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Observatoire de Paris - Site de Meudon

Recueil des résumés

Contents

Session 1 / 72

Investigating Galactic Fountain Effects in M101 with SITELLE, THINGS, and GALEX

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Stellar feedback redistributes gas in galaxies, shaping their star formation histories and the structure of the interstellar medium (ISM). Most previous studies of feedback-driven gas flows have focused on edge-on galaxies or examined only some of the wavelengths in the electromagnetic spectrum, limiting the ability to trace the full star formation cycle. Here, we present a multi-wavelength analysis of the nearly face-on spiral galaxy M101, using CFHT SITELLE (0.8″ resolution) for ionized gas, THINGS for HI (6”resolution), and GALEX for UV emission (5″ resolution). The low inclination of M101 provides a unique advantage by minimizing line-of-sight projection effects for the gas ejected above the plane, allowing us to directly identify HI holes and assess whether they coincide with young stellar populations and ionized gas outflows. Previous works have identified dozens of HI holes in M101, spanning a wide range of sizes and including a super-bubble, some of which are accompanied by high-velocity HI shells. This large variety corresponds both to a range of energy and age of the ejection phenomenon. By combining all three tracers, we can quantify the link between past or ongoing star formation, stellar feedback, and the recycling of gas in the ISM. The HII regions detected by SITELLE trace the recent star formation (10 Myr), the UV emission may trace star formation bursts up to 100 Myr, and HI holes larger than 1kpc trace bursts older than 100 Myr. Their spatial correlations provide insights into the timescales of different feedback phases.

Astrophysics Field:

galaxies, observations, feedback

Session 1 / 79

The interplay between galactic bar/bulges and nuclear stellar discs/clusters in Milky Way-like galaxy simulations

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We explore the internal dynamics and formation scenarii of the central regions of galaxies, by ways of Milky Way-like galaxy simulations. Using the SWIFT hydro+N-Body simulation code, we model the growth and evolution of Nuclear Stellar Discs (NSDs)/Nuclear Stellar Clusters (NSCs) under different physical recipes: with and without an initial gaseous disk & with and without stellar feedback effects. We investigate the orbital families of stars found within those structures and how they relate to the ones in the bar/bulge regions. We find that the formation of a bar and its evolution leads to torques and hence to gas infall into the central regions where the cool gas forms a distinct young stellar population. Thus, we find that, in a scenario where most of the mass comes from bar-driven gas infall, the star formation history in these central regions can give insight into the bar formation time. The evolution of the bar as well as the formation of a boxy/peanut bulge lead to variations in the bar properties and locations of resonances, both impacting gas infall and star formation. We quantify the effect stellar feedback has on the star formation efficiency, as well as the imprinted chemistry in these regions and how it relates to the overall chemistry of the disc.

Astrophysics Field:

Galaxies, Galactic Bulge, Galactic Bar

Session 1 / 69

Strong Mixing at the Cosmological Collider

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Apart from its manifest interest in the understanding of the first moments of the universe, the framework of cosmic inflation is also the best way we know to probe fundamental physics at very high energies. In particular, the spontaneous production of massive particles due to the expanding background can leave potentially visible imprints in cosmological correlation functions known as the cosmological collider signal. Within the effective field theory of inflation (EFTI), it is possible to treat these exchange processes in a model-independent way, and explicit computations taking advantage of the conformal invariance of late-time observables have been carried out using various techniques such as the cosmological bootstrap. More recently, the full parameter space allowed by the EFTI has been explored allowing for boost-breaking setups leading to more striking phenomenological signatures, and the recently developed cosmological flow approach numerically gives us access to any correlation function. In this talk, I will expose a treatment of a parameter space region that remains analytically unknown: the strong mixing regime where the inflaton field and the massive particle can experience an infinite number of flavor transformations during the process. I will describe ongoing efforts to describe this regime based on extensions of standard single-field effective field theory techniques.

Astrophysics Field:

Primordial Cosmology

Session 1 / 95

Particle acceleration in UFOs

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Ultra Fast Outflows (UFOs) are sub-relativistic dense winds of wide aperture angle, launched from Active Galactic Nuclei, at which strong shocks (Mach number » 1) are expected to form.

At these shocks, particle energisation through diffusive shock acceleration (DSA) should lead to the copious production of gamma rays and neutrinos, in the interaction of accelerated charged particles and the surrounding circumnuclear medium.

We model proton acceleration through DSA at UFO shocks and estimate the associated high-energy gamma-ray and neutrino fluxes, and investigate the prospects for detection with current and next generation gamma-ray and neutrino observatories.

For a selected list of nearby UFOs, we identify the best candidates for detection with next generation gamma-ray observatories such as CTAO, and discuss the potential for detection with neutrino observatories such as IceCube.

Astrophysics Field:

Cosmic rays / Gamma rays / Particle acceleration

Session 2 / 99

The asteroids Ryugu and Bennu. Investigating aslteration processes recorded in the Phyllosilicates of Bennu sample

Auteur: Laura Nardelli[1]

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Carbonaceous asteroids are considered to best preserve the early Solar System's mineralogical and molecular phases, but they have undergone transformation through space weathering and aqueous alteration. Sample-return missions like NASA's OSIRIS-REx and JAXA's Hayabusa2 have provided uncontaminated materials from asteroids Bennu and Ryugu, respectively, allowing for direct analysis. My study compares the phyllosilicate composition of both asteroid samples using hyperspectral microscopy and infrared spectrometry. Initial findings show similarities but also significant heterogeneity within Bennu's sample, particularly in OH and Si-O spectral features, suggesting distinct alteration processes. Further analysis aims to refine our understanding of these asteroids' formation and evolution.

Astrophysics Field:

Planetology and astrochemistry

Session 2 / 81

Unveiling the dynamics and physical property of asteroid systems based on Gaia astrometric data

Auteur: Ziyu Liu[1]

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Gaia is a space mission from the European Space Agency (ESA) that was launched in 2013. Apart from the survey of stars, it is also highly valuable to study solar system objects (SSO) with high precision. Its latest data release in October 2023 includes 66 months of data on about 160,000 SSOs. Gaia' s precise measurements can reveal astrometric signals of binary asteroids, for example the recently discovered (4337) Arecibo system. In this study, we analyze all available Gaia data on this system, estimating the mutual orbits, mass, and density of its components. Our findings suggest an ice-rich body in the outer main belt. The goal of this research is to demonstrate the scientific value of Gaia data on the study of solar system.

Astrophysics Field:

asteroids, Gaia, astrometry

Session 2 / 73

Characterisation of gas giant exoplanets through atmospheric modelling

Auteur: Alice Radcliffe[1]

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Despite the challenge of directly imaging exoplanets, we are seeing, thanks to instruments like JWST/NirSpec, ESO/CRIRES+ and ESO/HiRISE, the advent of high-spectral resolution observations tragetting wide-orbit gas giants; these Rosetta stones of planetary processes render the field mature to advance studies aimed at unveiling the atmospheric composition, orbital characteristics, chemistry, formation and evolution of exoplanets. To this end, the community is devising new multidimensional grids of simulated spectra, including the high-spectral resolution (R=200,000) model I have been developing: these are an updated, high-resolution version of the Exo-REM [1] 1-D radiative-convective model, with C/O ratio values, surface gravity, metallicity and effective temperature as model parameters. Exo-REM, so far only existing at low to medium resolutions, has been shown to robustly reproduce the L-T transition thanks to its inclusion of clouds and non-equilibrium chemistry. At high resolutions, this model allows us to unlock a myriad of information such as atmospheric abundances, surface gravity and vsin(i), which are poorly constrained with lower resolutions. The grids emerging from this model are state-of-the-art, as they incorporate the most up-to-date line lists and isotopologue abundances, which is key at these high resolutions. These allow us to carry out forward modelling on specific targets, most notably the elusive Af lep b. I will be presenting new results emerging from this such as evidence for the presence of H2O and CH4 in its atmosphere, and a value of C/O ratio, an important tracer for the type of planetary formation it underwent. With the impending bridge of the gap between directly imageable planets and those with closer orbits, we may hope to someday use such models on smaller and cooler planets, thus contributing to a deeper knowledge of the formation pathways for a wide variety of planets.
[1] "A Self-consistent Cloud Model for Brown Dwarfs and Young Giant Exoplanets: Comparison with Photometric and Spectroscopic Observations", Charnay et al. 2018

Astrophysics Field:

exoplanets, modelling, atmospheres

Session 2 / 76

Investigation of the Low Latitude Boundary Layer (LLBL) in Mercury's Magnetosphere Using MESSENGER Data

Auteur: Xue WANG[1]

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A comprehensive analysis of Mercury's Low-Latitude Boundary Layer (LLBL) has been studied using MESSENGER observations from 11 March 2011 to 30 April 2015. LLBL events were classified into three distinct categories based on energy dispersion trends: increasing, decreasing, and unclear cases. The results indicate significant differences in plasma transport mechanisms, energy evolution, and spatial distribution. Increasing cases are characterized by a continuous energy transition from the magnetosheath to the magnetosphere, suggesting efficient plasma penetration. In contrast, decreasing cases exhibit discontinuous energy transitions at the LLBL-magnetosphere boundary. Proton density, temperature, and pitch angle distributions further differentiate these LLBL types. Statistical analysis reveals a strong dependence on interplanetary magnetic field (IMF) orientation, with a majority of LLBLs occurring under northward IMF conditions, especially for flank dawn and dusk. Dawn-dusk asymmetry is also evident, with increasing cases dominating the dawnside and decreasing cases prevailing on the duskside. LLBL formation mechanisms vary across spatial regions. Future observations from BepiColombo's MSA instrument are expected to refine our understanding of Mercury's LLBL dynamics.

