected by the instrument. This features was attributed to energy straggling, causing a delay in the ions' detection with respect to their theoretical TOF. As protons are the most abundant ionic species of the solar wind (SW), this straggler induced noise is nearly always present, and contaminates strongly the rest of the measurements. Using the data acquired by MSA in the SW, we derive a generic statistical fit of the noise induced by the proton stragglers, connecting the proton counts to the noise level. By applying our method to re-analyze some of the data collected by MSA during the Mercury swing-bys (MSB), we demonstrate that : 1) the stragglers play an important role in the determination of the spacecraft outgassing rate and confirm that the outgassing follows an exponential decrease ; 2) the MSB3 data collected in Mercury's magnetosphere are heavily affected by the stragglers' noise. Using our noise subtraction method provides a refined constraint on the heavy ion populations during MSB3 and further strengthens the evidence ions detections from the O+, Na+, K+-groups. With our results, we try to infer the spatial distributions of the planetary ions during different Mercury flybys.

Émissions radio basses fréquences provenant de systèmes stellaires et exoplanétaires

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Grâce au développement d'une nouvelle technique combinant les avantages de l'imagerie et de l'analyse temps-fréquence, bien adaptée à la détection de transitoires polarisés lents, la détection de sursauts radio à basses fréquences provenant des couronnes stellaires, des interactions étoiles-planètes, voire des magnétosphères exoplanétaires arrive désormais à maturité. Des dizaines de détections de sursauts radio polarisés circulairement ont été obtenues avec les radiotélescopes LOFAR et NenuFAR. Leur interprétation se fonde sur la physique de la couronne solaire, la dynamique des magnétosphères planétaires du système solaire, et les théories de génération d'émissions radio. Je présenterai une brève synthèse et quelques exemples des détections obtenues. Appliquée à SKA, cette méthode devrait permettre d'obtenir plusieurs centaines de détections supplémentaires, élargissant aux interactions plasma étoile-planète la physique comparée des exomagnetosphères et la météorologie spatiale associée.

Thème 3 : Couplages entre enveloppes de plasma

Observations of a Fast Shocks and a Newly Identified Slow Shock in the Solar Wind from Solar Orbiter

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The study of heliospheric shocks plays a crucial role in understanding the space environment, space weather, and their effects on planetary magnetospheres. There are two fundamental types of magnetohydrodynamic shocks : fast shocks and slow shocks. Fast shocks are commonly observed and are characterized by an increase in magnetic field strength, accompanied by significant increases in plasma speed, density, and temperature, leading to strong plasma compression. In contrast, slow shocks in the solar wind are rarely observed, and their detection is considered particularly valuable. Slow shocks are identified by a decrease in magnetic field strength and only slight increases in speed, density, and temperature from upstream to downstream. In the Petschek reconnection model, slow shocks are believed to be the primary sites of energy conversion at the boundaries of reconnection outflow jets. Using magnetic field and plasma measurements from Solar Orbiter, we report the observation of both a slow shock and a fast shock in the so- lar wind. These observations provide an opportunity to compare the properties of the two shock types and to improve our understanding of shock dynamics in the heliosphere.

Magnetosphere-Satellite Coupling at Ganymede : Electron Precipitation and Surface UV Reflectance from Juno/UVS Observations

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Ganymede's ultraviolet (UV) aurorae provide a unique window into the coupling between its atmosphere, surface, and Jupiter's magnetosphere. Observed by HST and Juno/UVS, these emissions are dominated by the OI 130.4 and 135.6 nm lines, produced by electron impact on atmospheric species such as H_2O, O_2, and O. However, both the properties of the precipitating electrons and the impact of the magnetospheric precipitation on the surface remain poorly constrained.

In this work, we present a combined analysis of electron precipitation (Benmahi et al. 2025) and surface UV reflectance at Ganymede (Benmahi et al. 2026) using Juno/UVS observations acquired during the PJ34 flyby. We first retrieve the characteristic energy and flux of precipitating electrons by coupling the TransPlanet electron transport model with a non-local thermodynamic equilibrium (non-LTE) radiative transfer model. OI emission profiles are simulated for 17 auroral subregions, testing monoenergetic, Maxwellian, and kappa-type electron distributions. The I(135.6 nm)/I(130.4 nm) line ratio is used as a diagnostic of both electron energy and dominant target species.

Our results show that most auroral regions are best reproduced by monoenergetic electron populations with mean energies ranging from ∼17 to 300 eV and energy fluxes up to ∼2 mW m^{-2}. Broader distributions generally require higher fluxes but lead to poorer spectral agreement, while discrepancies in some regions are attributed to low signal-to-noise ratios or non-ideal electron populations.

We also analyzed the sunlit auroral regions to constrain the spectral reflectance of Ganymede's surface in the 140–205 nm range using the same radiative transfer framework, including reflection of the incident solar flux. The derived reflectance varies strongly with both wavelength and location, spanning ∼0.1% to 8%, revealing pronounced surface heterogeneity. The absence of correlation with visible surface features suggests that UV reflectance is primarily shaped by long-term irradiation processes rather than geological morphology.

Together, these results provide a self-consistent characterization of electron precipitation and surface reflectance at Ganymede, and constitute a critical reference for future UV auroral studies in the context of the JUICE and Europa Clipper missions.

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Plasma leakage through the magnetospheric boundaries of Jupiter and Saturn

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Jupiter and Saturn, the largest planets in our solar system, present complex and rich magnetized environments. Their magnetospheres, which form in the interaction between the solar wind and their intrinsic magnetic field, are characterized by the existence of a plasma disk fed by the production of particles coming from either the volcanic activity of Io or the geysers of Enceladus, and put in rotation by a magnetic interaction with Jupiter or Saturn itself, respectively. The plasma created deep inside the magnetosphere of Jupiter and Saturn is then transported radially, redistributed throughout the whole magnetosphere, before to be lost down tail or at the boundaries of the magnetosphere.

The NASA Juno mission, in orbit around Jupiter since July 2016, provides us with an excellent opportunity to conduct a precise study of the processes leading to the leakage of charged particles from the magnetosphere of Jupiter. Juno, with its JADE and JEDI particle spectrometers, together with its MAG magnetometer and WAVES plasma wave instrument, is ideally suitable for this type of analysis. The NASA/ESA Cassini mission, in orbit around Saturn during 13 years, provided a large datasets of bow shock and magnetopause crossings which have also been largely unexplored to date.

We will present the preliminary results of this study. We will first focus on Jupiter and Juno observations. We will present the catalog of Bow Shock and Magnetopause created, derive and compare statistical maps of ion composition when JUNO is in the solar wind, magnetosheath, magnetosphere.

Modelling the radial penetration of a cross-polar cap electric field in the Jovian magnetosphere, in relation to observed local-time asymmetries

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Many current models of plasma transport in the Jovian magnetodisk/plasmasheet consider it to be azimuthally symmetric over radial distances extending from the outer edge of the Io torus to about 50 Jovian radii. But there are also many pieces of evidence pointing to a local time asymmetry in this system at such radial distances, and in the upper atmosphere to which it is coupled. Many of these observed asymmetries have been interpreted as the result of a large-scale dawn-to-dusk electric field generated across the magnetospheric cavity that would be superimposed to the dominant corotation electric field. But no consistent model of this electric field, of its generation and of its mapping to different magnetospheric radial distances and ionospheric altitudes exists yet. We attempt to fill this gap by developing a simple semi-analytical model of electric fields, plasma convection, and current flows in the Jovian ionosphere and magnetosphere derived from the Earth case, which describes their variations with ionospheric colatitude and magnetospheric radial distance. Comparison to existing estimates of asymmetries and currents support the idea that the dawn-dusk electrostatic potential existing across the polar cap inside the main auroral emissions does penetrate to lower latitudes and down to the Io torus location, and is only partly attenuated by the shielding effect of trapped particles in the magnetodisk.

Caractérisation des perturbations ionosphériques itinérantes induites par les ondes de gravité générées par les orages à l'aide d'un réseau dense de capteurs GNSS

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Les mesures du contenu électronique total (TEC) effectuées au sol à l'aide de récepteurs GNSS (Global Navigation Satellite System) permettent de détecter des phénomènes naturels ou artificiels à travers les perturbations de l'ionosphère, tels que les tremblements de terre, les tsunamis, les explosions de forte puissance ou les lancements de fusées. Ces mesures permettent également de détecter les ondes de gravité générées par des événements météorologiques, tels que les orages (systèmes convectifs). Ces ondes de gravité font l'objet de simulations numériques et peuvent être observées à l'aide de diverses méthodes, dont la mesure du TEC. Des études menées au cours des dix dernières années ont révélé les caractéristiques des ondes de gravité produites par les orages, notamment une amplitude maximale comprise entre 0,1 et 0,6 unité TEC et une période comprise entre 5 et 15 minutes. La taille minimale des orages au-dessus desquels ces ondes peuvent être mesurées a également été déterminée. Ces dernières années, des réseaux denses de récepteurs GNSS et des constellations GNSS (GPS, Galileo, GLONASS et Beidou) se sont développés simultanément. Cela permet de visualiser les perturbations ionosphériques et leur évolution temporelle.
L'objectif de cette étude est de caractériser et de cartographier les ondes de gravité induites par les tempêtes lorsqu'elles se propagent dans l'ionosphère. Pour ce faire, nous analysons les mesures TEC prises par environ 1 200 récepteurs GNSS en Europe occidentale. Parmi les vingt situations météorologiques intéressantes entre 2019 et 2024, présélectionnées à partir des données des radars météorologiques et des rapports de localisation des éclairs, cinq tempêtes ont été étudiées en profondeur. L'analyse de la variation temporelle des signaux et des cartes obtenus pendant ces tempêtes montre qu'il est en effet possible de caractériser la distribution spatiale des ondes de gravité émises par les tempêtes. Ces perturbations peuvent être mesurées sur plusieurs heures, avec des amplitudes comprises entre 0,05 et 0,45 unité TEC, des périodes comprises entre 13 et 40 minutes et des vitesses de propagation comprises entre 120 et 165 m/s. Ces caractéristiques sont conformes aux travaux antérieurs et aux résultats théoriques. Il semble que l'amplitude des ondes augmente avec la réflectivité maximale des mesures des radars météorologiques. Pour trois des cinq tempêtes, l'évolution temporelle des ondes a pu être clairement cartographiée, ce qui a permis de mesurer une longueur d'onde d'environ 200 à 300 km et un diagramme de rayonnement non isotrope en fonction des directions de propagation, comme le prédisaient les modèles. L'émission semble provenir des zones les plus convectives.

Large-scale dynamics of an active region from high-resolution spectroscopic observations at THEMIS

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We performed spectroscopic scans of the active region NOAA13380 on July 29, 2023 at Themis in the non-magnetic FeI line at 709 nm.
As the line profile is not affected by the presence of magnetic field this line is very well suited to study the dynamics of the active region.
Taking advantage of the efficient Themis AO system we use images from successive scans at several line-cords, formed at various depths,

to explore the rotational profile and large-scale motions in the sunspot, the penombra and the granular region around the spot.

We find no rotational radial shear inside the sunspot nor in the granular region surrounding it, in contrast to the rotational shear observed

in the quiet photosphere. We are able to measure the difference of the rotational velocities of the spot and of the granular region, we find

a difference of 70 m/s, on the order of previous measurements using different methods.

We also find the evidence of a large-scale motion of the granular region in the direction of the spot with a speed on the order of 200 m/s.
Inside the spot we detect a differential motion towards the south that speed-up at altitudes between 40 km and 120 km.
We intend to apply this new analysis to a larger set of active regions in order to investigate the impact of such large-scale motions on their evolution.

Observation of thermal non-equilibrium cycles in a solar pseudo-streamer

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Thermal non-equilibrium (TNE) is a well known thermodynamic mechanism in solar coronal loops. These evaporation and condensation cycles are induced by a quasi-steady stratified heating. Long-period EUV pulsations and coronal rain are two manifestations of TNE. The quasi-periodicity of the cycles is a strong characteristic of TNE as the system dynamically evolves around an thermal equilibrium position that is not reachable.

There are recent reports of coronal rain at open-closed boundaries such a fan-spine topologies and pseudo-streamers. However, no definite conclusions were drawn on the physical mechanisms driving the coronal rain events.
In our study, we report the detection of long-period EUV pulsations and co-spatial periodic coronal rain showers in a pseudo-streamer observed with SDO/AIA. The magnetic topology and evolution of the pseudo-streamer are studied into details, using a combination of PFSS modeling and EUV dynamics. The event that last for 2.5 days shows all the characteristics of previous TNE events reported in coronal loops : periodic EUV pulses appearing sequentially in the different channels and according to their peak temperature response order, and coronal rain showers by the end of the cooling phases.

We further show that these TNE cycles occur not only in the closed field but also in the open field. Our observations support the findings of recent numerical works showing that TNE can also occur in open field and at open-closed boundaries. In parallel, interchange reconnection occurs continuously and non impulsively all along the open-closed boundary as seen in EUV. The interplay between TNE and interchange reconnection may play a role in the release of condensations below the open-closed boundary and should be studied into details in future works.

Our work opens further perspectives for the understanding of TNE in the solar atmosphere and its potential implication for the solar wind. Indeed, TNE could also inject mass and energy into the solar wind by its interplay with interchange reconnection. This is the topic of the CROSSWIND project funded by the ANR.

Coronal flux-rope formation through flux cancellation of a sheared arcade in a 3D convectively-driven MHD simulation

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Coronal flux ropes are generally believed to be one of the prime candidates for the magnetic configuration of solar prominences and of coronal mass ejection (CME) progenitors. Observations suggest that flux-rope formation should be ensured by series of flux cancellations that typically occur at the the Sun's surface, along the polarity inversion-line, below pre-existing sheared coronal loops. This has been the origin of the so-called flux-cancellation model. This model has first been proposed in the late eighties, and since then it has been implemented in many independent line-tied coronal MHD simulations of flux-rope formation and CME initiation, ours included. One major issue, however, is that the real Sun has no line-tied boundary. The fact that real-life flux cancellation does not work like in these simulations have raised questions about the validity of this scenario in particular, and even about the very existence of pre-eruptive flux-ropes in general. Given the CME onset-threshold which is now widely accepted for pre-eruptive flux ropes in the framework of the torus instability, this controversy becomes sensitive in terms of space-weather research. In order to address this issue, we used the BIFROST code to model the 3D coupling between the upper convection-zone and the above corona to model this scenario from first-principles. Through a careful setup, we find that the self-consistent stochastic plasma flows of the convection zone drive multiple small-scale flux cancellations and photospheric magnetic reconnection. And for the first time, we show and we interpret how these reconnections convert an initially linear force-free sheared coronal-arcade into a finite-size non-linear force-free flux rope. On one hand, we reveal that the flux-rope formation process is more complex than in the idealized simulations. Indeed, reconnection can happen at various altitudes, sometimes in the 3D slipping mode. Also there are some instances where cancellations are unrelated to reconnection. On the other hand, however, we confirm that the flux cancellation model works : it does form a flux rope.