Astrophysics Field:

Space physics

Session 2 / 98

3D Modelling of methane convective clouds on Titan

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Methane is the second most abundant component of Titan's atmosphere (~5% at the surface). The temperature and pressure enables liquid methane at the surface, forming lakes. In the atmosphere, methane can condense and form clouds, and rain. Titan clouds are monitored from Earth telescopes, but detailed images are scarce and come from the Cassini-Huygens mission that took place between 2004 and 2017. To know more about methane convective clouds, we use a new cloud resolving model adapted to Titan. The model is composed of dynamics coming from the WRF model (a model widely used for Earth meteorology), and of a physical part coming from the Titan-Planetary Climate Model (de Batz de Trenquelléon 2025). Here we present the first results of this model.

Astrophysics Field:

Planetology

Session 3 / 61

Diagnosing Systematic Effects Using the Inferred Initial Power Spectrum

Auteur: Tristan Hoellinger[1]

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The next generation of galaxy surveys has the potential to significantly deepen our understanding of the Universe, though this potential hinges on our ability to rigorously address systematic uncertainties. This was previously beyond reach in field-based implicit likelihood cosmological inference frameworks. We aim at inferring the initial matter power spectrum after recombination to diagnose a variety of systematic effects in galaxy surveys prior to inferring the cosmological parameters. Our approach is built upon a two-step framework. First, we employ the SELFI algorithm to infer the initial matter power spectrum, which we utilise to comprehensively investigate and disentangle how systematic effects influence the power spectrum reconstruction, using a single set of N-body simulations. Second, we obtain posterior cosmological parameters via implicit likelihood inference, recycling the simulations from the first step for data compression. We rely on a model of large-scale spectroscopic galaxy surveys that incorporates fully non-linear gravitational evolution and simulates multiple systematic effects typically encountered in astrophysical surveys. We demonstrate along with a practical guide how the SELFI posterior can be utilised to thoroughly assess the impact of misspecified linear galaxy bias parameters, selection functions, survey masks and inaccurate redshifts on the initial power spectrum after recombination. We show that a subtly misspecified model can lead to a bias greater than 2σ in the (Ωm, $\sigma 8$) plane, which we are able to detect and avoid using SELFI prior to inferring the cosmological parameters. This framework has the potential to significantly enhance the robustness of physical information extraction from full-forward models of large-scale galaxy surveys such as DESI, Euclid, and LSST.

Astrophysics Field:

cosmology, large-scale structure, statistical methods

Session 3 / 91

A catalog of high significance cosmic voids

Auteur: Rosa Malandrino[1]

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Cosmic voids are the largest objects emerging in the cosmic web, covering the majority of the volume of the Universe. They are a well-established probe to gather cosmological information from the large-scale structure, as well as interesting regions to study how an underdense environment affects the behaviour of astrophysical objects. Unfortunately, identifying voids from galaxy surveys is a challenging task: observational effects such as holes in the mask or magnitude selection hinder the detection process, while galaxies are biased tracers of the underlying dark matter distribution. Furthermore, with a single realization of the Universe, the characterization of statistical errors is not straightforward.

In order to overcome these problems, we use a set of constrained simulations of the large-scale structure that are consistent with the observed galaxies, effectively representing statistical independent realization of the probability distribution of the cosmic web. We combine the voids that are detected in separate simulations, accepting only the regions that are labeled as underdense with high statistical significance. As this framework is fully Bayesian, we evaluate the probability distributions of the positions and radii of the voids. Finally, we characterize the actual shape of these regions, effectively producing a template for density environments that can be used in astrophysical applications such as galaxy evolution studies.

Astrophysics Field:

voids, large-scale structure, cosmology

Session 3 / 75

Non-transiting exoplanets as a means to understand star-planet interactions in close-in systems

Auteur: Clémence Gourvès[1]

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Since 1995, more than 5,000 exoplanets have been discovered, largely thanks to the transit detection method. However, most exoplanetary systems do not exhibit transits, limiting this method to detecting only about 10% of existing exoplanets. To gain a more comprehensive understanding of exoplanet populations, alternative detection approaches are needed.
One particularly intriguing trend in the exoplanetary population is the dearth of close-in exoplanets around fast-rotating stars. This depletion zone results from the combined effects of intense tidal and magnetic interactions between the planet and its host star, acting on short timescales. Detecting more exoplanets undergoing such interactions is therefore crucial for refining our understanding of the underlying physical mechanisms. Fortunately, some non-transiting close-in exoplanets can be detected in photometry thanks to the signature of their phase curve.
In this talk, I will present a new search for non-transiting exoplanets in the Kepler data, focusing on very short orbital periods (below 2.3 days). Through the analysis of photometric variations in host star light curves, I identified 91 new objects whose signatures are consistent with the presence of a non-transiting exoplanet. I will also show that this sample lies within the depleted region associated with short-timescale orbital evolution around fast rotators. This new sample, if confirmed, could provide valuable insights into star-planet interactions in close-in systems.

Astrophysics Field:

Planets and satellites: detection. Star-Planet Interactions. Stars: solar-type

Session 3 / 64

A catalog of stellar magnetic fields for exoplanet radio emission predictions

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In the Solar system, planetary radio emission is strongly correlated to incident magnetic power (similar to the Poytning flux). To test this observational law in other stellar systems, and use it to determine interesting observation targets, we need to get an estimation of the stellar magnetic field of the host stars.
Here, we work on the compilation of measures of stellar magnetic fields from the literature, to form a catalog, and from this catalog, we try to infer relations allowing us to estimate the magnetic field using other correlated stellar parameters.

Astrophysics Field:

Stellar physics, star-planet interactions, exoplanet detection

Session 4 / 83

Turbulence in and around galaxy clusters

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Galaxy clusters are the most massive gravitationally bound structures in the universe. They are mostly made of dark matter, inducing a deep gravitational potential well, in which baryons are accreted from the cosmic web and heated up to millions of Kelvins, we call it the Intra-Cluster Medium (ICM). Lots of complex and linked physics processes happen in the ICM, one of them is turbulence. In this talk I will present why and how to study turbulence in the ICM and in the local environment of clusters using cosmological simulations.

Astrophysics Field:

Cosmology

Session 4 / 96

Dynamical Heating by Superbubbles and the Cusp-Core Transformation

Auteur: Eunhee Ko[1]

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Recent JWST observations have revealed superbubbles (SBs)—cavity-shell structures distributed across the galactic disk—formed by successive supernova explosions. The potential fluctuations generated by SBs can dynamically heat galactic systems. Using the orbit-averaged Fokker-Planck equation, we investigate the role of SB-driven stochastic heating in the context of cusp-core transformation. This formalism describes the cumulative impact of weak, local encounters induced by stochastic noise sources. By modeling the expansion and collapse of SBs, along with their inhomogeneous spatial distribution, we derive diffusion coefficients linked to the power spectrum of SB-induced fluctuations. Furthermore, we find simple analytic scaling relations that provide an intuitive understanding of how diffusion efficiency depends on noise source and system parameters.

Astrophysics Field:

Galaxy, Superbubble, Theory

Session 4 / 54

Impact of the M31 merger on the timing argument estimate of the Local Group mass

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The timing argument (TA) associates the motion of the Milky Way (MW) and Andromeda Galaxy (M31) to their internal gravity, and aims to find the total mass of the Local Group (LG). However, the classical TA always overestimates the LG mass, presumably because it ignores the hierarchical scenario and other interactions such as that with the Large Magellanic Cloud (LMC). This work focuses on the impact of the recent major merger experienced by M31. We used three models of this merger to account for its impact on the peculiar motion of the M31 within the simple two-body and point-mass system of the TA calculation. We found that the addition of the merger can both increase or decrease the TA mass depending on the tangential motion of M31, which has large uncertainties. Our result agrees with the findings from cosmological simulations, for which TA mass is found to be either higher or lower than the virial mass for LG analogues. If we determine the M31 tangential motion to search for the LG lowest mass, the M31 merger correction alone does not lower enough the TA mass to the level LG mass determined by the Hubble flow perturbation. However, the TA mass is found to be in agreement with the LG mass if both the M31 merger and LMC impact are corrected at the same time. Finally, we find that the TA is limited by the hierarchical scenario, since it becomes increasingly difficult to determine the progenitors of both MW and M31 at the earliest epochs.

Astrophysics Field:

Galaxies: Local Group –Galaxies: interactions –Galaxies: evolution

Session 4 / 94

The seperate universe approach to multifield inflation

Auteur: Hugo Holland[1]

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Primordial black holes could constitute part or all of dark matter but they require large inhomogeneities to form in the early universe. These inhomogeneities can strongly backreact on the large scale dynamics of the universe. Stochastic inflation provides a way of studying this backreaction and getting an estimation of the abundance of primordial black holes. Because stochastic inflation focuses on large scale dynamics, it rests on the separate universe approach. However, the validity of this approach has only been checked in single field models, but not in multifield models in which we expect strong boosts in the power spectrum, leading to the formation of primordial black holes. We will check the validity of a separate universe approach in multifield models by matching it with a complete cosmological perturbation theory approach at large scales. In particular, we wish to compare these two paradigms and their differences in the adiabatic and entropic directions of the phase space. This will give us a range of validity and conditions one needs to verify in order to apply the separate universe approach and stochastic inflation in multifield models. We will then focus on gauge fixing in these two paradigms and check when the matching still holds.

Astrophysics Field:

Theoretical cosmology

Session 4 / 102

Zoom-in Numerical Simulations for Star Formation

Auteur: Georges Abboudeh[1]

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Star formation plays a crucial role in shaping its environment and is central to the evolution of planets, the interstellar medium, galaxies, and the universe as a whole. To bridge the gap between galactic-scale processes—where the initial conditions for star formation are set—and the formation of individual stars, we conducted state-of-the-art numerical simulations of a portion of a galaxy. These simulations include a wide set of physical processes, including gravity, turbulence, magnetic fields, radiative heating and cooling, and stellar feedback. From this simulated volume, we selected multiple active star-forming regions and used adaptive mesh refinement (AMR) techniques to zoom in and resolve star formation at high resolution. We analyze the statistical properties of the resulting stellar populations and explore how they vary across different regions, providing insights into the diversity of star formation environments within galaxies.

Astrophysics Field:

Star Formation - Numerical Simulations

Session 5 / 74

High time-resolution analysis of X-ray data from Proxima Centauri

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The study of X-ray and extreme ultraviolet (together, XUV) emission from stars has experienced a renewed interest in recent years. The focus has shifted from the study of stellar physics towards the effects of these emissions on exoplanet atmospheres, and is now part of a bigger field concerned with star-planet interactions. Particular attention is given to M dwarfs, low-mass, cool stars that are the most common in our galaxy. Their systems are the most promising to detect and characterize Earth-like, potentially habitable planets. M dwarfs are known for their long-term activity. Although their flares are typically weaker (in terms of energy) than those usually found in our Sun, the small distances that define the habitable zone (HZ) for these stars imply that HZ planets around them may experience significantly more XUV fluxes. The combination of long-term activity and high XUV fluxes makes variability, in terms of dynamic range and frequency, a main concern to establish whether these planets retain their atmospheres. Stellar XUV radiation is extremely difficult to measure, as it is easily absorbed by the interstellar medium. For this reason, Proxima Centauri, the closest neighbor to us and classified as a flaring M dwarf, represents one of the best candidates for in-depth studies of XUV radiation. We have analyzed archival data of Proxima Centauri from the XMM-Newton and Chandra telescopes, and produced temporal series of its X-ray emission. We have paid special attention to calibration and time-binning.

We propose an original pile-up correction and find that, depending on the treatment of this instrumental effect, fluxes of radiation with energy between 0.3 and 5.0 keV may vary by up to 30%. Pile-up-induced flux-loss is a function of energy and, during the brightest flares, it can reach up to 200% for emissions between 2.5 and 5.0 keV. It reaches 350% when extrapolating the spectra to 10 keV. The quiescent and the flaring emissions from Proxima Centauri are characterized both in energies and in frequencies using nearly 6 days of observations spanning 19 years. Luminosities in the 0.3 - 5.0 keV energy range are presented with uncertainties less than 6% and average time-resolution of 10

minutes. Rates for extreme events are extrapolated from the distributions under different assumptions.

Astrophysics Field:

X-rays, M-dwarves, Exoplanets

Session 5 / 100

Oceanic tides : a hierarchy of models

Auteur: Baptiste Loire[1]

Co-auteurs: Frédéric Hecht [2]; Gwenaël Boué [1]; Jacques Laskar [1]; Pierre Auclair-Desrotour [1]; Yvon Maday [2]

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Oceanic tides play a fundamental role in the evolutionary dynamics of some orbital systems, influencing energy dissipation significantly. Their detailed understanding and precise quantification provide answers ranging from the fate of an orbit to the history of a planet. Achieving this understanding entails a stepwise incorporation of physical parameters, while accurate quantification demands reaching a level of realism commensurate with the intricacies of oceanic dynamics. Starting from validating the results of the analytical models, a numerical method allows then the introduction of a realistic bathymetry and continentality and the possibility to add non-linear terms. This presentation showcases results obtained from a numerical approach using finite elements for various oceanic tides models of increasing complexity and the work in progress to take into account a non-linear drag effect.

Astrophysics Field:

Oceanic tides, Earth-Moon system, Orbital evolution

Session 5 / 60

Cosmic Shear Nulling as a geometrical cosmological probe: methodology and sensitivity to cosmological parameters and systematics

Auteur: David Touzeau[1]

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The Weak Lensing Shear is a powerful probe of cosmology. Along with Galaxy Clustering and the cross-correlation of those two probes, it gives the most effective set of Data, used by cosmological observations, to constrain cosmological parameters and study the large-scale structure of the universe. Yet, the nature of the Dark Energy, representing around 68% of the energy content of our current universe, is still unknown. Thus, any additional cosmological feature, data or probe that would give new constraints or information on cosmological parameters is of interest. One of those features could be the BNT (Bernardeau, Nishimichi, Taruya) transform as it provides a mostly geometrical property

of Weak Lensing: The Nulling of the galaxy-galaxy lensing Cross-Spectra. This feature does not depend on the Galaxy Power Spectrum but only on background geometry of space time and brings few additional systematics to the current analysis on Weak Lensing and Galaxy Clustering. As part of the Euclid consortium, we wish to exploit the Nulling property of the BNT transform to reduce theoretical uncertainties on Dark Energy parameters derived by the Euclid Mission.

We present this idea in the context of the Euclid mission in the following paper: https://arxiv.org/abs/2502.02246 and in a more general context for future survey in the following letter: https://arxiv.org/abs/2502.02243

Astrophysics Field:

Cosmology LSS DarkEnergy

Session 5 / 84

Generation of Cosmological Simulations via Diffusion Models

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Next-generation large galaxy surveys, such as Euclid and DESI, will provide unprecedented datasets to tackle fundamental cosmological questions: What is the nature of dark matter? What drives the accelerated expansion of the universe? Exploring these mysteries requires the analysis of the three-dimensional distribution of large-scale structures, collectively known as the cosmic web, which form through the gravitational evolution of primordial density fluctuations in the early universe. However, statistical analyses of these datasets require an enormous number of numerical simulations that emulate the cosmic web, a process that is very computationally expensive. A potential way to circumvent this problem is to employ machine learning techniques, specifically generative models, which can generate these simulations orders of magnitude faster while also faithfully reproducing the statistics of the cosmic web. In this project, we utilise the power of generative models, particularly diffusion models trained on cosmological simulations, to overcome these computational constraints.

Astrophysics Field:

Cosmological Simulations, Generative Models, Diffusion Models

Session 6 / 62

Real-time detection and characterisation of solar flares from ground-based VLF data

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Solar flares are fast increases in the X-ray flux. When they reach Earth, these energetic radiations ionize the atmosphere, increasing thus the electron density down to the lowest D-region of the

ionosphere (60km). This, in turn, causes a greater absorption of the HF waves, which are frequency bands used by several actors like civil aviation and emergency services. Real-time detection of solar flares is thus needed to mitigate radio communications.

To study the D-region, we use Very Low Frequency waves, which propagate in the Earth-ionosphere waveguide. The rise in electron density during solar flares induces a change in the conductivity of the waveguide upper limit, which impacts the propagating waves. Ground-based VLF instruments are thus very efficient in detecting solar flares and enable continuous surveys of remote regions (such as oceans).

We present here a system for detecting and characterizing solar flares, based on the real-time analysis of VLF waves and an incremental algorithm based on the automated detection of the slope changes in the data (Guralnik & Srivastava, 1999). As a result, 85 % of the moderate and strong flares (M to X) are detected within 2.6 min (in average) after their start, forming the first step of a real-time alert system.

Astrophysics Field:

Space weather, Ionosphere, Solar flares

Session 6 / 92

3D Modelling and observations of solar flares

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The Sun is a fascinating physics laboratory where periodically phases of strong activity and of quietness alternate during a eleven years cycle. The phase of strong activity is linked to the appearance of sunspots. These sunspots are cooled down regions of the sun and are the place of energetic events called solar eruptions.

Solar eruptions are major events corresponding either to solar flares which are transient, energetic brightenings occurring in strong and complex magnetic structures. It happens due to the reconfiguration of the magnetic structures releasing energy up to 10^{32} erg in diverse forms (radiative, thermal and particle accelerations). The solar flares are sometimes associated to ejection of solar materials following magnetic structures expelled from the solar atmosphere. They are called, coronal mass ejections (CMEs), and are one of the main perturbation in the heliosphere, which can cause geomagnetic storms when Earth is on the trajectory of these CMEs. These geomagnetic storms can have a huge impact on our economy.