BepiColombo reveals a layered and active plasma sheet with bouncing-ion echoes at Mercury

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On 8 January 2025, during its sixth and final Mercury gravity assist, the BepiColombo spacecraft executed a polar swing-by with a low-altitude, high-latitude traversal of Mercury's magnetosphere, crossing the northern cusp at altitudes as low as ∼295 km. This trajectory enabled the in situ investigation of the planet's inner plasma sheet and cusp region. Despite operational constraints during cruise, measurements were obtained from the onboard magnetometer (MPO-MAG) and plasma particle instruments (MPPE-MSA and MIA), allowing novel insights into Mercury's dynamic plasma environment.
We report the first observations of persistent cold heavy planetary ions, mainly He+ and Na^+/Mg^+, and potential K^+/Ca^+ with energies extending down to ∼10 eV/e, coexisting with signatures of energetic H^+ ions (>1 keV/e). Notably, we identify energy-dispersed ion fluxes and echo-like signatures suggestive of bouncing ion populations, as well as sporadic injections of H^+ and heavier ions (He^+) toward the polar latitudes. In parallel, Alfvénic perturbations and compressional wave activity were detected near and within the plasma sheet, respectively, indicating active wave–particle coupling potentially driven by sunward flow bursts. These results highlight ongoing dynamic processes and a reconfiguration of Mercury's magnetosphere, possibly substorm-like activity, shaping Mercury's plasma environment.

Understanding Jupiter's polar Atmosphere & the Fate of the AeRosols (JAFAR)

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Jupiter's polar stratosphere exhibits unique chemical and dynamical processes that shape its atmospheric composition and structure. Hydrocarbon observations from multiple instruments (e.g., Voyager/IRIS, Cassini/CIRS, IRTF/TEXES, Juno/UVS, and JWST/MIRI) reveal abundance enhancements and strong latitudinal variations of C2 hydrocarbon species within the auroral regions. These enhancements are attributed to the influence of auroral energy deposition and possibly enhanced vertical mixing. IRTF/TEXES and JWST/MIRI observations also provide new constraints on the vertical structure of the polar atmosphere, suggesting that the methane homopause is located at higher altitudes in auroral regions than at lower latitudes. In addition, some observations indicate that Jupiter's previously known aerosol layer is situated at higher altitudes in the polar regions (above about 20 mbar) compared to lower latitudes (around about 50 mbar). Magnetosphere–ionosphere–thermosphere coupling in Jupiter's polar regions generates ionospheric winds with velocities of several km/s, which may propagate downward to the 0.1 mbar level, where neutral winds appear to be co-located with those measured at higher altitudes. Jupiter's polar atmosphere thus constitutes a highly complex system in which magnetospheric forcing is strongly coupled with chemistry and dynamics from the ionosphere down to the tropopause. Understanding the distribution of hydrocarbons at high latitudes, and the extent to which they control the atmospheric radiative balance, is crucial for constraining upper- atmospheric dynamics. In this contribution, we provide a general overview of the physical and chemical processes governing Jupiter's polar regions and present preliminary results from the JAFAR project, designed to investigate Jupiter's polar atmosphere and the fate of aerosols, in preparation for the JUICE arrival in 2031.

Modeling plasma-magnetic field coupling : from ionosphere phenomena to laser experiments

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The interaction between solar wind and ionosphere can generate geomagnetic storms and a depletion of the local geomagnetic field, where plasma blobs move along field lines [1]. This phenomenon was also observed during the AMPTE experiments in 1984, during which barium was released to study artificial comets [2]. In this presentation, we are interested in the expansion of a plasma embedded within a prescribed magnetic field. This dynamics creates areas of compressed plasma with a strong magnetic field downstream, and a magnetic depletion upstream, called a diamagnetic cavity. Recently, laboratory experiments and numerical simulations of this mechanism have been performed, with a focus on kinetic or hybrid approaches at a high computational cost [3]. Here, we use a complementary formalism, ideal magnetohydrodynamics (MHD), through a code solving the Euler–Maxwell equations [4].

We start with the numerical modeling of a laser experiment conducted at LAPD [3]. We obtain a similar cavity radius as in the experimental case, with a good agreement on the theoretical radii deduced from an energy balance equation. We find evidence of a coupling between the magnetic field and the plasma, with a transfer from kinetic energy to magnetic energy.

Building on these results, we develop a parametric study by varying the injected kinetic energy and a background conditions, matching two other LAPD experiments. The cavity radius increases with energy following the theoretical prediction, and decreases with higher ambient plasma densities. These conclusions are in agreement with other experiments and hybrid simulations, and give valuable insights to understand experimental measurements subject to density inhomogeneities.

This study shows that the MHD approach is relevant and efficient to estimate the maximal cavity radius for multiple sets of parameters. We further discuss current investigations of the effects of other initial parameters, as well as the impact of the coupling between ambient and debris plasma on magnetic compression intensity and speed. The wide range of parameters allowed by the fluid approach is valuable to better understand the energy transfer processes at stake, as these phenomena are relevant among a variety of regimes, encountered from the Earth's magnetotail to the solar wind-magnetosphere interactions.

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Hybrid modeling of Callisto's environment interaction with the Jovian magnetosphere

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Callisto is the furthest of the four Galilean moons, orbiting at a distance of around 26.3 Jovian radii from Jupiter. Composed of equal parts rock and ice, the moon has a tenuous atmosphere dominated by O2 and CO2 [Carlson, 1999 ; Cunningham et al., 2015], as well as an ionosphere characterized by densities of up to 10^4 cm^{-3} [Kliore et al., 2002]. The moon's environment interacts with the Jovian magnetosphere (surface weathering, Alfvén wings, etc.), whose physical characteristics vary greatly during its orbit, with a wide excursion in magnetic latitude. Due to a time-varying magnetic environment, electromagnetic induction occurs at Callisto in its ionosphere, but also in a potential subsurface liquid ocean, as it was observed by NASA's Galileo mission during flybys of the moon [Zimmer et al., 2000 ; Cochrane et al., 2025]. While the JUICE and Europa Clipper missions plan to carry out several flybys of Callisto, the interaction between the moon and Jupiter's magnetosphere remains poorly understood. Simulations describing the neutral and ionized environments of the Jovian satellite must therefore be set up. These simulations will use the LatHyS hybrid multi-species parallel 3D model [Modolo et al., 2016, 2018] already used to describe the environment of Ganymede in particular. The Larmor radii of freshly generated pick-up ions of ${O_2}^+$ and CO_2^+ being larger than the moon radius, a kinetic approach for the ion dynamic is more appropriate than a fluid model and enables the capture of asymmetries in Callisto's plasma interaction. Due to its rather dense ionosphere, a self-consistent resistivity model has been developed for the simulations. In addition to this, different neutral atmosphere inputs are used : a spherically symmetric model as well as adapted outputs from an EGM exospheric simulation of Callisto. Simulations incorporating these new features will be presented for various magnetospheric positions of the moon.

Effects of Foreshock Electron Impact Ionization on the Amplitude of Pick-up Proton Driven Waves at Mars : Implications for Exosphere Density Estimates

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Electromagnetic waves at the local proton cyclotron frequency are frequently observed upstream from the Martian bow shock. They are excited by unstable velocity distributions of newborn protons continuously produced locally by ionization of exospheric hydrogen atoms (pickup protons). The analysis of MAVEN magnetic field data demonstrates for the first time that the amplitude of these waves undergoes a sharp gradient when crossing the electron foreshock boundary. Moreover, a decrease of the amplitude with the increasing distance from the shock along the ambient magnetic field is observed inside the foreshock. Both signatures are correlated with the variations of the energetic electron fluxes. These two properties connecting the wave growth to electron physics raise an issue since the waves are excited purely through an ion-ion instability. We propose that the extra free energy necessary to increase the wave amplitude be due to additional ionization of hydrogen atoms by electron impact ionization inside the foreshock. These results imply that extreme caution is needed when directly deriving the exospheric densities at Mars and other similar environments from the local pickup ion wave amplitude, especially in the foreshock region.

Normalized Reconnection Rate and X-Line Location at the Magnetopause

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Magnetic reconnection at the magnetopause governs the coupling between the solar wind and the Earth's magnetosphere, yet two of its most fundamental aspects remain poorly understood : the normalized reconnection rate and the spatial location of the reconnection line. Addressing the first, we introduce a new statistical method based on more than one million in-situ subsolar magnetopause measurements to estimate the normal magnetic field and plasma inflow velocity as a function of the interplanetary magnetic field (IMF) clock angle. Both quantities increase with clock angle, consistent with ongoing reconnection, and their ratios to tangential components — corresponding to the normalized reconnection rate - converge to a remarkably stable value of 0.14 ± 0.05 for clock angles exceeding $60°$, indicating that the reconnection rate is independent of the guide field at the magnetopause. Addressing the second challenge, we present a new X-line model that identifies the dominant reconnection line by maximizing the reconnection rate on both a local and a global scale. Validated against four global MHD simulations spanning diverse dipole tilts and IMF orientations, the new model consistently performs better than both the maximum magnetic shear and global rate maximization approaches in predicting the magnetic separator location.

Magnetic-topology dependence of sulfur fractionation in the solar corona : a Solar Orbiter/SPICE survey

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Elemental composition provides a key diagnostic of plasma conditions and magnetic topology in the solar chromosphere and corona, and a tracer of solar-wind source regions through its transport from the corona into the heliosphere. Elemental composition variations in the solar atmosphere are commonly described by the First Ionization Potential (FIP) effect, which refers to the overabundance of elements with FIP below ∼10 eV (low-FIP elements) in the corona compared to their photospheric abundances. However, intermediate-FIP (mid-FIP) species such as sulfur (10.36 eV) are predicted to show distinct fractionation behaviour and may therefore provide additional constraints on where and how fractionation operates. We present a large-scale survey of Solar Orbiter/SPICE EUV spectroscopy designed to characterise sulfur fractionation across a broad range of solar magnetic structures, including coronal holes, plume and interplume regions, extended fan or open-like structures, and active regions and their boundaries.

Using a consistent analysis methodology applied to an extended three-year SPICE archive of composition observations across multiple targets, we derive sulfur-based composition diagnostics with uncertainty propagation and quantify their variability across structures. The resulting maps are interpreted in the context of magnetic topology using photospheric magnetograms and magnetic-field extrapolations, allowing us to relate sulfur fractionation patterns to different magnetic configurations.

The survey indicates that sulfur fractionation does not follow the typical low-FIP behaviour. Sulfur enrichment preferentially appears in open or open-like magnetic configurations, whereas compact closed-loop environments remain closer to photospheric sulfur abundances, in contrast to the low-FIP enrichment commonly observed in such loops. These trends support scenarios in which the depth and efficiency of fractionation depend on magnetic topology and on wave and reconnection conditions that control Alfvénic energy deposition in the chromosphere. The results establish sulfur as a practical mid-FIP constraint for fractionation physics and motivate combining low- and mid-FIP diagnostics to improve solar-wind source identification and connectivity studies.

Studying the impact of the active region dynamics on the solar wind variability

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Active regions on the Sun are known as being the birthplace of powerful energetic events like flares and coronal mass ejections (CMEs). However, active regions are also suspected to influence quasi systematically the solar wind, a continuous stream of charged particles originating from the solar atmosphere. Solar wind properties are fundamental in space weather predictions at Earth, and yet have a high variability that remains to be explained. The slow and dense solar wind is the most variable of all, and is suspected to take its sources nearby active regions. Interchange reconnection, between close and open magnetic field, occupies a central place in that problem because it provides a free way for the plasma and energy initially confined into closed active region loops to be released into the solar wind. The main triggering mechanism is believed to come from magneto-convection at the solar surface essentially, which forces a perpetual reconfiguration of the magnetic topology at larger scale. Another cause could be a change in the local plasma properties such as the plasma beta parameter, as during non-thermal equilibrium (TNE) cycles for instance. TNE cycles arise from an imbalance between plasma heating and radiative cooling in the corona, and exhibit hourly-long periods that could match with some of the periodicities that have been detected farther up in the slow solar wind. To answer this problem we must then have a global approach going from the lower solar atmosphere up to the corona and heliosphere, that necessitates the use of multi-instrument observations (from both space and the ground) combined with state-of-the-art numerical modelling. In this contribution, I will bring together some of the first pieces to this puzzle, by emphasising on preliminary works conducted within the CROSSWIND ANR project and by presenting future perspectives.

Des électrons froids à Mercure

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La mission BepiColombo de l'Agence spatiale européenne et de la Japan Aerospace Exploration Agency, menée conjointement, est la troisième sonde spatiale en route vers Mercure. Avant son insertion en orbite prévue en novembre 2026, la sonde a déjà réalisé six survols de la planète. L'Institut de Recherche en Astrophysique et Planétologie contribue à la mission grâce à deux capteurs d'électrons de basse énergie : les analyseurs d'électrons de Mercure (MEA). Les quatrième et sixième survols ont fourni les premières occasions d'explorer la région de la calotte polaire nord, du moins du point de vue des électrons de basse énergie. Grâce à l'analyse des données et à des simulations numériques, nous confirmons la détection de populations d'électrons très denses et froides. Cette observation, bien que simple, pourrait faire progresser de manière significative notre compréhension de l'interaction entre la magnétosphère de Mercure et son exosphère.

In-situ Switchback Variability as a Proxy for Source Region Variation

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Magnetic switchbacks are localised Alfvénic deflections of the heliospheric magnetic field away from its background orientation. Various mechanisms have been proposed to explain their formation, with interchange reconnection in the solar corona frequently invoked in the literature. Previous studies indicate that switchbacks potentially retain signatures of their source region, which persist in the solar wind out to Parker Solar Probe (PSP) distances. Their in-situ properties may therefore be used as a proxy to probe the source region properties and formation mechanisms.

We present our investigation on how variability in switchback properties and the associated solar wind links back to variability at the solar source. To address this, we use a combination of remote-sensing and in-situ data from several sources to conduct two studies on this topic. In our first study, we examine the long-term variability of switchback deflection angles as the global coronal magnetic field evolves over the ascending phase of the solar cycle from 2019-2024. In our second study, we characterise the changes in the in-situ switchback properties over a week-long interval during PSP Encounter 13, as the spacecraft connectivity transitions from a coronal hole to an active region and back. Finally, we report an example of a switchback observed during Encounter 13 with an unusual bi-directional strahl signature, representing a departure from the standard properties of an archetypical switchback.

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

Energy conversion and firehose instability during non-linear phase of tearing-driven reconnection : Hybrid simulation using Mobius boundary conditions

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Magnetic reconnection is a ubiquituous process in astrophysical plasmas, being at the origin of many eruptive phenomena, and typically inducing an important localized transfer of magnetic energy toward the acceleration of particles. The tearing instability can trigger several reconnection events along a same elongated current sheet, bringing even more complexity to the process.