In order to decipher these complex events, we need to use MHD simulations and observations conjointly. The use of different methods and tools is essential to dive into the convoluted processes occuring in the solar atmosphere. Our ultimate goal is to replicate the behaviour of the Sun and to predict the next solar eruptions that could impact us on a global scale.

Astrophysics Field:

Solar Physics, MHD, Simulation

Session 6 / 86

Simulation solaire sur grille non-cartésienne avec Dyablo

Auteur: Gregoire Doebele[1]

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Auteur correspondant gregoire.doebele@cea.fr

La physique solaire a encore beaucoup de défis à relever, tels que l'origine de son cycle solaire de 11 ans, la formation de taches solaires et leur rôle sur l'établissement du cycle magnétique, ou le déclenchement des éruptions solaires et le chauffage de son atmosphère étendue. Pour étudier ces questions difficiles il est nécessaire de développer de nouveaux outils afin de les traiter comme un tout cohérent. C'est le but du projet *ERC Whole Sun*, et dans cette optique, un nouveau code *Dyablo -Whole Sun* a été créé au sein de l'IRFU pour pouvoir modéliser le soleil comme un tout. C'est un code de volumes finis sur grille cartésienne avec raffinement adaptatif de maillage (AMR) qui doit pouvoir s'exécuter efficacement sur les super calculateurs exascale.

J'ai adapté ce code pour y ajouter de nouveaux types de géométries à l'aide de fonctions qui font correspondre la grille physique (non-cartésienne) vers la grille logique (cartésienne). J'ai implémenté de nouveaux solveurs (hyperbolique & parabolique) pour prendre en compte ces nouvelles géométries. J'ai vérifié la validité de mes solveurs sur différentes grilles et sur différents tests (sod, blast, rayleigh-taylor, …). Puis j'ai appliqué cette méthode au cas de la convection solaire.

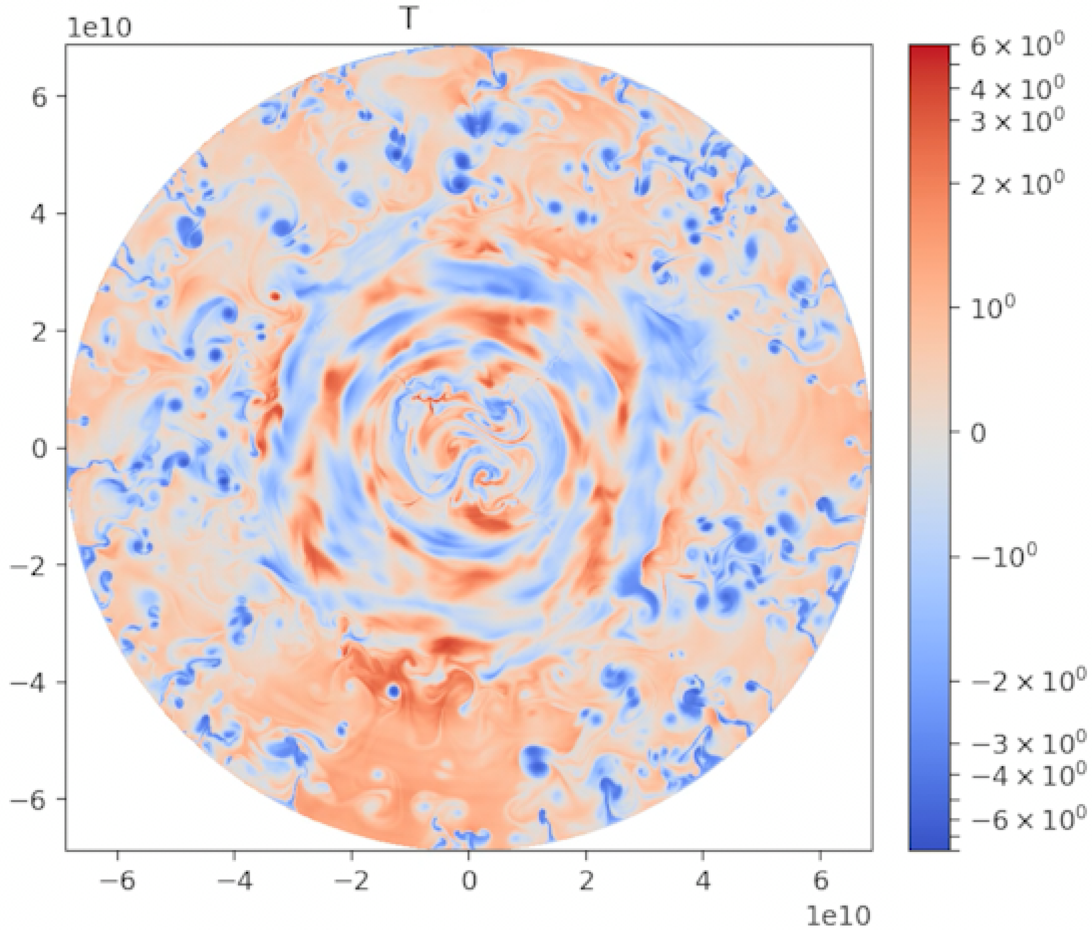

Figure 1: Convection solaire 2d

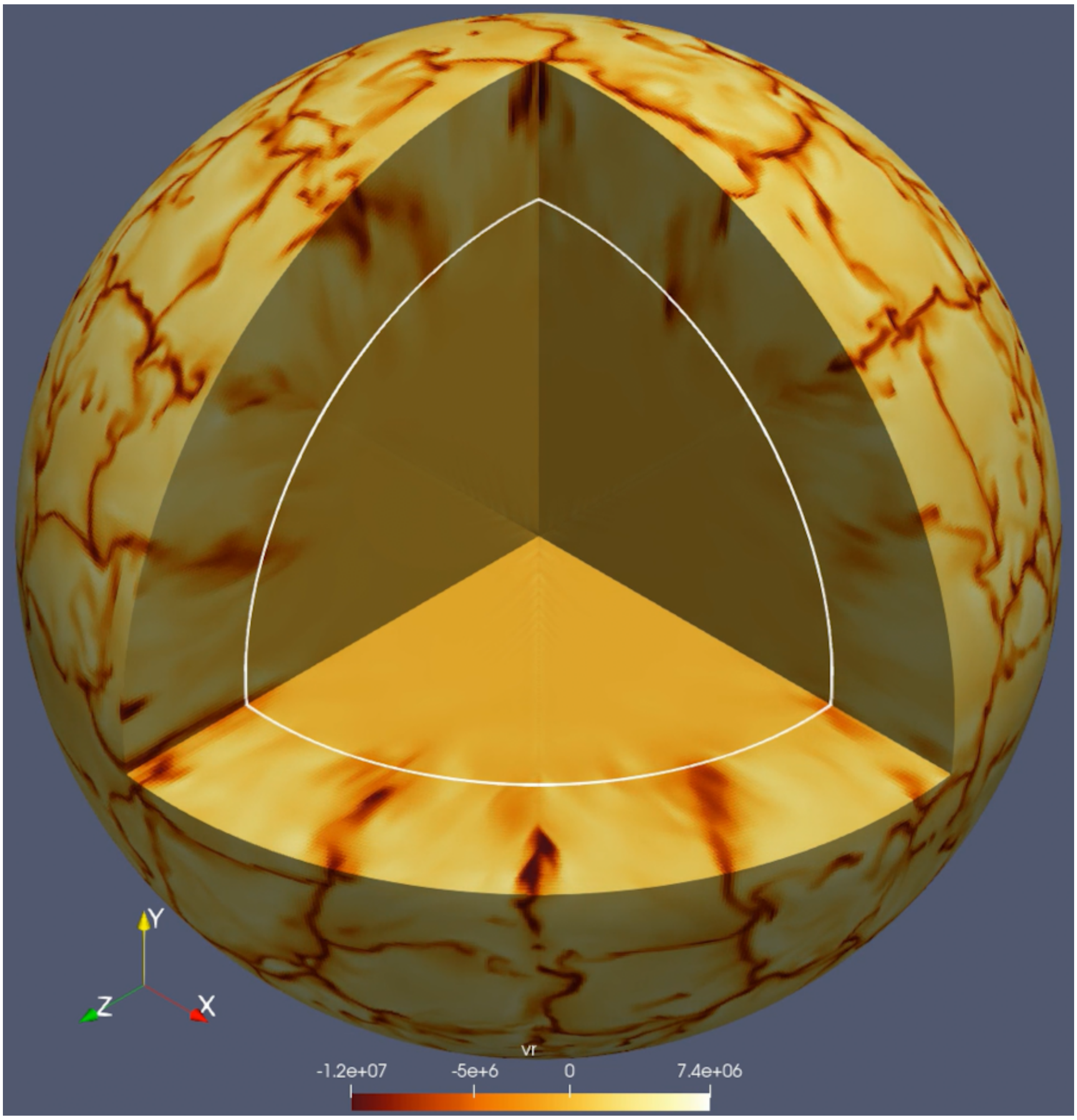

Figure 2: Convection solaire 3d

Astrophysics Field:

Numerical simulation, Solar physics

Session 6 / 88

Searching for galaxy protoclusters in Euclid quick release

Auteur: Tanguy DUSSERRE[1]

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The largest structures in the Universe to fully overcome cosmic expansion by their gravitational attraction are galaxy clusters. When they are still in their formation phase, they are called galaxy protoclusters and are expected to play an important role in star formation, giving rise to an epoch

called the Cosmic Noon (cosmological redshift $z \sim 2-3$). My goal is to find precise characteristics of the gas in galaxy protoclusters. To do so, I investigated Euclid Quick Release and found promising candidates in fields where the Planck satellite had previously detected a high star formation rate at Cosmic Noon redshift.

Astrophysics Field:

protoclusters

Session 6 / 93

Searching for successors: The fate of Little Red Dots at z<4.

Auteur: Jean-Baptiste Billand[1]

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The James Webb Space Telescope (JWST) has discovered a very surprising type of galaxy, a large population of compact red objects known as Little Red Dots (LRDs). To this day, this population remains misunderstood because of two opposing explanations: either they can be compact dusty star forming galaxies or Active Galactic Nucleus (AGNs). In both cases, the physics involved is very extreme, reaching the limit of our understanding of structure formation and super massive black holes seeds. This population also raises another puzzling question: where are they at low redshift? Indeed, they are typically observed at high redshift with 4<z<9. This last question is one of my goals as a first-year PhD student.

In this talk, I intend to present the work I have carried out to date: Using JWST NIRCam data in the CEERS field of view, I built a sample of 100 candidate galaxies that would succeed these LRDs. To see if this sample is a good candidate for evolved LRDs, I compare masses, compactness, number density and the usual selection criteria applied to select LRDs. The results are very promising: this sample is very similar to LRDs but at a lower redshift, with common characteristics such as mass (~10^10 M⊠), the central mass density (~10^11 M⊠.kpc^-2) and colors. One of the main differences is that this sample has benefited from a physical extension (Re~1 kpc) compared to the unresolved LRDs (Re < 0.5kpc). Moreover, this periphery seems to grow with z, which could be a sign of evolution over time. Finally, a correlation between the growth of this periphery and the presence of the V-shape is observed. All these clues could help explain the true nature of LRDs and answer the question of where are they at lower redshift.

Astrophysics Field:

Galaxy formation & evolution

Session 7 / 78

Advanced sky subtraction techniques and blind detection of Lyman Alpha Emitters in MOONS GTO data

Auteur: Kevin LUKE[1]

Co-auteurs: Mathieu Puech [1]; Myriam Rodrigues [2]

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MOONS/ Multi Object Optical and Near-infrared Spectrograph is a new fibre fed spectrograph that will be installed at the ESO's/ European Southern Observatory's VLT/Very Large Telescope at La Paranal, Chile. MOONS which will operate from 6000A to 18000A wavelength range will have very high multiplex of 1000 fibres and will use the full 25 arcminutes field of view of 8m mirror VLT and will make redshift surveys like SDSS at larger scale spanning from optical to near infrared regions. MOONS1D is a science simulator developed for the MOONS instrument by Dr. Myriam Rodrigues. I have redesigned the simulator so that it will be a high fidelity science spectra simulator with its inputs and outputs very closely resembling that of the actual instrument. The simulator takes realistic ESO OB as input along with ESO PAF fibre positioning information file and standard templates and simulates the entire observation to provide output based on the current data model of MOONS. The current version of simulator has been bench marked with the ESO's Exposure Time Calculators. From the simulated spectra I will develop new sky subtraction strategies based on PCA/NNMF analysis and neural networks for MOONS. After bench marking the strategies I will use these sky subtraction strategies to perform blind detection of Lyman Alpha Emitters in the MOONS data from the GTO/ Guaranteed Time Observation program.

Astrophysics Field:

Spectroscopy, Galaxies, Very Large Telescope

Session 7 / 56

Is turbulent convection the only exciting mechanism of acoustic modes in solar-like oscillators?

Auteur: Eva Panetier[1]

Co-auteurs: Antonio Jiménez [2]; Rafael A. García [3]; Sylvain N. Breton [4]; Thierry Foglizzo [5]

[1] *Université Paris Cité, Université Paris-Saclay, CEA, CNRS, AIM*

[2] *Instituto de Astrofísica de Canarias (IAC), Universidad de La Laguna (ULL), Departamento de Astrofísica*

[3] *Université Paris-Saclay, Université Paris Cité, CEA, CNRS, AIM*

[4] *INAF –Osservatorio Astrofisico di Catania, Italy*

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Auteur correspondant eva.panetier@cea.fr

The solar convective envelope generates, by dynamo effect, a surface magnetic field whose strength evolves on an 11-year cycle, with a change in polarity at the end of each cycle. A similar magnetic variability exists in other solar-type stars, influencing their dynamics. Furthermore, solar-like oscillators experience acoustic modes whose properties, such as their frequency, amplitude and energy vary over time in relation to the activity cycles. The turbulent motions in the convective envelope of these stars were so far considered as the only mechanism for exciting the modes. In this work, we investigate the variation of mode excitation during Cycles 23, 24, and the beginning of Cycle 25 for the Sun. To do so, we analyze data obtained since 1996 by the VIRGO SunPhotometers on the SoHO satellite, using a method that provides a better time resolution than classical methods such as peakbagging. By combining the small-time-scale variations in energy for several low-degree modes, we found a statistical discrepancy in the observed excitation rate compared to the one expected under the hypothesis that modes are only stochastically excited by convection. Our results indeed show that several modes can be excited at the same time. During this presentation, we will explore the possible sources of high energy in the modes, i.e. instrumental problems or other exciting mechanisms, which may be linked to the magnetic cycle of the star, such as flares or Coronal Mass Ejections, and compare the results with data from the GOLF spectrometer, also carried by SoHO. Applying the same analysis to a sample of 51 seismic stars observed by Kepler, which show magnetic variability, we found a similar behavior for 14 of them.

Astrophysics Field:

Stellar and Solar Physics

Session 7 / 57

LINKING THE SUN TO THE HELIOSPHERE: MEASUREMENTS OF THE SOLAR HELIUM ABUNDANCE WITH THE SOLAR ORBITER SPACE MISSION (ESA/NASA)

Auteur: Ganushan Ganesaratnam[1]

[1] *Institut d'Astrophysique Spatiale*

Auteur correspondant ganushan.ganesaratnam@universite-paris-saclay.fr

Résumé:

Du fait de sa masse et de son abondance, l'hélium joue un rôle fondamental dans de nombreux processus astrophysiques. La compréhension des phénomènes physiques qui lui sont associés ainsi que la détermination de son abondance ont des répercussions dans des domaines aussi variés que la cosmologie, la modélisation stellaire ou l'étude du vent solaire. Si des caractérisations des propriétés de l'hélium existent à la surface du Soleil et dans le vent solaire, très peu existent entre les deux, c'est-à-dire dans la couronne de l'étoile. Or c'est dans cette région qu'agissent les mécanismes encore mal compris d'accélération du vent solaire.

Les instruments EUI (Extreme Ultraviolet Imager) et Metis de la mission Solar Orbiter de l'Agence Spatiale Européenne (lancée en février 2020) ont la capacité de cartographier pour la première fois la distribution spatiale d'hélium dans la couronne solaire en observant simultanément les raies Lyman alpha des ions H0 et He+. L'IAS est co-responsable scientifique de EUI et est collaborateur de l'instrument Metis. Une analyse préliminaire des données obtenues montre clairement des variations de l'abondance d'hélium à la frontière entre régions de lignes de champ magnétique ouvertes et fermées, co-spatialement à une augmentation de la température. Cette morphologie n'était pas attendue, montrant que les modèles utilisés jusqu'à présent ne capturent pas toute la physique du vent solaire.

L'objectif de la thèse est de poursuivre l'analyse des observations déjà effectuées et d'en réaliser de nouvelles afin de quantifier les variations d'abondance observées. Pour ce faire, en se basant sur des codes numériques existants, il sera nécessaire de développer un modèle complet permettant de simuler l'émission coronale dans la bande passante de l'instrument. Dans un deuxième temps, les résultats obtenus seront comparés avec des modèles de vent solaire.

Abstract:

Because of its mass and abundance, helium plays a fundamental role in many astrophysical processes. The determination of the abundance of helium has consequences in a variety of fields including cosmology, stellar evolution models, or the study of the solar wind. However, if the properties of helium are characterized in the photosphere and in the solar wind, few observations exists in the corona of the star, where the still unexplained acceleration processes are taking place.

EUI and Metis on board the Solar Orbiter mission of the European Space Agency (launched in February 2020) are able for the first time map the spatial distribution of Helium in the solar corona by simultaneously observing the Lyman alpha lines of H0 et He+. IAS led the development of the EUI wide field imager and is collaborator of the Metis instrument. Preliminary analysis reveals bright structures located at the boundary between regions of open and closed magnetic field lines. Increases of temperatures are also measured in these areas. This morphology was unexpected, which shows that the existing models do not capture all the physics at play in the solar wind. In particular, these structures seem to be a signature of local helium abundance variations.