Here, we study the tearing instability in a 2.5D hybrid-PIC simulation using the Hybride code, and with boundary conditions similar to the topology of a Mobius strip. We show that the energy conversion predominantly takes place during the non-linear stage of the instability, by evaluating the ion electric work rate and pressure-strain interaction terms. We show that at the X-points, the magnetic energy gets converted in similar amounts to heating and plasma jetting, and that overall, there is more heating within the magnetic islands than around the X-points. Moreover, the reconnection outflows present an important ion temperature anisotropy with T||>Tperp, which is sustained by the contraction of the magnetic islands. The firehose instability then eventually regulates the temperature anisotropy within the islands and participates to the energy conversion.

J-Filtering : Unveiling Current Structures in Space Plasmas with Multipoint Data Analysis

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We present J-Filtering, a newly developped multi spacecraft analysis technique for measuring and visualizing local current distributions in space plasmas, designed to overcome the limitations of the traditional Curlometer method. The Curlometer, which uses four-spacecraft magnetic field measurements to estimate current density via the Maxwell-Ampère law, assumes a linear spatial variation of the magnetic field—a condition rarely met in dynamic space plasmas. J-Filtering adapts the optimal filter determination principle from the K-filtering method, defining filters to identify the current structures responsible for the magnetic fields measured by the spacecraft. This approach enables the estimation of current density without relying on the restrictive assumption of magnetic field linearity, and can therefore allow the detection of currents at scales both larger and smaller than the spacecraft configuration. We first detail the principles of J-Filtering and present how we validated the method by comparing the obtained results with those of the Curlometer for a crossing of the magnetopause by CLUSTER, i.e. when the linear approximation should hold. Next, we present the use of simulated currents and spacecraft configurations to assess the performance of J-Filtering in scenarios involving small-scale structures and imperfect tetrahedral shapes. We found that the technique is less sensitive than Curlometer to geometry, and that it can indeed accurately retrieve small scale currents. These results paves the way for applying J-Filtering to data of present mission, like the Magnetospheric Multiscale (MMS) mission, and in preparation of future multi points mission like HelioSwarm and Plasma Observatory.

Magnetic flux sheets and bubbles : Investigating extended granular-sized magnetic flux emergence in the quiet Sun

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Magnetic flux emergence is a pervasive process that occurs across the solar atmosphere on several spatial and temporal scales, ranging from large-scale active regions to sub-granular loops. Particularly, small-scale magnetic flux emergence in the quiet Sun is crucial for maintaining solar magnetic activity. At such scales, convective plasma flows driving photospheric granulation are central to turbulent magneto-convection. These flows transport internal magnetic flux upward via an advective-diffusive regime, resulting in non-linear plasma-magnetic field interactions. Within individual granules, two primary mechanisms have been identified : the emergence of sub-granular magnetic loops and the formation of magnetic flux sheets covering the granule. In this contribution, we present an observational study of these granular-sized magnetic flux sheets, inferring their frequency on the solar surface and their contribution to the photospheric magnetic budget. We investigate the plasma dynamics and granular-scale phenomena associated with their emergence, alongside their chromospheric counterparts : magnetic bubbles. Our study used spectropolarimetric datasets from the ground-based Swedish Solar Telescope (SST) and the Solar Optical Telescope (SOT) aboard the Hinode satellite. In addition, we explore data products from the MiHi (Microlensed Hyperspectral Imager) instrument operating in SST and the Sunrise-III balloon-borne mission, which provide the spatial, spectral, and temporal resolution necessary to resolve the fine-scale properties of magnetic flux sheets, as well as their evolution and chromospheric response. Our analysis suggests that the magnetic flux sheet events could be considered part of the larger component of the distribution of small-scale magnetic flux that feeds the solar atmosphere in quiet Sun regions.

Evidence of an extended Alfvén wing system at Enceladus : Cassini's multi-instrument observations

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The Cassini spacecraft has provided clear evidence that Enceladus and Saturn are electrodynamically coupled, through energetic ion measurements by the Magnetospheric Imaging Instrument (Jones et al. 2006 ; Roussos et al. 2007 ; Andriopoulou et al. 2014), thermal electron measurements from the Cassini Plasma Spectrometer (CAPS), and the EUV and FUV emission measurements by the Ultraviolet Imaging Spectrograph (Pryor and Rymer et al., 2011, Pryor et al., 2024), large-scale perturbations to the low-frequency magnetic field from MAG (Dougherty et al. 2006), and high-frequency plasma waves from the Radio and Plasma Wave Science Investigation (RPWS, Gurnett et al., 2011 ; Sulaiman et al., 2018). However, a systematic investigation of the detailed electromagnetic interactions between Enceladus and Saturn with all Cassini measurements has yet to be carried out.

Between 2004 and 2017, the Cassini spacecraft sampled the magnetic field lines connected to Enceladus' orbit, offering a unique opportunity to investigate this coupling in detail. In this study, we explore the interaction region(s) between Saturn and Enceladus using comprehensive data from MAG, RPWS and electron instruments CAPS/ELS and MIMI/LEMMS. We report on 15 case studies that reveal enhanced Alfvénic activity linked to Enceladus, including the main Alfvén wing (MAW) and reflected Alfvén waves (RAW) in the moon's tail. These observations not only shed new light on the spatial extent of the electrodynamic coupling between Saturn and its icy moon, but also show for the first time that the tail of Enceladus extends and persists up to about 100 Enceladus radii downstream of the moon illustrating the extensibility of the coupling processes with the gas giant Saturn [Hadid et al., JGR, 2026].

Radiation efficiency of electromagnetic wave modes from beam-generated solar radio sources

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During type III solar radio bursts, electromagnetic waves are radiated at the plasma frequency and its harmonics by electrostatic wave turbulence generated by electron beams ejected from the Sun in randomly inhomogeneous solar wind and coronal plasmas. These emissions, detected for decades by spacecraft and radiotelescopes, are split by the plasma magnetic field into three modes, X, O and Z, with different dispersion, polarization and radiation properties. Here, using three independent and converging approaches—particle-in-cell simulations, a theoretical model of waves in a random medium and analytical calculations in the framework of turbulence theory—we demonstrate that only a small fraction of electromagnetic energy radiated at the plasma frequency escapes from beam-generated radio sources, mainly as O-mode waves and, depending on plasma conditions, as X-mode waves. Most energy is radiated in the Z-mode and can therefore be observed only close to sources. The results provide strong support for interpretation of observations performed up to close distances from the Sun by spacecraft such as Parker Solar Probe and Solar Orbiter. This work, based on general approaches requiring few assumptions, makes it possible to study the properties of radio emission under realistic solar conditions, and thereby provides a solid basis for the development of theoretical tools for probing space and time variations of beam–plasma systems in the solar wind.

Martian Atmospheric Ion Energization And Escape During The 2022 Disappearing Solar Wind Event : A Hybrid Simulation Study

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Mars has experienced substantial atmospheric loss, largely attributed to the absence of a global intrinsic magnetic field. Without such shielding, the solar wind can interact directly with the upper atmosphere, driving ion escape processes that progressively deplete the atmosphere. This long-term erosion has reduced the planet's capacity to maintain a stable climate and is thought to have contributed to the disappearance of liquid water from its surface.

Extreme solar wind events—such as Coronal Mass Ejections (CMEs), Corotating Interaction Regions (CIRs), and radially oriented Interplanetary Magnetic Field (radial IMF)—can significantly modify the plasma environment around Mars and enhance the energization and escape of atmospheric ions. Because these extreme conditions were likely more frequent and intense in the early Solar System, studying such events provides insight into the historical evolution of the Martian atmosphere.

In this work, we investigate the response of atmospheric ions during extreme solar wind conditions, focusing on the 2022 "Disappearing Solar Wind" (DSW) event associated with a CIR, during which the solar wind density decreased by more than an order of magnitude. Simulations are performed using the latest Latmos Hybrid Simulation (LatHyS) model, in which ions are treated as macro-particles obeying Newtonian dynamics while electrons are modeled as an inertialess fluid. We analyze how variations in solar wind density—from nominal conditions ($n_{SW} = 3.0$ cm^{-3}) to the DSW regime ($n_{SW} = 0.1$ cm^{-3})—affect the energization and transport of O^+ ions. Particular attention is given to escape rates through the magnetotail and plume structures, as well as to inward precipitation and the associated energy deposition into the ionosphere.

The atypical plasma environment created during the DSW event offers a rare opportunity to examine Mars–solar wind coupling under extremely low-density conditions. Combined with the hybrid modeling capabilities of LatHyS, this event provides a useful natural experiment for probing ion energization mechanisms and for constraining scenarios of atmospheric escape that may have been common during the early evolution of Mars.

The Life Cycle of Electron Phase-Space Vortices and Their Control of Magnetic Reconnection

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Electron phase space vortices (EPSVs) are nonlinear electrostatic structures formed by trapped electron populations that frequently emerge in collisionless plasmas. We investigate the dynamics of EPSVs and their feedback on magnetic reconnection using 2.5D electromagnetic particle-in-cell simulations initialized with asymmetric dayside magnetopause conditions. We identify a recurring life cycle for EPSVs situated near the reconnection X-point, characterized by growth, secondary nucleation, and decay. We show that the nucleation of secondary vortices is not always stochastic but can be driven by a systematic mechanism, which evacuates the phase space to form bimodal distributions that are unstable to electrostatic instabilities. Furthermore, we demonstrate a bidirectional coupling where EPSVs significantly modify the reconnection dynamics. The interaction of EPSVs with the electron diffusion region, which has remained uncharacterised so far, results in a periodic modulation of the reconnection rate of approximately 25%, driven by the passage the temperature anisotropies associated with EPSVs. The interaction concludes with the destruction of EPSVs via phase mixing at the X-point, contributing to bulk electron heating in the outflow.

Evidence of Langmuir/Z-mode Wave Decay into Z-mode Electromagnetic Radiation in the Solar Wind

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The nonlinear decay of Langmuir/Z-mode waves into electromagnetic Z-mode wave radiation near the plasma frequency is studied in the framework of Particle-In-Cell simulations. Guided by the numerical study, a Langmuir wave snapshot recorded during the encounter of the Solar Orbiter satellite with an electron beam associated with a Type III radio burst is found to exhibit the generation of Z-mode waves through this process. The decay process is identified through multiple lines of evidence : satisfaction of frequency and wavevector resonance conditions, strong phase coherence and temporal coincidence between the interacting waves, exclusion of competing mechanisms, and full agreement with theoretical predictions. Two-dimensional Particle-in-cell simulations, conducted under close beam-plasma conditions, successfully reproduce the key features of the observations. Notably, they suggest that the wave packet observed by Solar Orbiter may be trapped within an extended, nearly flat-bottomed density well, where the decay process is not overcome by wave scattering on random density fluctuations and subsequent mode conversion effects.

Magnetic reconnection and the scale-variability of alfvénicity in the solar wind

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Magnetic reconnection is ubiquitous in the solar wind. This phenomenon converts magnetic energy into kinetic and thermal energies. As expected from the nature of the reconnection exhaust boundaries (opposite Walén relations), we show that both Elsässer modes (Elsässer, 1950) are typically observed when reconnection is detected in the solar wind. However, the exact and quantitative relation between solar wind alfvénicity and reconnection has not been yet explored extensively, and the interplay with turbulence remains an open question.

Fargette et al. (2023) have recently designed a reconnection detection algorithm, based on various known reconnection signatures. We extend the use of this algorithm on a larger Solar Orbiter dataset such as to augment the exhaust database. We further investigate the alfvénicity and compressibility time scale-dependency by using averaging windows between 1 and 100 minutes (where analyses in the literature commonly use 1h). We always find opposite alfvénicity signatures at the boundaries of the reconnection exhaust, corresponding to the Walén relation. Magnetic compressive structures stand out in the analysis, consistent with magnetic energy decreases at reconnection exhaust boundaries. Small-scale changes in alfvénicity (averaging window $< \sim$10min) are thus frequently explained by the occurrence of reconnection, but we also observe many alfvénicity reversals that are unrelated to reconnection. Their origin and properties will be discussed.

3D numerical reconstruction of a quiescent filament showing counter-streaming velocities in IRIS and THEMIS spectra

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We present a multi-instrument study of a quiescent filament observed on 2023 September 28–29, utilizing high-resolution spectral data from THEMIS (H alpha) and IRIS (Mg II k), alongside magnetic field data from Hinode/SOT and SDO/HMI. Spectral analysis reveals ubiquitous counter-streaming flows characterized by alternating blue and red Doppler-shifted strands. These flows, which reach supersonic velocities (20 km/s), are interpreted as kink transverse oscillations of independent magnetic threads rather than field-aligned motions. Photospheric magnetic field observations indicate that parasitic polarities and flux cancellation drive the reorganization of filament feet and longitudinal extension.

A 3D MHD reconstruction confirms the evolution of the magnetic topology into a full flux rope (FR), with quasi-separatrix layers and current sheets becoming increasingly organized as the FR grows. Longitudinal oscillations in the extended filament are attributed to heating from flux cancellation in underlying bright points. Our results suggest that filament dynamics are governed by a combination of transverse wave modes and the continuous reconfiguration of the coronal magnetic field into a flux rope topology.

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

Modélisation de l'accélération des électrons ultra-relativistes dans les ceintures de radiation terrestres

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Durant certains orages géomagnétiques, les ceintures de radiation terrestres sont capables d'accélérer les électrons piégés jusqu'à des énergies ultra-relativistes pouvant atteindre 5 à 7 MeV, ce qui pose un sérieux risque pour les satellites en orbite autour de la Terre. Ces dernières années, la communauté scientifique a cherché à mieux comprendre les mécanismes qui pilotent cette accélération, pour pouvoir mieux modéliser et prédire l'apparition de cette population à très haute énergie. Il semble clair aujourd'hui que cette accélération est le fruit d'une action combinée entre la diffusion radiale et les interactions locales avec différents types d'ondes de la magnétosphère, et en particulier hors de la plasmasphère. La modélisation précise des électrons énergétiques dans les ceintures nécessite donc une prise en compte fine de la dynamique de la plasmasphère et du plasmatrough, et des différents types d'ondes dans la magnétosphère.

Nous présentons ici des résultats récents obtenus à l'aide du modèle Salammbô, suite à des travaux menés dans le cadre des projets MENTHE (ANR/AID) et FARBES (Horizon Europe). Nous introduisons un nouveau modèle empirique de la dynamique de la densité du plasmatrough, ainsi qu'un nouveau modèle d'intensité des ondes VLF, qui conjointement permettent à Salammbô de reproduire de manière remarquable différents événements d'accélération des électrons ultra-relativistes.

Diagnostic of the suprathermal electrons strahl scattering mechanism with Parker Solar Probe and Solar Orbiter data

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The solar wind shows different electrons populations, namely, the core, a thermalized isotropic component, and the suprathermals, at energies larger than a few kT, which exhibit non-gaussian energy tails. The latter is divided among an isotropic halo and the strahl population which we can describe as an excess of electrons aligned with the magnetic field line direction.