The aim of this thesis is to quantify these variations and to develop a coherent model of the solar wind propagation taking into account these new observational constraints. Building upon existing codes, it will be necessary to develop a comprehensive model of the coronal emission in the passband of the instrument. Then it will be interesting to compare our model to solar wind models.

Astrophysics Field:

Astrophysics, Solar physics, Plasma physics

Session 7 / 71

Characterization of molecular biomarkers in lava tube samples, as analogues for Mars: implications for Martian subsurface habitability and exploration

Auteur: Clara Christiann[1]

Co-auteurs: Maëva Millan [1]; Mathilde Mussetta ; Dina M. Bower [2]; Amy C. McAdam [2]; Sarah Stewart Johnson [3]; Cyril Szopa [4]

[1] *LATMOS*

[2] *NASA Goddard Space Flight Center*

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[4] *LATMOS, UVSQ*

Auteur correspondant clara.thomas@latmos.ipsl.fr

The search for traces of past or present life is a major objective of the exploration of Mars. Subsurface environments, such as caves and lava tubes, are of significant exobiological interest for their potential as both refuges for extant life and/or reservoirs for 'preserved'traces of life (i.e., biosignatures). Unlike the Martian surface, subsurface environments can provide protection from intense radiation and oxidants and more stable climatic conditions 1. Thousands of lava tubes have been identified on Mars through orbital radar imaging 2, but their habitability potential has yet to be assessed by in situ space missions. Terrestrial analogues are being used in support of planetary exploration because of their similarities with the conditions and mineralogies of planetary bodies target by space missions. On Earth, lava tubes are formed by volcanic processes, and host diverse microbial communities that interact with their mineralogical environment, leading to the formation of secondary mineral deposits. Those terrestrial lava tubes can serve as natural analogues [3] to investigate the types of biomarkers and geological processes that might also be found in Martian subsurface environments.

This ongoing work focuses on the chemical characterization of basalt and secondary mineral deposit samples from Lava Beds National Monument (LBNM), California, and Mauna Loa, Hawaii (USA). The objectives are: to assess the content and diversity in organic molecules and their relationship with the microbial life present in these environments, to evaluate the ability of flight-like analytical techniques to detect biomarkers, and to better understand the relationship between microbial activity, mineralogy, and biomarker content.

To characterize the samples, we employed a multidisciplinary approach consisting in mineralogical, biological, and chemical analyses. X-Ray Diffraction, Raman spectroscopy, and Laser-Induced Breakdown spectroscopy measurements revealed that the LBNM and Hawaii samples are dominated by silicates and sulfates, respectively, while metagenomics studies showed that most samples are dominated by Proteobacteria and Actinobacteria, and host a diversity of chemotrophic microorganisms. At LATMOS, Gas Chromatography-Mass Spectrometry experiments (GC-MS) are being performed under both laboratory and flight-like conditions encompassing pyrolysis, thermochemolysis and derivatization (a chemical transformation aiding the detection of polar compounds by GC-MS) to reproduce the analytical methods of current and future Martian rovers [4, 5]. Results showed the

detection of a great variety of organic molecules including biosignatures such as lipids, nucleobases, sugars, and amino acids. These findings improve our understanding of the biogeochemical processes in subsurface environments and confirm recent and uprising studies about secondary minerals in lava tubes being promising targets for future planetary missions.

1 Boston et al, Astrobiology 2001, 1 (1), 25–55; 2 Cushing et al, J. Geophys. Res. Planets 2015, 120, 1023-1043; [3] Léveillé et al, Planetary and Space Science 2010, 58 (4), 592–598; [4] Mahaffy et al, Space Sci Rev 2012, 170:401–478; [5] Goetz et al, Int J Astrobiol 2016, 15:239–250.

Astrophysics Field:

Planetology, Exobiology

Session 8 / **85**

Space weathering on Mercury: investigation of the spectra of recent impact craters

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Co-auteurs: Alain Doressoundiram [2]; Sebastien Besse [3]

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Space weathering is the physical and chemical alteration of planetary surfaces caused by exposure to the space environment and specifically to the solar wind and to micrometeoroid impacts. It is currently the main process affecting the surface of Mercury.

Whereas on most of the surface space weathering appears to have reached saturation, the process is still ongoing in the youngest terrains on the planet: recent impact craters and their ejecta. The lesser degree of space weathering to which these surfaces have been subjected is evident from their higher albedo. However, current knowledge on the effect of space weathering on surface reflectance spectra is insufficient to use it to estimate surface age or establish a correspondence with the spatial distribution of its progenitors.

I present my ongoing study of the spectral properties of fresh impact craters on Mercury. In particular, I have attempted to train a neural network to distinguish crater ages on the basis of their spectra. The ultimate goal is to develop indicators of space weathering that may be used to more effectively quantify its effect across Mercury.

Astrophysics Field:

Planetary science, Mercury, spectroscopy

Session 8 / **77**

M15pc : The search for Giant Planets around M dwarfs with astrometry

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M-type stars, the most common in the universe, are a major focus for surveys because they are well-suited for detecting low-mass planets in the habitable zone. Despite their importance in the formation and evolution of low-mass planets, little is known about giant planets (GPs) in M star systems. Detecting long period GPs is difficult with transit methods and challenging with radial velocities (RV) due to the faintness and relatively high activity level of M stars. This significant limitation can be effectively addressed by combining RV and high-contrast imaging (HCI) with Gaia-Hipparcos absolute astrometry.

To this extent, I use the GaiaPMEX tool presented in Kiefer et al. (2024) to detect GPs around M stars with Gaia Data Release 3 data. GaiaPMEX uses astrometric data from Gaia and Hipparcos data when available to build a two-dimension confidence map to constrain the mass and the semi-major axis of the companion. When combining these maps with RV and HCI detection limits, we can strongly constrain the orbit and characterize the companion.

I will present the first results of this work, along with perspective of work with GaiaPMEX, RV and HCI. More precisely, I built a catalog of M dwarfs within 15pc and performed a systematic search for GPs with GaiaPMEX to produce a list of 120 planetary candidates.

Astrophysics Field:

Exoplanets, M dwarfs, Astrometry, Long-Period Giant Planets

Session 8 / 101

Innermost stable circular orbit of comparable-mass compact binaries at the fourth post-Newtonian

Auteur: Etienne Ligout[1]

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We compute by means of post-Newtonian (PN) methods the innermost stable circular orbit of comparable-mass compact binaries. Two methods are used with equivalent results: equations of motion in harmonic coordinates and Hamiltonian formalism in ADM coordinates.

Astrophysics Field:

General relativity

Session 8 / 97

Investigation of the dominent strahl scattering mechanism near the Sun with PSP

Auteur: Erwan CHERIER[1]

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The suprathermal electrons in the solar wind are categorized in two different populations. The halo is nearly isotropic while the strahl is highly anisotropic. Following previous studies, we characterize the strahl by its pitch angle width. We aim at finding correlations between this quantity and local plasma or magnetic field parameters, and to compare these correlations with prediction from diffusion models for solar wind electrons. For this, we used data from the SPAN and FIELDS instruments of the Parker Solar Probe mission, during 17 approaches. We show that the correlations between the strahl PAW and the density and the energy are in a relatively good agreement with a pitch angle diffusion due to the Coulomb collisions at distances from the Sun smaller than 30 Rs at energies around 300 eV. At larger distances, we show that the pitch-angle width cannot be explained by Coulomb scattering. We discuss the likely causes of the non-coulomb strahl broadening, from whistler waves or background magnetic fluctuations.

Astrophysics Field:

Plasma, Electrons, Heliosphere

Session 8 / **63**

Diagnostic of the electron density and temperature in the solar wind using the Quasi-Thermal Noise Spectroscopy on Parker Solar Probe

Auteur: Baptiste Verkampt[1]

Co-auteurs: Karine Issautier [1]; Léa Griton [1]; Pietro Dazzi [1]; Nicole Meyert-Vernet [1]; Michel Moncuquet [1]

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The Quasi-Thermal Noise (QTN) spectroscopy is an efficient tool to study, in the frequency domain, the 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 $f_e(\vec{v})$, in addition to the antenna response. The shape of the QTN in a weakly magnetized plasma allows one to yield an accurate diagnostic of the electron properties such as the total electron density n_e and core temperature T_c, which allows one to analyze the electronic populations in the solar wind with great precision.

We will present a semi-automatic method, based on the simplified sQTN from Moncuquet et al. 2020 to determine the density and a proxy of the core temperature of the electrons. The method has been applied on the 19 first Encounters of Parker Solar Probe (PSP), during biased and non biased mode, on the voltage power spectrum measured with both dipole of PSP V1V2 and V3V4.

We present the large-scale structure of the solar wind down to 11 $R_\odot$ and discuss on the radial variations of the electron density and temperature. Finally, we discuss on the implementation of a full fitting to deduce the suprathermal electron properties.

Astrophysics Field:

Solar Wind, Instrumentation,

Session 9 / 82

CO2 Ice Properties using CRISM Data: Implications for Martian Gullies Formation Mechanisms

Auteur: Apolline Leclef[1]

Co-auteurs: Mathieu VINCENDON [1]; Cateline LANTZ [1]

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The study of Martian ices provides key information into the formation mechanisms of gullies on Mars. Using infrared spectroscopy data from CRISM (Mars Reconnaissance Orbiter, NASA), this work focuses on seasonal CO2 ice deposits near Mars' poles, with particular attention to Sisyphi Cavi, where active gullies are observed. The properties of CO2 ice are characterized by evaluating its translucent or granular structure, comparing ice thicknesses predicted by a climate model from LMD to optical paths derived from CRISM observations. By assessing these ice properties, the study aims to offer valuable insights into the mechanisms driving gully formation, including CO2 sublimation and the possible role of liquid water.

Astrophysics Field:

Mars, Surface Geological processes, IR spectroscopy, Photometric modelisation, CRISM

Session 9 / 67

In situ research of organic matter on Mars surface using Gas Chromatograph and Mass Spectrometer (GCMS) with the SAM (MSL mission) and MOMA (ExoMars mission) space experiments

Auteur: Théo Govekar[1]

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Mars'surface is currently one of the environments in the solar system, where the research about prebiotic chemistry is the more active, because of the possibility of a past biologic activity considering Mars gathered the conditions required for the emergence of life at the time it arose on Earth 1.

In this context, a gas chromatograph mass spectrometers (GCMS) instrument was sent to Mars in the Sample Analysis at Mars (SAM) experiment onboard the Curiosity rover. The role of this instrument is to detect and identify organic and inorganic molecules in Gale crater 2. Currently, the rover is passing through a sulphate rich geological unit, containing a high concentration in magnesium sulphate which is likely to withhold organic molecules. A part of my PhD thesis focusses on the interaction between sulphate and organic molecules, and the ability to detect it with GCMS.

A second GCMS is part of the ESA ExoMars rover payload with the Mars Organic Molecule Analyser (MOMA) instrument. The Rosalind Franklin rover should land in 2030 in Oxia Planum, an ancient delta above Valles Marineris. This landing spot is characterized by a certain amount of clay. Clay formation need water exposure for a long time, thus if complex organic molecules happened to have existed in the water flowing through the delta, they might have been trapped the layers of clays.

To analyse in situ samples, MOMA (and SAM) uses several sample preparation technics. Pyrolysis heats the sample up to 850℃ and allows organic molecules to evaporate or to be fragmented into

volatile species prior their injection into the GCMS. Chemical reactants are also used to help making molecules of prebiotic interest analysable by GCMS, such as amino or carboxylic acids. Some reactants are used at a relatively low temperature for analysing relatively small molecules, this is the derivatization process, whereas others are used at high temperature for the analysis of large organic molecules, this is the thermochemolysis process [3].

To prepare the interpretation of the future data to be collected by the different instruments onboard the Exomars rover, the project scientist organized an intercomparison campaign of the analysis of a variety of samples relevant to Oxia Planum. With this aim, Mars analogue samples were sent to the laboratories participating to the Exomars project, including LATMOS to perform their analysis in MOMA analytical conditions. My work in this study is the characterization of the molecular composition of the analogue samples under laboratory conditions mimicking the MOMA conditions. This characterization will serve two objectives: 1) To be a reference point for the team mimicking MOMA; 2) To understand which organic molecules may be preserved in Mars analogue samples and under which conditions.

1 Cockell, C. S., Bush, T., Bryce, C., Direito, S., Fox-Powell, M., Harrison, J. P., … & Zorzano, M. P. (2016). Habitability: a review. Astrobiology, 16(1), 89-117.
2 Mahaffy, P. R., Webster, C. R., Cabane, M., Conrad, P. G., Coll, P., Atreya, S. K., … & Mumm, E. (2012). The sample analysis at Mars investigation and instrument suite. Space Science Reviews, 170, 401-478.
[3] Goesmann, F., Brinckerhoff, W. B., Raulin, F., Goetz, W., Danell, R. M., Getty, S. A., … & van Amerom, F. H. (2017). The Mars Organic Molecule Analyzer (MOMA) instrument: characterization of organic material in martian sediments. Astrobiology, 17(6-7), 655-685.

Astrophysics Field:

Planetary science

Session 9 / 65

Effective theory reproducing MOND phenomenology based on a non-Abelian Yang-Mills graviphoton

Auteur: Emeric Seraille[1]

[1] *LPENS*

Auteur correspondant emeric.seraille@phys.ens.fr

Despite the remarkable success and relative simplicity of the standard ΛCDM model, some phenomena remain unexplained. Most notably, the puzzling relationship between galaxy rotation curves and the observed baryon density that motivated the development of MOND. However, most field theories attempting to reproduce MOND predictions have to rely on ad hoc free functions, preventing them from being considered fundamental.
In this presentation, I will introduce a new theory that reproduces MOND phenomenology, built on a fundamental non-Abelian Yang-Mills gauge field based on SU(2), with a gravitational coupling constant that emerges in a low-acceleration regime. Using a mechanism of gravitational polarization within the dark matter medium, I will discuss how certain solutions of this theory naturally recover the deep MOND regime.

Astrophysics Field:

Dark matter, MOND theory, Modified gravity

Session 9 / 66

On the shape of pancakes: post-collapse perturbation theory

Auteur: Abineet Parichha[1]

[1] *Institut d'Astrophysique de Paris - Sorbonne Université*

Auteur correspondant abineet.parichha@sorbonne-universite.fr

Cold dark matter is typically modelled as a collisionless and self-gravitating fluid with negligible velocity dispersion and can be thought of as a 2D (3D) sheet of particles in 4D (6D) phase-space whose topology evolves as per the Lagrangian equations of motion of particles. The collapse of dark matter particles in the neighborhood of an initial overdensity into points of singularity, i.e. points with theoretically infinite density, can thus be identified with the folding of the phase-space sheet onto itself marked by a change in the topology of the sheet. Such an event is called as catastrophe and the study of the singularities characterising a collapse falls under the regime of catastrophe theory, which has wide applications, e.g. caustics seen below water surface, edge of rainbows, etc. In this work, I shall present its application to cold dark matter halo formation, particularly in the analytical description of the shape of pancakes, i.e. the earliest structures formed upon the crossing of particle trajectories when an initial overdensity collapses onto itself, in 2D. A perturbative treatment of the post-collapse motion of particles around the collapse location is introduced to improve upon the standard Lagrangian perturbation theory. Finally, I will discuss its extension to 3D cosmology in tracing the 'cosmic web'of our universe.

Astrophysics Field:

Cosmology, dark matter

Session 10 / 59

Optical Modeling of the BISOU Instrument

Auteur: Morgane LOQUET LE GALL[1]

Co-auteur: Bruno Maffei

[1] *IAS*

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The last and unique measurement of the CMB blackbody spectrum was made by COBE-FIRAS in 1991. However, deviations from the perfect blackbody spectrum serve as a probe of the thermal history of the universe. To test the technology and feasibility of a space mission aimed at measuring these so-called spectral distortions, the balloon-borne mission BISOU (Balloon Interferometer for Spectral Observations of the Primordial Universe) will, for the first time, achieve the sensitivity required to measure some of these distortions. To test the onboard instrument (including a Fourier Transform Spectrometer (FTS)), a cryogenic facility will be built at the Institut d'Astrophysique Spatiale (IAS). This breadboard will allow us to study the variety of subsystems and to characterize systematic effects of this new concept, in order to reach the high sensitivity required.

To compare future measurements with theory, it is essential to have an accurate modeling of the instrument and its focal plane. To achieve this, we use different approaches such as geometrical and Gaussian optics. These methods then allow us to simulate the optical design in dedicated physical optics software, to predict the overall performance of the instrument.

Astrophysics Field:

Cosmology Instrumentation Optics

Session 10 / 80

Adaptive optics in Microscopy

Auteur: Jean Commère[None]

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A presentation on adaptive optics, how it can be used in microscopy, the main differences and difficulties when compared to astronomical applications. I will then give some details on my use case of clarified rat's brain imagery.

Astrophysics Field:

Instrumentation, microscopy, adaptive optics

Session 10 / 87

Innovations in High Angular Resolution Optical Interferometry with FIRST

Auteur: Jehanne Sarrazin[1]

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Optical interferometry enables levels of resolution beyond the capabilities of current direct imaging telescopes by coherently combining light from multiple apertures. When applied to a single telescope, it enhances resolution up to the diffraction limit of the telescope, helps to mitigate the effects of atmospheric turbulence and enables spectro-imaging.
Considering these advantages, my talk will focus on the Fibered ImageR for a Single Telescope (FIRST), a spectro-interferometer installed on the Subaru Telescope and the central topic of my thesis. Since first light, FIRST has undergone major upgrades, and as such serves as an ideal case study for discussing the key optical components used in optical interferometry and their performance.
The first mode of the instrument, FIRST-FIZ, introduced the application of aperture masking combined with optical fiber, allowing for high contrast and better calibrated images 1. The second one, FIRST-PIC, applied the use of photonic integrated chips (PICs) to replace the bulk optics previously used in the recombination of the light, for a significantly more compact and precise recombination of the light 2. Finally, the latest mode of the instrument currently in use at the Subaru telescope is FIRST-PL, and incorporates a photonic lantern, a novel component that couples light from the entire telescope aperture into different single mode fibers. This innovation dramatically increases throughput, and returns results of high angular resolution [3]. In my presentation, I will discuss these technological advancements and their respective advantages in the development of high-resolution optical interferometry in the context of FIRST.