For this study, we aim at characterizing the strahl electrons distributions and their radial evolution in the close neighborhood of the Sun. For this purpose we study their pitch angle width (PAW) and look for correlations between this quantity and other local plasma or magnetic field parameters. Using the data from Parker Solar Probe and Solar Orbiter missions, respectively the Solar Probe ANalyzers (SPAN-electron and SPAN-ion) and the Solar Wind Analyser (SWA) for the electrostatic analysers and the so called magnetometers (respectively FIELDS-MAG and MAG).

We explore the repartition of the SPAW in a parameter space including distance to the Sun, plasma moments (n, T, v, ...) and magnetic fluctuations properties (alfvenicity, intensity of fluctuations, etc.).
First, we show that Coulomb collisions are the main scattering process closer than 35 solar radii, a region where the SPAW decreases with distance to the Sun - this is a first unambiguous and quantitative observation of the effect of coulomb collisions on suprathermals.
Further away from the Sun, we identify two solar wind type of streams : one in which SPAW are very small, and one characterized by large SPAW. The characteristics of magnetic fluctuations and background plasma properties in these two type of streams are identified, and we discuss the possible reasons of the existence of these low and high scattering regimes.

Detection of Jovian kilometric and hectometric auroral radio harmonics with Juno/Waves in situ measurements

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Auroral radio emissions from Earth, Saturn, and Jupiter are now known to all be generated by the cyclotron maser instability near the electron cyclotron fundamental frequency f_ce. This common generation mechanism results in similar wave properties in terms of beaming and polarization. However, while harmonics at 2 × f_ce and 3 × f_ce have been identified in the terrestrial and kronian cases, none of the components of Jupiter's auroral radio spectrum had been associated with harmonics. In this study, we confirm the existence of first harmonic emissions for the Jovian broadband-kilometric (bKOM) and hectometric (HOM) components (200-700 kHz) in 6 cases using in situ data from Juno/Waves observations close to the source. Among these cases, 2 second harmonics were also identified. These harmonics are three orders of magnitude weaker than the associated fundamental and were identified in regions where the f_pe/f_ce(f_pe the electron plasma frequency) ratio is of the order of 10^{-2}. This discovery confirms the universality of the CMI and suggests that harmonics in the decametric range could exist.

Reanalysis of Cassini's Saturn Kilometric Radiation source crossing : Search for loss cone Cyclotron Maser Instability

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Saturn Kilometric Radiation (SKR) are strong non-thermal radio auroral emissions between a few kHz and 1 MHz. They were detected by Voyager in the 1980s, and Cassini analysed their sources in 2008 with its radio, plasma and magnetic measurements. At that time, the generation mechanism was confirmed to be the Cyclotron Maser Instability (CMI), which generates waves close to the local cyclotron frequency, in highly magnetized plasma from mildly relativistic electrons exhibiting a gradient in the direction perpendicular to the magnetic field. The source of free energy for SKR was then identified to be the shell distributions of 6-12 keV themselves generated by parallel currents that is assumed to be upward field aligned currents. Since then, new results from Juno identified shell distributions as a secondary source of free energy at Jupiter. In these Jovian sources, shell distributions were identified in upward fiedl aligned currents regions along with unstable broadened loss cones.

Therefore, in light of these new results, we propose to reanalyze the data from Cassini during SKR source crossings to verify whether similar enlarged loss cone concomitant with shell distributions exist at Saturn and whether they can be a secondary source of free energy at Saturn and to compare these newly identifed loss cone distributions with the Jovian case.

Fluid and Kinetic Properties of the Near-Sun Heliospheric Current Sheet

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The heliospheric current sheet (HCS) is an important large-scale structure of the heliosphere, and, for the first time, the Parker Solar Probe (PSP) mission enables us to study its properties statistically, close to the Sun. We visually identify the 39 HCS crossings measured by PSP below 50 $R_\odot$ during encounters 6-21, and investigate the occurrence and properties of magnetic reconnection, the behavior of the spectral properties of the turbulent energy cascade, and the occurrence of kinetic instabilities at the HCS. We find that 82% of the HCS crossings present signatures of reconnection jets, showing that the HCS is continuously reconnecting close to the Sun. The proportion of inward and outward jets depends on heliocentric distance, and the main HCS reconnection X-line has a higher probability of being located close to the Alfvén surface. We also observe a radial asymmetry in jet acceleration, where inward jets do not reach the local Alfvén speed, contrary to outward jets. We find that turbulence levels are enhanced in the ion kinetic range, consistent with the triggering of an inverse cascade by magnetic reconnection. Finally, we highlight the ubiquity of magnetic hole trains in the high-β environment of the HCS, showing that the mirror mode instability plays a key role in regulating the ion temperature anisotropy in HCS reconnection. Our findings shed new light on the properties of magnetic reconnection in the high-β plasma environment of the HCS, its interplay with the turbulent cascade, and the role of the mirror mode instability.

Fine Structures of Type III Radio Bursts

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Solar eruptions, such as flares or coronal mass ejections, cause energetic electrons to travel out along magnetic field lines into the corona and solar wind. Here they interact with the ambient plasma and cause the growth of Langmuir waves. By non-linear processes, that are not yet fully understood, the electrostatic Langmuir waves are converted into an electromagnetic wave and ion acoustic wave, where the former can be observed as Type III radio bursts [1]. The occurrence of the so called slow extraordinary mode has as of recently had reports of unambiguous measurements of the magnetic component [2] using observations in the inner heliosphere by the Parker Solar Probe (PSP) Mission. This project aims to use PSP and Solar Orbiter (SO) measurements to look for similar events whereby the presence of a magnetic component is clear. These measurements will be analysed alongside electron beam data in an attempt to better understand the properties of beam-plasma interactions.

[1] H. A. S. Reid, H. Ratcliffe, Res. Astron. Astrophys. 14, 773, (2014).
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Interchange Reconnection and ion kinetic instabilities in coronal plasma

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The magnetic field in the chromosphere and low corona near the boundaries of equatorial coronal holes in the quiet Sun is thought to reconfigure through interchange reconnection (IR). This process occurs in low-beta plasma with a strong guiding field and may produce an ion distributions known as "hammerhead." These distributions have been observed in coronal plasma associated with current sheets and in regions whose foot points lie near equatorial coronal holes. They usually consist of a core plus a perpendicularly diffuse beam feature at a specific velocity relative to the core. The mechanism we propose involves the interpenetration of two plasmas with different properties—one on closed field lines and one on open field lines. In the chromosphere and low corona, these distributions can generate ion-sound and ion-cyclotron waves once the beam's relative velocity exceeds a threshold. As such plasma distributions travel toward the solar wind through a funnel region where the magnetic field and plasma density rapidly drop, they may become unstable and produce Alfvén-type magnetic perturbations that can evolve nonlinearly into switchback structures. These threshold conditions are likely met near the transition from sub-Alfvénic to super-Alfvénic wind.

Characterizing variabilities of Callisto's magnetospheric orbital environment with the Galileo and Juno missions

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Callisto, the outermost Galilean moon, orbits within Jupiter's dynamic magnetosphere, traversing highly variable plasma and magnetic conditions. Despite its interest, Callisto remains the least understood Galilean satellite, with no dedicated flybys since the Galileo mission ended in 2001. To bridge this knowledge gap and accurately characterize the moon's interaction with Jupiter, this study focuses on describing the pristine electron [Le Liboux et al., 2025] and heavy ion [Le Liboux et al., submitted] environment and its variability by combining measurements taken by two particle detectors onboard Juno (JADE, JEDI) and one onboard Galileo (EPD). Juno's JADE and JEDI observations showcase a high electron and heavy ion intensity variability depending on magnetic position, varying by a factor of 4 to 60. Based on these observations, we provide empirical models of the energy spectra of electron and heavy ion intensity at various magnetic positions, along with electron density, and pressure. Galileo's EPD observations reveal a modulation of intensity variability according to local time, with increased variability on the dawnside. These results establish critical inputs for modeling and experimentation in preparation for the upcoming JUICE and Europa Clipper missions in the 2030s.

A new rotation period and longitude system for Uranus at the basis of a long-term analysis of magnetospheric dynamics

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The rotation period of Uranus was estimated to be 17.24 ± 0.01 h in 1986 from radio auroral measurements during the brief Voyager 2 flyby. This value is the basis for the Uranian SIII longitude system still in use. However, the poor period uncertainty limited its validity to a few years, after which the orientation of the magnetic axis was lost. Alternate, conflicting, rotation periods have also been proposed since then. Here we use the long-term tracking of Uranus' magnetic poles between 2011 and 2022 from Hubble Space Telescope images of its ultraviolet aurorae to achieve an updated, independent, extremely precise rotation period of 17.247864 ± 0.000010 h, only consistent with the Voyager 2 estimate. Its 28-s-longer value and improved accuracy yields a new longitude model now valid over decades, up to the arrival of any future Uranus mission, which will allow the reanalysis of the whole set of Uranus observations. In particular, average cylindrical projections reveal that Uranus acceleration mechanism apply to the same, limited, range of longitudes whatever the Uranus geometric configuration with respect to the solar wind, revealing an important invariant of the Uranian magnetosphere.

Study of thermal non-equilibrium in a 3D hydrodynamic simulation of an active region and comparision with EUV observables

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One of the fundamentals questions in solar physics is, how the Sun's outermost layer, the solar corona, is heated to reach temperatures exceeding a million degrees ? In order to adress this issue, we study a phenomenon that occurs in the corona due to a specific type of heating : thermal non-equilibrium (TNE). TNE is a common feature of active-region loops. TNE consists of cyclic plasma evaporation and condensation driven by a highly stratified and quasi-steady heating. Long-period (several-hours) EUV pulsations and coronal rain are two observables linked to these periodic variations in coronal temperature and density. However, the bias of current Fourier-based detections toward ideal cases hinders accurate evaluation of the coronal volume undergoing TNE cycles, a key parameter for coronal heating models. Based on a 3D hydrodynamic simulation (MAS) and synthetic observations of AR 11139, we aim to determine : (1) the fraction of the active-region volume subject to TNE cycles, and (2) the proportion of these cycles that can be detected in synthetic EUV observations. To address these questions, we adapt the method of Auch'ere et al. 2014 in order to detect 3D temperature and density periodicities. We identify regions exhibiting TNE in the volume of the active region and compare them with those of long-period EUV pulsations. A significant part of the AR volume (between 30% and 50%) undergoes TNE cycles, mostly in coronal loops. This result is most likely model-dependent, estimating the TNE volume in an active region could therefore serve as a novel method to discriminate coronal heating models. However, not all the cycles are detected in the synthetic observations, especially when there are multiple TNE cycles along the line-of-sight. We conclude that the current observational studies may greatly underestimate the volume occupied by TNE. We additionally detect TNE in open magnetic structures. This finding reinforces the hypothesis of Scott et al. (2024) that TNE can develop in open field regions and may inject material periodically into the solar wind.

Investigation of two macroscale energization processes : the Kelvin-Helmholtz instability at the dayside magnetopause and reconnection-driven transport in the plasma sheet

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This study investigates two distinct mechanisms energizing ions within Earth's magnetosphere : the Kelvin-Helmholtz instability (KHI) at the dayside magnetopause and reconnection-driven transport in the plasma sheet, using the MAGE 3D global MHD model.

At the dayside magnetopause, we study the development of the KHI with and without a southward-to-northward (SN) turning. We show that the SN transition moves the magnetopause outward, increasing plasma density near its inner edge and creating an additional mixing layer. We establish general KHI growth rate diagrams, which depend sensitively on the transverse profiles of both flow velocity and density. In this study, we demonstrate that there are three mechanisms that lower KHI frequencies at the dayside magnetopause. First, we show that the SN transition modifies KHI frequency response : the enhanced plasma density at the shear interface suppresses small-scale KHI structures while amplifying larger-scales, acting as a low-pass filter. Consequently, KHI spectrum shifts to lower frequencies, promoting Pc5-Pc4 pulsations. Furthermore, we find multiple KHI onsets promoting various growths throughout the magnetopause : KH frequencies and growth rates are found to decrease downstream. Finally, in the rest frame, KH frequencies are lowered due to a Doppler shift (Pc6-Pc5) suggesting that KHI can amplify fast magnetosonic waves propagating along standing field lines. KHI is thought to trigger field line resonance that enhances the dayside ions radial diffusion toward the Earth.

In the plasma sheet, the energization process is dominated by magnetic reconnection, driven by the orientation and variability of the IMF. Northward IMF produces a quasi-steady tail with weak, persistent fluctuations, while southward IMF induces intermittent, bursty reconnection-mediated transport, characterized by earthward plasma jets and tailward plasmoid ejecta. Tailward plasmoids remain localized near the sheet center, with fast earthward flows deflecting above or below, consistent with split-flow channels constrained by momentum and magnetic tension. Statistical analyses, including probability density functions, lagged-increment statistics, and autocorrelation times, uncover a recurring 35-40 minute modulation across the plasma sheet, signaling global tail reconfiguration. These signatures align with spacecraft observations of intermittency, exhibiting similar fluctuation amplitudes and decorrelation times despite variations in density and velocity maxima.

Together, these processes illustrate how large-scale magnetospheric dynamics, such as KHI and magnetic reconnection, energize ions, shaping the magnetosphere's plasma variability and intermittency.

Fluctuations in Solar Type III Radio Burst Spectra Observed by Parker Solar Probe and Solar Orbiter

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Solar Type III radio bursts are generated by electron beams accelerated during solar flares and propagating through the heliosphere. The most widely accepted mechanism involves the excitation of Langmuir waves by the electron beam through the bump on tail instability, followed by their conversion into electromagnetic (EM) wave emission near the local plasma frequency. This can occur through nonlinear processes or by linear mode conversion from Langmuir waves to EM waves in the presence of density fluctuations. Observational and theoretical studies have suggested that density fluctuations contribute to structured patterns frequently observed in the radio emission of Type III bursts. In this work, we analyze data from Solar Orbiter (SolO) and Parker Solar Probe (PSP) across a wide range of heliocentric distances and observational angles to investigate the spectral structures of these bursts through the fluctuations in Type III spectra. For 595 Type III burst events, we analyse the fluctuations of the maximum spectrum of each burst, obtained from the peak value of the temporal profile at each frequency. We observed strong agreement between the fluctuations measured by both spacecraft, with no clear dependence on their radial distance from the Sun or longitude separation, suggesting that local effects are responsible for these fluctuations. We also find that the fluctuation bandwidth increases with frequency, while relative bandwidth and amplitude decrease, consistent with previous studies. These trends are similarly observed for both large and small fluctuations, suggesting that well-defined structured Type III bursts and those with smaller fluctuations may share the same generation mechanism.

Connecting Electrons at the Sun and in the Heliosphere through X-ray and Radio Diagnostics

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One of the main objective of the Solar Orbiter mission concerns the production of energetic particles in the heliosphere, and the link between energetic particles at the Sun and in the Heliosphere. For energetic electrons, part of this question can be addressed by combining X-ray and radio observations. The launch of the Solar Orbiter in early 2020 marked a significant milestone, as it is equipped with the capability to simultaneously capture both types of emission. In this contribution, we shall present the results of a first statistical study (Paipa-Leon et al. 2026) based on several tens of events with associated X-ray and interplanetary type III emissions. We will investigate the correlations between the properties of interplanetary type III radio bursts and of their associated HXRs : energy density of the X-ray emitting electrons and characteristics of the radio burst (peak flux, exciter velocity and energy contained in the radio emitting electrons). We will then present preliminary results obtained from the combination of the RPW interplanetary type III catalog recently published (Pesini et al. 2026) and the list of X-ray flares observed by STIX (Hayes et al. 2025) and will investigate how the association rates varies with the distance of the spacecraft to the Sun, the GOES class, the connection with particular active regions, the longitude of the flaring active region.

Thème 6 : Activité éruptive ou impulsive dans les plasmas

Relations Soleil-Terre et météorologie de l'espace Surveillance de l'activité solaire

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Depuis 1908, l'Observatoire de Paris à Meudon fait des observations systématiques de la chromosphère et de la photosphère solaire avec le spectrohéliographe de Deslandres. Une collection exceptionnelle de plus de 11 cycles solaires comprenant 90 000 plaques photographiques monochromatiques, puis numérique et depuis 2017, nouvelle génération de spectro images avec des profils en CaII K et en Hα en tout point du soleil. L'ensemble est proposé à la communauté internationale par la base de données BASS2000.

Les données historiques sont notamment utilisées par plusieurs équipes internationales pour la météorologie de l'espace : variabilité de la couverture en protubérances, progéniteurs des éjections coronales de masses (MPS, Allemagne) et pour caractériser ; caractérisation des éruptions extrêmes qui peuvent avoir des impacts géo-effectifs majeurs (Obs de Paris) (LMSAL, USA) (NAOJ, Japon).

La collaboration SOLAP entre astronomes professionnels et amateurs est un atout pour soutenir la continuité de ces observations. Avec le spectrohéliographe compact SOL'EX ou SHG700, SOLAP permet d'enregistrer des données tous les jours, et même plusieurs fois par jour, grâce à des dizaines de stations d'observation réparties dans des lieux variés, pour compenser l'aléa météorologique de Meudon.

Whole-Sun solar jet model to study switchback formation and properties

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Switchbacks are magnetic field deflections observed by Parker Solar Probe and remain a puzzling phenomenon in solar wind physics. While their origins are still debated and several mechanisms are under study, recent work by Touresse et al., 2024 showed that a propagating solar jet can produce such magnetic deflections that can help in understanding the observable properties of switchbacks. While none of their simulations produced a full reversal switchback, they noted that the angle of deflection depends on the plasma beta profile, i.e., the radial magnetic field decay profile. This raises the question of the influence of the magnetic field profile on the formation and properties of switchbacks.

We extend this investigation by developing new numerical experiments that aim to study the propagation of a self-induced coronal jet in a more realistic magnetic configuration including the whole 3D magnetic corona. In this study, we simulate solar jets embedded in an equatorial coronal hole using two distinct magnetic field profiles, one decreasing as $1/r^2$ and another as $1/r^3$. The simulation in the $1/r^2$ profile serves as a reference case to the work of Touresse et al., 2024, while the $1/r^3$ configuration represents a new setup.

The 3D MHD simulations rely on the Adaptive Refined MHD Solver (ARMS) code. After a relaxation phase, an untwisting magnetic jet is self-consistently generated through interchange magnetic reconnection following sub-alfvénic and sub-sonic photospheric flow at the line-tied solar surface boundary. We show that from these original whole-Sun 3D MHD simulations we create solar jets that propagate into the heliosphere, generating switchback signatures.

Augmentations d'intensités EUV impulsives aux petites échelles le long de boucles du réseau

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Les boucles de réseau sont des types de boucles communes dans le Soleil calme, et les procédés responsables de leur chauffage ne sont pas encore entièrement compris. Notre objectif est de mesurer les signatures du chauffage aux petites échelles, par le biais des fluctuations de champ magnétiques au pied des boucles à l'émission EUV du plasma dans la couronne. Pour cela, nous avons exploité les données d'une observation multi-instrumentale (Solar Orbiter/EUI, Solar Orbiter/PHI, IRIS) de six heures d'une région du Soleil calme, afin d'observer des augmentations d'intensités EUV le long de trois boucles du réseau. Pour quatre augmentations d'intensité EUV, nous avons mesuré des vitesses sur le plan du ciel (POS) élevées (> 200 km/s) ; et deux d'entre elles étaient accompagnées de pics d'intensité avec une vitesse plus basse (< 80 km/s). Nous avons confirmé que cette composante lente était associée à du mouvement réel de plasma, comme le montre le décalage Doppler de -30 km/s que nous avons mesuré sur la raie Si IV avec IRIS. Enfin, les observations de PHI-HRT ont montré des signatures d'émergence et de la fluctuation du champ magnétiques aux petites échelles (8E16 Mx) près de l'un des points d'ancrage de la boucle. Nous avons conclu que ces augmentations d'intensité EUV pourraient être la conséquence de reconnections magnétiques entre la boucle du réseau et de petites boucles magnétiques émergeant au niveau de ses pieds ; ou encore de reconnections « internes » entre les différentes lignes de champ de la boucle.

Electron transport in a radiation-dominated plasma, application to solar corona brightenings

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Bremsstrahlung scattering of fast electrons on ions can be enhanced by the microwave radiation present in the solar corona. It can account for the electron diffusive transport along magnetic loops and high precipitation rates [Duclous et al., PoP, 31, 2, 022904, (2024)]. This process can also dominate the transport of thermal electrons confined in such loops, which calls for a dedicated study. The influence of stimulated Bremsstrahlung scattering on the electron transport is studied here, with focus on the return current induced by the fast electron population trapped in magnetic loops. From a more general standpoint, transport coefficients need to be reevaluated in the radiation-dominated plasma, characterized by the stimulated action of radiation on the Bremsstrahlung electron-ion collision frequency, down to thermal velocities.
We develop a theoretical framework for electron transport driven by a large bandwidth, bright low-frequency part of the photon spectrum and compute a set of radiation-enhanced transport coefficients. UV, XEUV and hard X-ray signals from flares are reinterpreted, in order to put maximum constraints on the fast electron/return current model. These observations evidence anomalous resistivity, thermal conduction inhibition and high precipitation rates of fast electrons, which are quantified by the model.

Stimulated Bremsstrahlung scattering provides the enhancement of electron collision frequency needed to account for the observed anomalous resistivity in flares. The anomalous resistivity systematically dominates over the classical resistivity in the flaring corona plasma by at least an order of magnitude. The runaway effect due to Coulomb collisions is suppressed. Thermal conduction is inhibited compared to the Spitzer conduction, in agreement with coronal seismology of slow-mode waves.
Stimulated Bremsstrahlung scattering is found to be the key process in flaring events of the solar corona. It can explain the above loop-top hard X-ray signal due to the fast electrons, and the measured electrical conductivity due to the thermal ones. As a perspective, the corresponding transport coefficients can be used in radiation MHD codes. To that aim, a simple model is proposed to self-consistently describe the transport coefficients and the infrared part of radiation spectrum. The radiation model could also be applied to stimulate large-angle electron scattering in the kinetic or hybrid models used to study the reconnecting regions of the solar.

Instabilité de dérive électrostatique dans la queue magnétosphérique terrestre : est-elle si universelle que ce que l'on dit ?

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Afin de comprendre comment l'équilibre d'une couche de courant peut être rompu de manière explosive, lors des sous-orages magnétosphériques, un modèle cinétique complet a été développé dans une couche de courant bidimensionnelle (Fruit et al. 2017, Tsareva al. 2020).
L'ingrédient essentiel dans cette structure est le mouvement de rebond des électrons piégés dans la couche. Ce mouvement constitue un oscillateur naturel qui peut entrer en résoance avec des perturbations électrostatiques ou plus généralement électromagnétiques.
Dans cette présentation, seule la version électrostatique sera présentée.

L'état d'équilibre initial est celui d'une couche de Harris modifiée par l'existence d'une composante normale Bz du champ magnétique (queue magnétique proche). La présence d'un gradient de densité perpendiculaire au champ magnétique rend la structure instable vis à vis de modes de dérive électrostatique (electrostatic drift waves).
Le problème est le caractère "universel" de cette instabilité qui rend la queue magnétique tout le temps instable, même avec un très faible gradient de densité. Cette anomalie est régularisée en incluant les effets de dérive de gradient et de courbure sur la population électronique : on parvient ainsi à tuer cette instabilité électrostatique, tout en en générant une autre, de nature différente, lorsque la courbure magnétique devient importante.

Cette présentation vise à brosser un tableau synthétique des interactions cinétiques entre les électrons piégés dans la structure, leur dérive due à la courbure magnétique et les perturbations électrostatiques pouvant se propager de manière stable ou instable...

Magnetic interactions of sungrazing comets : the case of comet Lovejoy

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Some comets, known as sungrazers, approach close enough to the Sun during their perihelion to orbit well inside the corona. This makes them prime candidates to probe the local coronal magnetic field as well as the plasma properties of the wind. In the case of the well known comet Lovejoy, it survived its perihelion passage, allowing for prolonged observations of its ionized tail. Several aspects of this event have been investigated, including the EUV emission (McCauley et al. 2013 ; Bryans & Pesnell 2012), UV spectroscopy (Raymond et al. 2018) and time-dependent chemistry of the plasma tail (Pesnell & Bryans 2014) ; the use of the tail morphology to probe the coronal magnetic field (Downs et al. 2013 ; Raymond et al. 2014) ; multi-fluid magnetohydrodynamic (MHD) modeling of the plasma tail (Jia et al. 2014) ; and analyses of the comet's orbit and dust tails (Sekanina & Chodas 2012). However, the potential impact of magnetic interactions between the comet and the Sun on solar activity during this event has not been studied yet.

In this work, we report for the first time a tentative detection of a solar eruption induced by magnetic interactions. Based on a 3D magnetohydrodynamic solar wind solution calculated using the WindPredict-AW model (Réville et al. 2020, 2022 ; Parenti et al. 2022), we modeled the magnetic connectivity between comet Lovejoy and the Sun during the perihelion. Then, by considering the propagation of hypothetical Alfvén waves from the comet to the solar surface, we were able to assess the spatial and temporal correspondence of energy transfer by these Alfvén waves with the location of the flare. Finally, we used the numerically derived scaling law of Paul and Strugarek (2026) in the context of star-planet magnetic interactions to estimate the energy budget of this event. Ultimately, we conclude that the passage of comet Lovejoy could have acted as a perturbation for the trigger of the flare.

On the acceleration and transport of relativistic particles in solar eruptive events

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In some rare eruptive solar flares protons are accelerated to relativistic energies, up to several tens of GeV. These events challenge our understanding of the processes by which particles gain such high energies, starting from a few hundreds of eV in the corona. Besides the acceleration itself, the process by which the energetic particles reach the Earth is poorly understood. The standard idea that the particles are guided by a heliospheric magnetic field with the geometry of the Parker solar wind model does not explain why the energetic particles may be observed even when the parent activity occurs several tens of degrees away of the coronal footpoint of the Parker spiral. Possible solutions comprise the acceleration by a spatially-extended structure, namely the shock wave driven by a fast coronal mass ejection, or coronal transport across the average magnetic field through the wandering of magnetic field lines or guiding-centre drifts. We confront these ideas with some well-observed relativistic solar particle events, using the observations of relativistic protons and electrons by ground-based neutron monitors and space-borne particle detectors, respectively, and employ radio emission from electrons in the corona and Heliosphere to trace charged-particle propagation. These observations argue against the role of guiding-centre drifts in particle transport, and in favour of transient magnetic connections from Sun to Earth due to a heliospheric magnetic field disturbed by previous mass ejections.

Multi-spacecraft signatures of the merging of two coronal mass ejections during propagation

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Coronal mass ejections (CME) interact with their surrounding during lift-off in the corona as well as during their propagation in the interplanetary medium. CMEs may also interact with other CMEs if they are released in sequence, and closely separated in space and time. Scenarios where the interaction leads to the merging of sequential CMEs have been modelled using global simulations, but direct observation of this merging from two vantage points at different distances has not been reported so far. We present observations from the Solar Orbiter - Wind and BepiColombo - STEREO-A spacecraft pairs, in radial alignments at separate longitudes, which permit to study such interactions. Although the CMEs at both longitudes look alike, analysis of the helicity sign suggests they are different CMEs. A focus on measurements along the Solar Orbiter - Earth line shows signatures consistent with the merging of two CMEs. While two apparently distinct CMEs, with a compressed sheath region in between, are observed at Solar Orbiter close to the Sun (at 0.45 AU), only an apparent single CME is observed near Earth at Wind. Analysis suggests that the CME near Earth is in fact made of two CMEs after merging. Solar observations as well as in situ flux ropes orientations, suprathermal electron properties and magnetic reconnection signatures at both locations support this scenario.

Tearing instability and plasmoid formation in pseudo-streamer current sheets from 3D MHD simulations

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Context.
The onset of solar flares is thought to be governed by magnetic reconnection occurring within thin and intense current sheets in the solar corona. In sufficiently elongated current sheets, the tearing instability can develop, fragmenting the sheet into multiple plasmoids and enabling fast reconnection. While this process is well studied in "in-box" simulations, reproducing it in large-scale models of the solar corona remains challenging due to the scale differences.
Aims.
The main objective of this project is to investigate the development of the tearing instability and the formation of plasmoids in pseudo-streamer configurations using three-dimensional global simulations. In particular, we aim to investigate 1) how current sheet properties and spatial resolution influence the onset and evolution of the tearing instability, 2) how these small-scale structures affect the large-scale dynamics of solar flares and 3) what are their observational signatures of these structures by producing synthetic white-light images. Methods. We perform 3D magnetohydrodynamic (MHD) simulations using the ARMS code on whole-Sun magnetic configurations of pseudo-streamer. The adaptive mesh refinement capabilities of ARMS allow us to increase spatial resolution within current sheets and capture the development of the tearing instability and the associated plasmoid formation. To connect the simulations with observations, we also develop a forward-modelling pipeline to generate synthetic white-light images comparable to those obtained by the WISPR instrument onboard Parker Solar Probe. Results. Our simulations show the formation and nonlinear evolution of tearing-driven plasmoids within pseudo-streamer current sheets for a 3D whole-corona model. In addition, our white-light forward-modelling produces realistic synthetic images that can be used to investigate the possible observational signatures of plasmoid-mediated reconnection.