1 : « FIRST, a fibered aperture masking instrument », E. Huby et al (2012)
2 : « Laboratory characterization of FIRSTv2 photonic chip for the study of substellar companions » K. Barjot et al (2021)
[3] : « Spectroscopy using a visible photonic lantern at the Subaru Telescope: Laboratory characterization and the first on-sky demonstration on Ikiiki (α Leo) and ʻAua (α Ori) » S. Vievard et al (2024)

Astrophysics Field:

Instrumentation, High angular resolution, Optical interferometry

Session 10 / 70

Black Holes in modified gravity theories

Auteur: Hugo Candan[1]

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The search for alternative theories of gravity is motivated by several considerations, such as Dark Energy, or the existence of singularities in General Relativity. A general subclass of modified gravity theories are scalar-tensor theories, which have been developed in the last decades. It is rather interesting to search for observables that could constrain those theories. Black Holes are objects with extreme gravitational field, making them very suitable for testing gravity theories, and so are in the scope of this work. The goal of the work presented is to find new Black Hole solutions in scalar-tensor theories, which might differ from the unique Kerr Black Hole of General Relativity. With the upcoming of high precision detectors such as LISA, or Einstein Telescope, we will have the observational tools required to assess whether or not real Black Holes are compatible with General Relativity, or with the ones of alternative theories.

Astrophysics Field:

Compact Objects / theory

Session 10 / 68

From cosmic dust to planet formation : Building new dust models.

Auteur: Marie-Anne Carpine[None]

Co-auteurs: Anaëlle Maury ; Nathalie Ysard

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The characterisation of cosmic dust properties is key for understanding, among other things, planet formation processes. Astronomical observations provide us information from which it is possible, but not trivial, to deduce physical properties of cosmic dust. For instance, recent observations of 12 young protostars found dust emissivity indices with values $\beta < 1$ [Maury et al. 2019, Galametz et al. 2019], which would imply that dust coagulated into grains over 100µm in size [Ysard et al. 2019], much larger than what predicts actual paradigms of planet formation at this stage of stellar evolution. However, relating the grain sizes to their opacity measured in the millimetre bands is not straightforward and rely heavily on the validity of current dust models used as astrophysical analogues in the community. For example, the optical properties of large dust aggregates in cold environments, as observed in millimetre wavelengths were not explored in a systematic way, limiting the astrophysical interpretation that can be done from the measurements, especially for the dense ISM. Our work addresses this blind spot, building new physically-motivated dust models to interpret the dust signatures in protostellar environments.
Our study concentrates on the optical properties of a few examples of dust grains. Using laboratory-measured material properties from the THEMIS 2 dust model [Ysard et al. 2024], we derive various grain shapes in the scope of picturing the evolution from small compact grains to potentially large fluffy aggregates. We used the Discrete Dipole approximation (DDA) code ADDA [Yurkin et al. 2011] to compute our grains'optical properties. First results show a heavy dependence of these optical properties on the shape, but also on the composition of dust grains.
Building reliable dust models is decisive in the interpretation of observations of the dense ISM, in our understanding of dust evolution towards planet formation. We hope to build a robust model of dust grains population, challenge fiducial dust models, and permit to make progress in these fields.

Astrophysics Field:

Interstellar medium, Star formation

Session 11 / 103

The Epoch of Reionisation: From Theory to Data

Auteur: Lilian Crascall-Kennedy[1]

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The Epoch of Reionisation marks the transition between the end of the cosmic dark ages and the beginning of the universe as we know it today. During this time the radiation from the first stars and galaxies ionised the neutral hydrogen around them, fundamentally transforming the universe. The EoR is one of the last major phases of cosmic evolution that remains mostly unexplored as no direct observations have yet been made. However, this will change with the upcoming Square Kilometre Array (SKA), which will detect the 21cm signal from the EoR for the first time. This new data will provide a wealth of untested cosmological information ranging from the properties of the first luminous sources to the distribution of large-scale structure.

The 21cm observations from the EoR are expected to be highly complex, and so will require the use of statistics beyond the power spectrum to capture a full picture of the information. While the power spectrum is widely used to characterize the large-scale structure, it does not capture the non-Gaussian features introduced by reionisation. This presentation will focus on the Triangle Correlation Function (TCF) - a three-point-correlation function - which probes specifically the morphology and evolution of the "bubbles"of ionised hydrogen that surround the first ionising sources. The TCF is first applied to simple toy models of the EoR and then to more realistic simulations (such as 21cmFAST and LoReLi) to evaluate its potential for constraining cosmological and astrophysical parameters. This work will contribute to the SKA white book, which aims to specify the expected scientific outcomes of the SKA and the statistical tools that will be used to analyse future EoR observations.

Astrophysics Field:

Cosmology, Epoch of Reionisation

Session 11 / 90

Inclined coorbitals in the three-body problem

Auteurs: Alexandre Prieur[1]; Jacques Fejoz[2]; Philippe Robutel[1]

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In the three-body problem with two equal small masses, the Lagrange equilibrium is well-known. But what if we start inclining the small masses' orbits? We find numerical evidence of a family of quasi-periodic orbits emerging from the Lagrange equilibrium. We then draw links to the restricted problem, as well as the P12 family in the case of equal masses.

Astrophysics Field:

Celestial mechanics, Dynamical systems, Solar System dynamics

Session 11 / **55**

Complex nitriles at the surface of TNOs revealed by DiSCo-JWST

Auteur: Sasha Cryan[1]

Co-auteurs: Aurelie Guilbert-Lepoutre [2]; Elsa Hénault [3]; Pinilla-Alonso Noemi [4]; Rosario BRUNETTO [3]

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CN-bearing constituents in refractory organic residues have been reported across various regions of the Solar System, from the moons of the giant planets to the dark refractory material observed on some comets and in rare ultracarbonaceous micrometeorites recovered on Earth. These compounds form and evolve through thermal, photochemical, and irradiation-driven chemical pathways. Consequently, CN-bearing organics can unveil important information about the current and past physical conditions of the Solar System. Our work investigates a tentative detection of the CN functional group on trans-Neptunian objects (TNOs) observed as part of the DiSCo-TNOs program (#2418; P.I.: N. Pinilla-Alonso), mapping its distribution across the dataset and uncovering its molecular origin. We find the objects that formed in the outermost region of the protoplanetary disk exhibit the highest contribution of the CN feature, an indication the nitrogen distribution on TNOs may be tied to a primordial origin. Further, we show that the CN functional group likely belongs to an organic N-rich macromolecular structure. Our work has important implications for understanding the interconnection between small bodies in the Solar System and the chemical and physical conditions from which they evolved.

Astrophysics Field:

Astrochemistry, tran-Neptunian objects, JWST

Session 11 / **58**

Model the N+ emission in the Milky Way

Auteur: Guillaume Vigoureux[1]

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Context : Stars are formed in the neutral regions of a Galaxy. However, in the Milky Way, the neutral and ionised regions represent almost the same volume. To have a better understanding of the star formation, we then need to understand which phenomena are responsible of the ionisation in the Milky Way. The common view is that the star radiation is the phenomenon which creates ionized regions. But recent observations led by P.Goldsmith showed that the N+ (which is a tracer of fully ionized regions) distribution in the Milky Way can't be explained only with the star radiation.

Aims : My goal is to see to what extent the supernova remnants could reproduce the measured quantity of N+ in the Milky Way.

Methods : To do so, I have first modeled the galactic distribution of supernova. Then I used the Paris-Durham shock code to model the N+formation during the propagation of high velocity (30 to 400km/s) shocks in diffuse mediums (0.01 to 100 particles/cm3).

Results : Combining these two modelisations, I was able to estimate the N+ abundance in the Milky Way. My modelisation is at the moment able to reproduce between 10% and 50% of the observed N+.

Conclusions : This work, which is still ongoing, shows that the ionisation in the Milky isn't due to a single phenomenon but is probably a mix of -at least - the radiation emitted by stars and the kinetic energy at the end of their lifes.

Astrophysics Field:

Interstellar Medium - Modeling - Supernova

Session 11 / 89

Planet-forming regions of disks in the JWST era

Auteur: Pacôme ESTEVE[1]

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Despite the tremendous number of exoplanets detected, planet-forming scenarios are not yet able to fully explain the large diversity of planets. They form in protoplanetary disks, by accreting gas and dust in their surroundings. It is thus necessary to study the composition of disks, especially the Carbon-to-Oxygen ratio (C/O), to better constrain planet formation. In this context, the James Webb Space Telescope opens an unprecedented observation window on the inner disks (<10-50 au), where planets are forming. Amongst molecular features in the observed spectra, water and acetylene (C2H2) are widely detected.
The aim of this work is to study the extent to which H2O and C2H2 emission are good tracers of the C/O ratio of the gas in the inner disk, using the 2D thermochemical model DALI (Dust And Lines). After significant improvements in the model, especially a refined Carbon chemistry, first results show that the line flux ratio C2H2/H2O is highly sensitive to the C/O ratio, making it a promising tracer.

Astrophysics Field:

Protoplanetary disk, chemistry, Interstellar Medium