Thin coronal jets and plasmoid-mediated reconnection : Insights from Solar Orbiter observations and Bifrost simulations

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Coronal jets are ubiquitous, collimated million-degree ejections that contribute to the energy and mass supply of the upper solar atmosphere and the solar wind. Solar Orbiter provides an unprecedented opportunity to observe fine-scale jets from a unique vantage point close to the Sun. We aim to (1) uncover thin jets originating from Coronal Bright Points (CBPs), revealing previously unresolved contributions to coronal upflows ; and (2) improve our understanding of plasmoid-mediated reconnection and its observable signatures. We analyze eleven datasets from the High-Resolution Imager (HRI) 174 Å of the Extreme Ultraviolet Imager (EUI) onboard Solar Orbiter, focusing on narrow jets from CBPs and signatures of magnetic reconnection within current sheets and outflow regions. To support the observations, we compare with CBP simulations performed with the Bifrost code. We have identified thin coronal jets originating from CBPs with widths ranging from 253 km to 706 km : scales that could not be resolved with previous EUV imaging instruments. Remarkably, these jets are 30–85% brighter than their surroundings and can extend up to 22 Mm while maintaining their narrow form. In one of the datasets, we directly identify plasmoid-mediated reconnection through the development within the current sheet of a small-scale plasmoid that reaches a size of 332 km and propagates at 40 km/s. In another dataset, we infer plasmoid signatures through the intermittent boomerang-like pattern that appears in the outflow region. Both direct and indirect plasmoid-mediated reconnection signatures are supported by comparisons with the synthetic EUI-HRI 174 Å emission from the Bifrost simulations. The high spatial and temporal resolution of EUI-HRI 174 Å enables the detection of previously unresolved narrow jets and plasmoid-mediated reconnection signatures from CBPs. These findings highlight Solar Orbiter's unique capability and motivate future statistical studies to assess the role of such fine-scale phenomena in coronal dynamics and solar wind formation.

Small EUV Brightenings in the Quiet Solar Atmosphere : New Insights from the Solar Orbiter Mission

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One of the many outcomes of the Solar Orbiter mission is the evidence for the solar atmosphere being filled by highly impulsive bursts, down to $\approx$ 200 km scale : the limit of the EUV instruments' spatial resolution. Small-scale events of this kind were already known, but their observation was occasional or with limited, lower resolution. Their similarity with known larger features, are the witnesses that the physical processes causing them are independent of the spatial scales involved.

Their highly dynamic property is the signature of energy transfer and/or local dissipation.

Their investigation can thus elucidate on the dominant physical processes acting on the solar atmosphere and on the possible role in the origin of the hot solar corona.

This work reviews the observational and simulation results on this topic, led by the results from data taken by the The Extreme Ultraviolet Imager (EUI)/High Resolution Imagers (HRIEUV) instrument. Here, we will cover both statistical properties and analyses of individual events.

Accélération et transport de particules durant l'orage géomagnétique intense de Mai 2024

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Les augmentations de neutrons mesurées au niveau du sol (GLEs) surviennent fréquemment lors de fortes activités solaires, quand le milieu interplanétaire est déjà très perturbé par des éjections de masse coronale (CMEs) se propageant jusqu'à à la Terre. Pour atteindre la Terre, ces particules très énergétiques doivent alors se propagent à travers des champs magnétiques interplanétaires complexes. De telles conditions ont été réunies lors de la super-tempête géomagnétique de mai 2024. À l'arrivée des CMEs sur la Terre, les moniteurs à neutrons au sol du monde entier ont enregistré une forte diminution de Forbush en réponse aux effets d'écrantage de ces CMEs sur les flux de rayons cosmiques galactiques. Lorsque les flux de rayons cosmiques ont atteint un minimum le 11 mai à 01 :00 UT, le GLE74 a été soudainement détecté entre 01 :30 et 02 :00 UT, conjointement à un puissant épisode de particules énergétiques solaires (SEP) mesuré au point de Lagrange L1 et par le Solar-Terrestrial Relations Observatory Ahead (STEREO-A). Nous utilisons une combinaison de modèles numériques pour étudier cette séquence complexe d'événements en nous concentrant sur le transport des particules de haute énergie à l'intérieur des nuages magnétiques ayant impactés la Terre. Nous illustrons les effets de conditions interplanétaires complexes sur le timing, l'étendue spatiale et les propriétés spectrales des SEPs de haute énergie.

Sympathetic flares and magnetohydrodynamical avalanches

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Solar eruptions stem from a variety of phenomena involving the release of magnetic energy. The phenomenology of solar flares can be mimicked with so-called cellular automata, or avalanche models. These toy models have the advantage of reproducing many statistical features of solar flares, and can even be used to reproduce the features of sympathetic flare. Though, they generally lack a sound physical justification. In this presentation we will cover recent endeavours that aimed to (i) uncover the statistics of sympathetic flares — including the STIX flare list (Guité et al. 2025a, doi 10.1051/0004-6361/202452381) ; (ii) model this sympathy with coupled avalanche models reproducing their statistics (Guité et al. 2025b, doi 10.1007/s11207-025-02501-4) ; and (iii) unveil the avalanche nature of dissipative regions within MHD simulations, bridging the gap between MHD and avalanche models (Lamarre et al. 2025, doi 10.1103/28ws-d57z).
We will report on a recent statistical analysis of sympathetic flares, utilizing data from multiple instruments (SDO/AIA, RHESSI, and Solar Orbiter/STIX) that collectively span from the peak of solar cycle 23 to the present. Our analysis reveals a significant overabundance of hemispheric pairs of flares with short waiting times (w $\leq$ 1.5 hours) that are separated by approximately 30 degrees in longitude. The occurrence rate of sympathetic flares is estimated to be around 5% across the three instruments.
Following this study, we will show how simple, coupled avalanche models can be built to reproduce some features of sympathetic flares. In particular, our study suggests that sympathetic solar flares are adequately simulated by weakly coupled avalanche models, showing an excess of pairs of events at short waiting times but with no correlation in the energy of the sympathetic flare pairs. It also suggests a pathway to identify sympathetic flares on other stars, if they happen to have stronger couplings. Those sandpile models, though, generally lack a sound physical justification. We will end our presentation by reporting on the identification of avalanching behavior in magnetohydrodynamical (MHD) numerical simulations of chromospheric dynamics driven by photospheric motions (with both the BIFROT and PLUTO codes). We will briefly discuss the potential of such MHD simulations in providing guidance towards designing better physically motivated evolutionary rules for existing avalanche models used for e.g. flare prediction.

On resolving the dynamics and Oxygen and Iron ion abundance variations in coronal microjet modelling

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Magnetic inversions known as switchbacks and velocity spikes have been ubiquitously observed in solar wind observations from the Parker Solar Probe and Solar Orbiter. Previous studies have suggested that they are formed due to interchange reconnection in the solar corona, from jetlets originating from small bipoles located at the base of coronal plumes. Remote sensing observations also show variations in the ion abundances of the solar wind that appear to be linked to the wind speed, but the underlying reason remains unclear. In this study, we present 2D MHD numerical modelling results using the IDEFIX code of a magnetic bipole emergence leading to microjets. We solve the ion-charge state ratio in the tracer variables of the code to obtain the Oxygen and Iron ion abundances in the structure. From the results, we find that the reconnection events and the resulting velocity jets can produce small-scale variations in the ion abundances, where the dominant effects from the jets push the lower ionisation states along the jet, potentially travelling into the outer corona. Combined with forward modelling of the microjets in the AIA, Solar Orbiter EUI/HRI, and MUSE passbands and resolutions, the results highlight the need for high spatial and temporal resolution observations to clearly resolve such structures visually and its resulting transient ion composition variation. If these signatures survive to the heliosphere, they may pinpoint the origins of the solar wind variation.

Dynamics of a switchback-like magnetic deflection induced by a propagating coronal jet

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The Parker Solar Probe (PSP) mission has revealed the ubiquity of switchbacks (SBs), namely sharp and localised magnetic deflections, in the nascent solar wind. Rarely observed near Earth, these features have spurred investigations into their origin and the processes responsible for their formation. A prominent theory is that switchbacks originate in the lower corona through magnetic reconnection processes, linked to solar jet activity. Solar jets are collimated, impulsive and sharp-edged features associated with magnetic reconnection that generate an Alfvénic torsional wavefront propagating outward into the heliosphere.

In this work, we investigate whether a realistic spacecraft crossing the path of a propagating solar jet can generate synthetic in-situ signatures comparable to the SBs observed by PSP. We also characterise the three-dimensional (3D) magnetic topology of the underlying structure and assess how the magnitude of the magnetic deflection evolves with the surrounding environment.

To this end, we perform a 3D magnetohydrodynamic simulation of a solar jet propagating through the ambient solar wind. A virtual spacecraft trajectory, constructed from the actual PSP orbit during its 22nd perihelion, is embedded within the simulation to produce synthetic in-situ measurements.

The simulation reproduces SB-like magnetic signatures with durations and profiles consistent with PSP observations, confirming earlier results obtained with simplified trajectories. This demonstrates that the torsional Alfvénic wavefront of the propagating jet naturally reproduces SB-like structures. For the first time, we directly visualise the full 3D magnetic topology of a jet-induced SB region. Two distinct families of magnetic field lines are identified : one displaying a single magnetic deflection and another exhibiting two sequential deflections propagating along the same field line. We note that the evolution of the magnitude of the magnetic deflection is strongly modulated by the background plasma beta, suggesting that the magnetic reversals require longer residence times in low-beta environments.

This provides strong support for a solar origin of at least a fraction of the SBs observed by PSP and sets new constraints for interpreting PSP measurements in terms of their underlying magnetic structure.

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

Automatic Detection of Dipolarization Fronts in the Earth's Magnetotail With Supervised Machine Learning

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Plasma jets, such as dipolarization fronts (DFs), are ubiquitous in astrophysical plasmas and play a crucial role in planetary magnetospheres. These fronts form boundaries between jetting and ambient plasma and are sites of electromagnetic energy conversion and particle energization. Most statistical studies of DFs rely on manual identification or automated methods based on threshold criteria applied to selected plasma parameters, which are time-consuming and can introduce selection biases. The recent availability of large, high-quality in situ plasma data now enables automated detection of plasma structures using machine learning. In this study, we apply a fully convolutional neural network (FCN) to data from the Magnetospheric Multiscale (MMS) mission to automatically detect DFs in the Earth's magnetotail. The network is trained using time series of magnetic field and plasma measurements corresponding to fronts that have been previously identified and labelled through the MMS selective downlink procedure. The results demonstrate that the FCN accurately detects plasma jet fronts and successfully identifies additional events that were not included in the original manual selections, highlighting the potential of machine learning for large-scale, unbiased DF surveys.

Global Compression of the Plasma Sheet and Magnetotail During Intense Storms From THEMIS Observations

Soboh Alqeeq (1)

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We estimate the global impact of storms on the global structure and dynamics of the night side plasma sheet from observations by the NASA mission THEMIS. We focus on an intense storm occurring in December 2015 triggered by interplanetary coronal mass ejections (ICMEs). It starts with a storm sudden commencement (SSC) phase (SYM-H∼+50nT) followed by a growth phase (SYM-H∼-188 nT at the minimum) and then a long recovery phase lasting several days. We investigate THEMIS observations when the spacecraft were located in the midnight sector of the plasma sheet at distances typically between 8 and 13 Earth's radii. It is found that the plasma sheet has been globally compressed up to a value of about ∼>4nPa during the SSC and main phases, i.e. 8 times larger than its value during the quiet phase before the event. This compression occurs during periods of high dynamic pressure in the ICME (20 nPa) about one order of magnitude larger than its value in the pristine solar wind. We infer a global increase of the lobe magnetic field from 30 nT to 100 nT, confirmed by THEMIS data just outside the plasma sheet. During the SSC and main phases, the plasma sheet is found thinner by a factor of 2 relative to its thickness at quiet times, while the Tsyganenko T96 magnetic field model shows very stretched magnetic field lines from inner magnetospheric regions toward the night side. During the recovery phase, whereas the interplanetary pressure has dropped off, the plasma sheet tends to gradually recover its quiet phase characteristics (pressure, thickness, magnetic configuration, etc) during a long recovery phase of several days.

Investigation of the homogeneity of energy conversion processes in a flux rope observed in the Earth's magnetotail using MMS measurements

Soboh Alqeeq

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We investigate the properties and energy conversion processes associated with an earthward-propagating flux rope (FR) using observations from the Magnetospheric Multiscale (MMS) mission on 6 July 2017. Ohm's law analysis indicates that ions are primarily decoupled from the magnetic field by Hall fields within the FR. In the spacecraft frame, the energy conversion exhibits a bipolar signature near the FR center, corresponding to energy transfer from plasma to electromagnetic fields ($J . E < 0$) and back from fields to plasma ($J \cdot E > 0$). This reversal is associated with a local cross-tail current reversal, suggesting substructure within the FR. In the plasma fluid frame, the energy conversion term (J·E') shows sharp energy exchanges between plasma and fields. We further show that the energy conversion process is not homogeneous at the scale of the tetrahedron (electron scales), largely due to electric field fluctuations arising from intense whistler-mode wave activity.

Variations of the magnetic flux content in the inner magnetosphere during an intense storm

Soboh Alqeeq (1)

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During the intense storm in December 2015, triggered by a coronal mass ejection (CME), we benefited from an exceptional configuration of several spacecraft and constellations in the inner magnetosphere from the dayside magnetopause to 13 Earth's radii in the geomagnetic tail (Magnetospheric MultiScale mission (MMS), THEMIS, Van Allen probes and GOES 15). The simple Tsyganenko model T96 is found to reproduce satisfactory all their magnetic field observations. We used it to compute the pattern of closed drift shells of equatorial energetic particles. Relative to the quiet phase before the storm, this pattern shows a strong compression during the Storm Sudden Commencement (SSC) and the main phase and then a gradual expansion during several recovery days. We have computed the magnetic flux content in the region of closed drift shells between an inner shell at 1.5 Earth's radii and the last closed drift shell. During the SSC, caused by the arrival of the CME, we have found a global increase, in the range 100-400 MWb, above the value during the quiet phase, with a dominant contribution from the whole diurnal magnetosphere including the inner distances close to Earth. All other phases show a decrease relative to the value during the quiet phase. The minimum is reached during the main phase and first day of the recovery phase, with values in the range -600 to -800 MWb, which could be caused by the effects of cross-tail currents observed to be particularly enhanced at larger distances in the nightside plasma sheet.

Refining Boundary Conditions for SEP Trapping and Detrapping in the Salammbô Radiation Belt Dynamics Code

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Radiation belts are toroidal regions surrounding Earth where electrons and protons are trapped by the geomagnetic field, intersecting most satellite orbits and threatening spacecraft. The density and energy of these protons are driven by solar-wind and solar flare injections, as well as geomagnetic storms that can both populate and deplete the proton radiation belt.

ONERA's DPHY department developed the Salammbô Proton code to model the dynamics of the proton belt by solving a Fokker-Planck equation. However, its current boundary conditions do not allow for a correct modelling of the injection and de-trapping of protons. The main objective of this work is to propose numerical model driven methods to estimate new boundary conditions from limited satellite data.

In the high-energy limit of protons (40-200 MeV), a code already existed at ONERA to determine the location (averaged in MLT and pitch angle at magnetic equator) in magnetic coordinates of a so-called shielding limit, the location at which the proton flux measured in geostationary orbit was injected into Salammbô. This limit is derived using statistical results of a trajectory integration code named MASHCode, developed at ONERA since 2013, with a major evolution conducted recently (2025-2026).

The main focus of this contribution is to demonstrate that this limit should account for the pitch angle at equator. We will illustrate that this trapping limit should also be determined considering the latitude of injection, as particles are more easily trapped at the magnetic equator and thus sampling them only at equator will tend to overestimate the shielding limit. Finally, we will discuss the implementation of a new model replacing the simple shielding limit with a more realistic transition zone based on MASHCode results. We will also outline the technical challenges that the integration of this new model in Salammbô raises, as the injection of protons will no longer be only a boundary condition, but also a source term.

Extension temporelle et robustesse instrumentale des modèles de Deep Learning pour la météorologie de l'espace : étude du modèle SERENADE

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Cette présentation traitera de SERENADE, un pipeline d'apprentissage profond permettant de prédire l'indice géomagnétique Kp maximal quotidien plusieurs jours à l'avance à partir d'images SDO/AIA EUV. Les premiers prototypes, publiés en 2022 (Bernoux et al., 2022, JGR : SP), avaient déjà atteint des performances comparables à celles des meilleurs modèles pour les événements liés au vent solaire rapide, mais plusieurs limites avaient été identifiées. Des travaux récents (Tahtouh et al., 2025, JGR : MLC) ont remplacé l'extracteur de vecteurs latents générique GoogLeNet par un Auto-Encodeur Variationnel spécialement entraîné sur des images solaires, ce qui a permis d'obtenir un espace latent plus significatif sur le plan physique, et donc des prévisions plus stables.
L'un de nos principaux axes de travail actuels est l'enrichissement de la base de données d'apprentissage de SERENADE. Pour dépasser les limites imposées par la base de données AIA « ML-ready » d'origine (Galvez et al., 2019, ApJS), couvrant la période 2010-2020, nous avons constitué un nouvel ensemble de données destiné à l'apprentissage automatique, couvrant la période 2010-mi-2025 (qui inclus donc les phases ascendante et maximale du cycle solaire actuel, plus actif), ainsi qu'un ensemble de données SOHO/EIT complémentaire, qui remonte à 1996. Nous disposons ainsi de près de 30 ans d'observations prétraitées de façon homogène, au lieu des 11 ans initiaux.
Nous analysons l'impact de cette extension temporelle et évaluons dans quelle mesure notre modèle précédent a pu être limité non pas en raison de son architecture, mais des données utilisées. Étant donné que de nombreuses études s'appuient sur l'utilisation de l'ensemble de données SDOML, nos résultats sont potentiellement généralisables à d'autres modèles et pourraient indiquer que des gains de performance pourraient être obtenus sans modifier l'architecture de ces modèles, mais simplement en étendant la base de données.
De plus, nous profitons du fait de disposer de deux ensembles de données provenant d'instruments différents pour mener une étude préliminaire visant à caractériser la capacité du modèle SERENADE à généraliser à des données non-vues provenant d'autres instruments que ceux utilisés pour l'entrainement initial. Cette capacité deviendra cruciale une fois que les missions SDO et SOHO auront pris fin et que le modèle ne pourra plus être alimenté par ces données.

Inferring the parametric location of the magnetopause reconnection X-Line from in situ measurements

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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. A paradigm, supported by evidence in simulations and in-situ data, is that magnetic reconnection happens along a global line called the X line. On the Earth's magnetopause, reconnection events have been identified locally, but until now, the global position and shape of the X line were accessible from global simulations only. This work presents a method to locate the X line from ion flow maps of the boundary layer, built from large amounts of boundary layer data selected automatically with a machine learning algorithm on multiple satellites. This allows the study of the position of the X line for different conditions. Notably, the rotation of the X line with IMF clock angle and its vertical shift with dipole tilt have been evidenced with unprecedented precision. Finally, a comparison between the measured X line and the ones predicted by different models is possible, which eventually should give us more insight about which physical parameters control where magnetic reconnection occurs.

Constraining Solar Structure Propagation in the Heliosphere : A Multipoint Approach

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In the era of multipoint measurements in the heliosphere, analysing multi-spacecraft conjunctions with BepiColombo, Parker Solar Probe, Solar Orbiter, STEREO and others provides a series of opportunities to study the structure and radial evolution of the solar wind at different locations. Multipoint measurements are key to better understanding complex phenomena in space plasma physics and, in this scenario, offer a unique opportunity to derive upstream conditions relevant to constrain the Sun-planet magnetospheric interactions. We detail here a first use case and compare in-situ plasma and magnetic observations from Parker Solar Probe and STEREO-A during a time interval of two months when the two spacecraft were first aligned along the same Parker spiral, then radially aligned. We compute the temporal evolution of the time lag between the two spacecraft and trace back STEREO-A observations to Parker Solar Probe's orbit. We show that they observed similar solar wind conditions and apply the same method to a second use case in order to derive the solar wind context during the first flyby of Mercury by BepiColombo.

(Pre-)Operational space weather forecasting tools : focus on the United States and European resources

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Space weather is a natural hazard with potentially large socioeconomic impacts worldwide in various sectors of the energy, aviation, transportation, and space industries. The scientific community has been developing space weather prediction tools for the past two decades. However, the increasing dependence of human society on modern technologies, the rapid growth of commercial satellites, and the evolving near-Earth environment associated with climate change and space pollution have raised questions about our ability to mitigate the risks posed by major space weather events. Our project surveys the state-of-the-art of the development in space weather prediction, especially for extreme events, focusing on tools from the NOAA Space Weather Services and the ESA Space Safety Programme. In particular, our project aims to assess the current state of readiness of tools for predicting major space weather events using research facilities in the US and Europe, particularly in France, as examples. Our assessment will facilitate the future development of physics-based and AI applications to improve major space weather warning capabilities. This project is funded by the Transatlantic Research Partnership, a program of the Albertine Foundation and the French Embassy.

Vers l'utilisation des smartphones bi-fréquence pour caractériser le contenu total en électron de la ionosphère

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Les récepteurs GNSS de l'IGS constituent une source d'informations importante pour déduire le TEC et alimenter les modèles ionosphériques[1]. Malheureusement, ces stations sont parfois très dispersées [1]. Ainsi, les modèles doivent linéariser ou prédire le TEC en utilisant des fonctions mathématiques provenant elles même de modèles physiques biaisés dans de nombreux endroits. Aujourd'hui, nous savons que les récepteurs bifréquences à faible coût des smartphones pourraient présenter un grand intérêt pour l'avenir de la caractérisation ionosphérique de par leur nombre à travers le monde [2,3]. Le problème de ces récepteurs est qu'ils ne sont pas suffisament précis à eux seuls pour mesurer le TEC localement. D'une part parce que les données de phase ne sont pas faciles à obtenir et d'autre part en raison des antennes linéaires dont ils sont équipés [3]. Ainsi, travailler avec la pseudo-distance devrait être le seul moyen d'obtenir un maximum de données pour l'instant, mais il s'agit également d'une mesure très bruyante en raison, par exemple, des trajets multiples [3]. Nous souhaitons ici présenter une comparaison entre certains récepteurs à faible coût et un récepteur GNSS Septentrio local. L'objectif de ce travail est de présenter une méthode qui permettrait d'atteindre la précision des récepteurs coûteux avec seulement quelques récepteurs à faible coût. Par la suite, l'extension de cette méthode à une zone plus large nous permettra peut-être d'obtenir des résultats aussi bons que les résultats actuels et une meilleure estimation locale des structures de TEC.

Temporal evolution of Jupiter's rotation period based on a study of the evolution of the periodicity of Jovian radio emissions over three decades

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Jupiter's rotation period has been revised several times, most recently in 2006, based on the rotation period of radio sources. In this study, we therefore use data from the Nançay Decameter Array and an extended version of the Marques et al. (2017) catalogue, covering the period 1990–2020, to study the long-term evolution of the periodicity of Jupiter's decameter radio emissions. We apply a Lomb-Scargle analysis to characterise the temporal variations in the periodicity of the radio signal. The results show that the radio periodicity of Jovian auroral and Io-induced emissions has remained stable over 30 years, albeit with significant variations on an annual scale.

Modeling the high-latitude MIT system with the IPIM model

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The Earth's Magnetosphere-Ionosphere-Thermosphere (MIT) system is strongly controlled by the laws of electrodynamics, which include significant contributions from all three components. Today, we face a growing need for a better representation of this MIT system, at all latitudes due to the growing use of GNSS satellites for positioning, which face accuracy and forecasting challenges that are not accessible with current data coverage and processing tools.

The IRAP Plasmasphere-Ionosphere Model (IPIM) is one of the only physical models developped in Europe which solves plasma transport equation along magnetic field lines and provides a complete 3D coverage of Earth's ionosphere and plasmasphere in latitudes, longitudes and altitudes.

The model is suited to study the high latitude ionosphere, but some adjustement has to be done on the inputs in order to simulate geomagnetic disturbances.

Thus, we will present the model and some interesting results at high latitudes for geomagnetic events, especially during a High Speed Stream event.

Etudes d'ondes VLF et des interactions ondes-électrons dans les expériences actives

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Pierre-Louis Blelly (2), Aurélie Marchaudon (2), Olivier Le Contel (3), A. Retino (3), Frederic Lescoat (4), Marc Sevoz (4)

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Nous étudions des expériences actives récentes, conduites hors laboratoire, dans la haute ionosphère. Elles permettent de générer ou d'amplifier des ondes électromagnétiques VLF existantes, par exemple en modifiant l'environnement électronique ambiant. 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 d'électrons énergétiques rayonné. Nous montrons 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. Ce faisant nous discutons du rôle du plasma froid et de sa modélisation ainsi que de l'importance du modèle de champ magnétique terrestre.

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.

Etude de la dynamique des électrons des ceintures de radiation de la Terre depuis la Lune à partir du rayonnement synchrotron

Angélica Sicard (1)

Antoine Brunet (1), Gwendoline Marc (2), Quentin Nenon (3)

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Les ceintures de radiation terrestres sont des régions dynamiques de la magnétosphère où des particules chargées de haute énergie sont piégées par le champ géomagnétique. Leur structure et leur évolution dépendent étroitement de l'activité solaire : les orages géomagnétiques modifient drastiquement la distribution des électrons, menaçant ainsi l'intégrité des infrastructures spatiales. Une surveillance précise et continue de ces régions est donc cruciale. Or, les observations actuelles reposent principalement sur des mesures satellitaires in situ, par nature limitées en termes de couverture spatiale et temporelle, ce qui restreint notre compréhension de la dynamique globale de ces ceintures. Issus de la thèse de Gwendoline Marc, ces travaux explorent une approche novatrice de télédétection fondée sur les émissions cyclo-synchrotron générées par les électrons piégés aux longueurs d'onde radio. Bien qu'indétectables depuis le sol à cause de l'absorption ionosphérique (en dessous de 10 MHz), ces émissions pourraient être observées depuis l'espace, notamment depuis la face visible de la Lune. La problématique centrale est la suivante : peut-on reconstruire la distribution 3D des électrons des ceintures de radiation à partir d'images 2D du rayonnement cyclo-synchrotron observé depuis la Lune ? Pour y répondre, nous avons développé une méthode d'inversion s'appuyant sur l'Analyse en Composantes Principales (PCA), permettant une reconstruction robuste et flexible sous diverses conditions géomagnétiques. Une seconde partie de l'étude évalue l'exploitation directe de ces images, indépendamment de toute procédure d'inversion. En analysant différentes périodes de tempêtes et de calme, nous avons mis en évidence des corrélations entre les caractéristiques morphologiques des images et les paramètres géomagnétiques. Ces résultats suggèrent que l'imagerie cyclo-synchrotron constitue, en soi, un outil de diagnostic précieux. En conclusion, ces travaux démontrent la faisabilité d'utiliser des observations radio lunaires pour caractériser, à distance et de manière globale, le comportement des ceintures de radiation terrestres.

D-region response to solar flares : chemistry modelling and HF absorption

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The ionosphere D-region (60-90 km) is responsible for a large part of the HF absorption, a frequency band used by civil and military operations. However, it is highly sensitive to perturbations, and in particular increases in the Sun's X-ray flux during solar flares. It is thus crucial to monitor an understand the D-region response to solar flares to model the resulting HF absorption and mitigate any impact on communications.

One peculiarity of this region is its complex chemistry. To model this, chemistry schemes are necessary. The Mitra-Rowe scheme (Mitra & Rowe, 1972) includes the six dominant ion species. It reproduces well the main processes in the D-region, with limited computational cost and without detailed measurements of minor species. With this model, we reproduce the ionisation of the neutral species by external source (cosmic-rays, solar Lyman-alpha, UV and soft and hard X-rays radiation) to study both quiet periods and perturbed conditions. The resulting HF absorption is then computed from these densities (Davies, 1990 ; Zawdie et al., 2017).

The D-region perturbations are also studied through Very Low Frequency (VLF, 15-45 kHz) waves recorded in Nançay (Sologne, France). Indeed, VLF waves propagate in the waveguide defined by the Earth and the ionosphere. Thus, any change in the electron or ion densities impacts their propagation.

We present here a study of several solar flares and their impact on the D-region. The behaviour of the various species is modelled through our new chemistry code, the Lower Ionosphere Region - Absorption and Chemistry Modelling (LIR-ACheM), which is based on the Mitra-Rowe scheme. VLF measurements are then reproduced by a propagation model (LMP ; Gasdia & Marshall, 2021) from the output of the chemistry code. We thus highlight the relevant parameters governing the D-region response to forcing and the enhanced HF absorption for different flares.

Autres thèmes

Analyse du bilan (BGES) des activités spatiales du LPP

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(1) LPP, CNRS, Ecole Polytechnique Université Paris Saclay, Sorbonne Université, Observatoire de Paris

L'outil GES 1point5 de Labos1point5 permet d'obtenir de manière simple un bilan des émissions de gaz à effet de serre associées aux activités de recherche effectuées hors du laboratoire, ce qui se résume pour le LPP essentiellement à l'exploitation des données des missions spatiales. Le résultat obtenu varie dans des proportions importantes d'une année sur l'autre, ce qui rend l'analyse compliquée puisque l'activité réelle de l'équipe n'est pas si variable. Nous analyserons comment ce résultat est lié à notre activité réelle. Nous comparerons la méthode de calcul, initiée par les collègues de l'IRAP, avec celle qui est utilisée pour les autres « grands instruments » dont les émissions sont prises en compte par Labos1point5. L'objectif de ces calculs de bilan est d'avoir un instrument pour évaluer les évolutions de l'impact de notre activité d'une année sur l'autre dans le but de tenter de diminuer cet impact sans dégrader la qualité de la science produite. Nous nous interrogerons sur ce qui est possible pour améliorer le « thermomètre » et le bilan des missions spatiales.

Programme du colloque

LUNDI 1er JUIN

11h00-13h50 : Accueil des participants et café d'accueil

12h00-13h50 : Déjeuner au centre de conférence

14h00-14h15 : Introduction du colloque (Benoît Lavraud)

Thème 3 "Couplages entre enveloppes de plasma"

14h15-14h30 : Large-scale dynamics of an active region from high-resolution spectroscopic observations at THEMIS (Marianne Faurobert)

14h30-14h45 : Coronal flux-rope formation through flux cancellation of a sheared arcade in a 3D convectively-driven MHD simulation (Guillaume Aulanier)

14h45-15h00 : Magnetic-topology dependence of sulfur fractionation in the solar corona : a Solar Orbiter/SPICE survey (Slimane Mzerguat)

15h00-15h15 : Studying the impact of the active region dynamics on the solar wind variability (Nicolas Poirier)

15h15-15h45 : Flash poster - Session 1

15h45-16h45 : Pause café et posters

Thème 3 "Couplages entre enveloppes de plasma"

16h45-17h00 : In-situ Switchback Variability as a Proxy for Source Region Variation (Gabriel Suen)

17h00-17h15 : Des électrons froids à Mercure (Mathias Rojo)

17h15-17h30 : Hybrid modeling of Callisto's environment interaction with the Jovian magnetosphere (Thomas Le Liboux)

17h30-17h45 : Magnetosphere-Satellite Coupling at Ganymede : Electron Precipitation and Surface UV Reflectance from Juno/UVS Observations (Bilal Benmahi)

17h45-18h00 : Modelling the radial penetration of a cross-polar cap electric field in the Jovian magnetosphere, in relation to observed local-time asymmetries (Marie Devinat)

18h00-19h30 : Accès aux chambres

19h30-20h00 : Apéritif régional

20h00-21h00 : Dîner sur place

MARDI 2 JUIN

Thème 3 "Couplages entre enveloppes de plasma"

9h00-9h15 : Normalized Reconnection Rate and X-Line Location at the Magnetopause (Bayane Michotte de Welle)

9h15-9h30 : Caractérisation des perturbations ionosphériques itinérantes induites par les ondes de gravité générées par les orages à l'aide d'un réseau dense de capteurs GNSS (Thomas Farges)

9h30-9h45 : Modeling plasma-magnetic field coupling : from ionosphere phenomena to laser experiments (Alixende Koulmann)

Thème 1 "Simulations et outils numériques"

9h45-10h00 : PHARE - Helioplasma modeling with adaptive mesh refinement (Nicolas Aunai)

10h00-10h15 : Modelling of space plasma from Vlasov to fluid : machine learning approach to the closure problem (Pietro Dazzi)

10h15-10h30 : Fokker-Planck Modelling of Solar Wind Electron Velocity Distributions : Diffusive Transport vs. Ballistic Effects (Tomas Formanek)

10h30-11h15 : Pause café et posters

11h15-11h30 : Réseaux de neurones informés par la physique appliqués à la ceinture de radiation d'électron externe de la Terre : évaluation dans le cadre d'une expérience-jumelle (Emerick Laborde)

11h30-11h45 : The SciQLop Ecosystem : Open-Source Tools for Interactive Multi-Mission In-Situ Plasma Data Exploration and Analysis (Alexis Jeandet)

11h45-12h00 : Real-time detection of Solar and Jovian radio bursts with NenuFAR : a part of the EXTRACT project (Emilie Mauduit)

12h00-12h15 : Où sont les taches dans les simulations de dynamos solaires cycliques ? (Sacha Brun)

12h15-12h30 : Un seuil magnétique pour l'émergence des taches : faire un lien entre les courbes de lumière et les simulations MHD globales (Lucie Degott)

12h30-14h00 : Déjeuner sur place

Thème 1 "Simulations et outils numériques" (suite)

14h00-14h15 : Étude des modes d'une simulation solaire globale à l'aide d'un code hydrodynamique compressible (Grégoire Doebele)

14h15-14h30 : Whistler-mode waves in the tail of Mercury's magnetosphere : A numerical study (Giulio Ballerini)

14h30-14h45 : PHARE : Modeling planetary magnetospheres with Adaptive Mesh and Model Refinement (Ulysse Caromel)

14h45-15h00 : Modeling X-ray Emissions near Earth Magnetosphere During a CME and Magnetopause Extraction from X-ray Image (Qiuyu Xu)

Thème 6 "Activité éruptive ou impulsive dans les plasmas"

15h00-15h15 : Small EUV Brightenings in the Quiet Solar Atmosphere : New Insights from the Solar Orbiter Mission (Susanna Parenti)

15h15-15h45 : Flash poster - Session 2

15h45-16h45 : Pause café et posters

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

16h45-17h00 : THEMIS solar telescope : a new era begins (Etienne Pariat)

17h00-17h15 : Modélisation de la réponse en impédance mutuelle des ondes acoustiques ioniques pour la mission Bepi Colombo (Melody Pallu)

Autres thèmes

17h15-17h30 : Analyse du bilan (BGES) des activités spatiales du LPP (Laurence Rezeau)

17h30-17h45 : Actions pour la transition environnementale à l'IRAP (Victor Réville)

17h45-18h00 : Discussion transition environnementale

18h00-19h30 : Temps libre

19h30-21h00 : Dîner sur place

MERCREDI 3 JUIN

Thème 2 “Nouvelles missions et instrumentation (sol et espace)”

9h00-9h15 : Reconstruction des flux de particules auroraux à l’aide d’instrumentation optique (Mathieu Barthelemy)

9h15-9h30 : Statistical Noise Removal Method for the Mass Spectrum Analyzer on-board BepiColombo/Mio (Sébastien Verkercke)

9h30-9h45 : Émissions radio basses fréquences provenant de systèmes stellaires et exoplanétaires (Philippe Zarka)

9h45-10h00 : European Solar Telescope for the French heliophysics community (Etienne Pariat)

10h00-10h30 : Démos outils pour la communauté

10h30-11h15 : Pause café et posters

Thème 4 “Transport d’énergie multi-échelles et turbulence”

11h15-11h30 : Radiation efficiency of electromagnetic wave modes from beam-generated solar radio sources (Catherine Krafft)

11h30-11h45 : The Life Cycle of Electron Phase-Space Vortices and Their Control of Magnetic Reconnection (Arghyadeep Paul)

11h45-12h00 : Evidence of Langmuir/Z-mode Wave Decay into Z-mode Electromagnetic Radiation in the Solar Wind (Francisco Javier Polanco Rodríguez)

12h00-12h15 : Energy conversion and firehose instability during non-linear phase of tearing-driven reconnection : Hybrid simulation using Mobius boundary conditions (Olga Alexandrova)

12h15-12h30 : J-Filtering : Unveiling Current Structures in Space Plasmas with Multi-point Data Analysis (Mehul Chakraborty)

12h30-14h00 : Déjeuner sur place

14h00-21h00 : Temps libre
AUCUN DÎNER N’EST PRÉVU AU CENTRE DE CONFÉRENCE

JEUDI 4 JUIN

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

9h00-9h15 : Martian Atmospheric Ion Energization And Escape During The 2022 Disappearing Solar Wind Event : A Hybrid Simulation Study (Matías Notonica)

9h15-10h30 : Nouvelles INSU/CNRS, CNES, CEA, ONERA - Discussion SNO

10h30-11h15 : Pause café et posters

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

11h15-11h30 : Connecting Electrons at the Sun and in the Heliosphere through X-ray and Radio Diagnostics (Nicole Vilmer)

11h30-11h45 : Study of thermal non-equilibrium in a 3D hydrodynamic simulation of an active region and comparision with EUV observables (Nicolas Le Nestour)

11h45-12h00 : Fluctuations in Solar Type III Radio Burst Spectra Observed by Parker Solar Probe and Solar Orbiter (Panisara Thepthong)

12h00-12h15 : Fluid and Kinetic Properties of the Near-Sun Heliospheric Current Sheet (Naïs Fargette)

12h15-12h30 : Diagnostic of the suprathermal electrons strahl scattering mechanism with Parker Solar Probe and Solar Orbiter data (Erwan Cherier)

12h30-14h00 : Déjeuner sur place

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

14h00-14h15 : Modélisation de l'accélération des électrons ultra-relativistes dans les ceintures de radiation terrestres (Antoine Brunet)

14h15-14h30 : Investigation of two macroscale energization processes : the Kelvin-Helmholtz instability at the dayside magnetopause and reconnection-driven transport in the plasma sheet (Guillaume Peyrichon)

14h30-14h45 : Characterizing variabilities of Callisto's magnetospheric orbital environment with the Galileo and Juno missions (Thomas Le Liboux)

14h45-15h00 : Reanalysis of Cassini's Saturn Kilometric Radiation source crossing : Search for loss cone Cyclotron Maser Instability (Brieuc Collet)

15h00-15h15 : A new rotation period and longitude system for Uranus at the basis of a long-term analysis of magnetospheric dynamics (Laurent Lamy)

Thème 7 “Relations Soleil-Terre et météorologie de l’espace”

15h15-15h30 : Extension temporelle et robustesse instrumentale des modèles de Deep Learning pour la météorologie de l’espace : étude du modèle SERENADE (Guillerme Bernoux)

15h30-15h45 : Inferring the parametric location of the magnetopause reconnection X-Line from in situ measurements (Ambre Ghisalberti)

15h45-16h45 : Pause café et posters

16h45-17h00 : Modeling the high-latitude MIT system with the IPIM model (Antoine Resseguier)

17h00-17h15 : Global Compression of the Plasma Sheet and Magnetotail During Intense Storms From THEMIS Observations (Soboh Alqeeq)

Thème 6 “Activité éruptive ou impulsive dans les plasmas”

17h15-17h30 : On the acceleration and transport of relativistic particles in solar eruptive events (Karl-Ludwig Klein)

17h30-18h00 : Démos outils pour la communauté

18h00-19h30 : Temps libre

19h30-22h00 : Dîner de conférence sur place

VENDREDI 5 JUIN

Thème 2 “Nouvelles missions et instrumentation (sol et espace)”

9h00-9h15 : Modelling the EUV coronagraphic observations of the Full Sun Imager on board Solar Orbiter (Ganushan Ganesaratnam)

Thème 6 “Activité éruptive ou impulsive dans les plasmas”

9h15-9h30 : Augmentations d’intensités EUV impulsives aux petites échelles le long de boucles du réseau (Antoine Dolliou)

9h30-9h45 : Electron transport in a radiation-dominated plasma, application to solar corona brightenings (Roland Duclous)

9h45-10h00 : Sympathetic flares and magnetohydrodynamical avalanches (Antoine Strugarek)

10h00-10h15 : Thin coronal jets and plasmoid-mediated reconnection : Insights from Solar Orbiter observations and Bifrost simulations (Daniel Nóbrega Siverio)

10h15-10h30 : On resolving the dynamics and Oxygen and Iron ion abundance variations in coronal microjet modelling (Ayu Ramada Sukarmadji)

10h30-11h15 : Pause café et posters

11h15-11h30 : Dynamics of a switchback-like magnetic deflection induced by a propagating coronal jet (Jade Touresse)

11h30-11h45 : Whole-Sun solar jet model to study switchback formation and properties (Léa D'herbomez)

11h45-12h00 : Accélération et transport de particules durant l'orage géomagnétique intense de Mai 2024 (Alexis Rouillard)

12h00-12h15 : Instabilité de dérive électrostatique dans la queue magnétosphérique terrestre : est-elle si universelle que ce que l'on dit ? (Gabriel Fruit)

12h15-12h30 : Magnetic interactions of sungrazing comets : the case of comet Lovejoy (Louis-Simon Guité)

12h30-13h30 : Déjeuner sur place

13h30 : Départ - Fin du colloque

Liste des participants

ALEXANDROVA	Olga	LIRA
ALQEEQ	Soboh	LPP
AMSIF	Kader	CNES
ANNÉZO-SÉBRIE	Esther	ONERA
AULANIER	Guillaume	LPP
AUNAI	Nicolas	LPP
BALLERINI	Giulio	LPP
BARAKA	Mohammed	LPP
BARBIER	Lucas	AIM
BARREAU	Gabriel	AIM
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BIZIEN	Nina	IAS
BLELLY	Pierre-Louis	IRAP

BOCCHIALINI	Karine	IAS
BOMBONEL	Arnaud	IRAP
BOUCHEMIT	Myriam	IRAP
BOURDARIE	Sébastien	ONERA
BRIAND	Carine	LESIA
BRUN	Allan Sacha	AIM
BRUNET	Antoine	ONERA
BUCHLIN	Eric	IAS
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CAROMEL	Ulysse	LPP
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CHANE-YOOK	Martine	IAS et OSUPS
CHERIER	Erwan	LIRA
CHUST	Thomas	LPP
COLLET	Brieuc	LAM
CORBARD	Thierr	Lagrange
CORNU	Florence	LIRA
COUSTILLET	Camille	IRAP
D'HERBOMEZ	Léa	LPP
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DEEGAN	Philip	LPP
DEGOTT	Lucie	IAS

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FERRAND	Renaud	CEA, DAM, DIF
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FROMENT	Clara	LPC2E
FRUIT	Gabriel	IRAP
GANESARATNAM	Ganushan	IAS
GÉNOT	Vincent	IRAP
GISALBERTI	Ambre	LPP
GIRAULT	Ivan	LPP
GONNET	Anderson	IRAP
GUITÉ	Louis-Simon	AIM
HADID	Lina	LPP
HARFF	Vincent	LAM

HENRI	Pierre	LPC2E
HUE	Vincent	LAM
JEANDET	Alexis	LPP
JOUVE	Laurène	IRAP
JOYEUX ALCINDOR	Nicolas	ONERA
KIEOKAEW	Rungployphan	IRAP
KIRKWOOD	Hannah	LPC2E
KLEIN	Karl-Ludwig	LIRA
KOULMANN	Alixende	LMCE
KRAFT	Catherine	LPP
KRASNOSSELSKIKH	Vladimir	LPC2E
KRETZSCHMAR	Matthieu	LPC2E
LABORDE	Emerick	ONERA
LAFFITAU	Ulysse	IRAP
LAMY	Laurent	LAM
LAMY	Philippe	LATMOS
LAVRAUD	Benoît	LAB
LE CONTEL	Olivier	LPP
LE LIBOUX	Thomas	IRAP
LE NESTOUR	Nicolas	LPC2E
LOUARN	Philippe	IRAP
LOUIS	Corentin	LIRA

MAGET	Vincent	ONERA
MAGROU	Jonas	LPP
MAHY	Vincent	LPP
MAKSIMOVIC	Milan	LIRA
MARCHAUDON	Aurélie	IRAP
MASSON	Sophie	LPP
MATIAS	Notonica	LATMOS
MAUDUIT	Emilie	LIRA
MAZELLE	Christian	IRAP
METFAH	Mustapha	LATMOS
MENU	Mélissa	DAM
MICHOTTE DE WELLE	Bayane	NASA
MODOLO	Ronan	LATMOS
MZERGUAT	Slimane	IAS
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ROMERO CASTANEDA	Jorge	LPP
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VERKERCKE	Sébastien	LPP
VILMER	Nicole	LIRA
XU	Qiuyu	LATMOS
ZARKA	Philippe	LIRA
ZASLAVSKY	Arnaud	LIRA

Comités d'organisation

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Action Thématique Soleil-Terre