Symposium abstracts

Tuesday 27th June, morning:

- **Rui Pinto** : " Solar eruptions : MHD modeling "

- **Sophie Masson** : « Modeling of solar eruptions & CMEs : dynamics and link with SEPs and energetic particle injection »

  Abstract: Among the more hazardous forms of space weather at Earth and in the heliosphere are the intense solar energetic particle (SEP) bursts associated with fast coronal mass ejections (CMEs) and eruptive flares. Understanding how energetic particles are accelerated and escape into the heliosphere during solar eruptive event is a fundamental question in solar physics. I will first present 3D MHD models of CMEs, the associated coronal dynamics and discuss how it can be used to constrain and understand the acceleration and escape of solar energetic particles in the heliosphere

- **Oreste Pezzi**: "Particle transport and acceleration in structured plasma turbulence"

  Abstract: The fundamental mechanisms responsible for particle acceleration in space and astrophysical plasmas remain largely elusive. Coherent structures, such as reconnecting current sheets and flux ropes/plasmoids, may cooperate to accelerate particles in several ways through, for example, the reconnection electric field or drift terms. On top of this, possible trapping effects in such coherent structures may lead to extremely powerful particle energization. In this talk, I will review some of these mechanisms. Then, I will discuss recent numerical results investigating particle transport and acceleration in fully-developed magnetohydrodynamics turbulence, as well as nearby a turbulent large-scale flux rope. When trapped in the flux rope or in large-scale structures generated by turbulence, particles experience an exponential acceleration. Finally, I will also comment on the applicability of these results in space and astrophysical contexts.

- **Silvia Perri (remote):** "New insights in particle transport and acceleration at collisionless shocks"

  Abstract: Supra-thermal particles are ubiquitous in the heliosphere. Spacecraft observations have detected energetic particles accelerated at impulsive events in the solar corona and at interplanetary shocks. Thanks to the joint effort made by in-situ spacecraft observations, numerical simulations, and theoretical models, our knowledge on the particle acceleration processes has advanced significantly in recent years. Here we review new developments on particle acceleration at collisionless shocks, in particular in relation with the transport properties of supra-thermal particles. The latter can be inferred from the analysis of particle fluxes upstream of interplanetary shocks; we address how anomalous, superdiffusive transport is common in the interplanetary medium.

  Further, we discuss some interplanetary shock events where ion fluxes within the energy range 100 keV- 2 MeV tend to be overlapped, which means that particle energy spectra are flat. We interpret these observations in terms of a velocity filter mechanism that is energy dependent.

- **Nina Dresing:** "Multi-spacecraft analysis of the 17 April 2021 widespread SEP event"
  Abstract: https://ui.adsabs.harvard.edu/abs/2023A%26A...674A.105D/abstract

Tuesday 27th June, afternoon:

- **Karl-Ludwig Klein**: "Radio diagnostics of the acceleration and release of solar energetic particles”

  Abstract : Spectral imaging at radio wavelengths probes non thermal electrons in the solar corona and the interplanetary space. It is the only direct radiative diagnostic of such electrons in the dilute plasma of the corona, where collisional processes such as hard X-ray bremsstrahlung and nuclear gamma-ray emission are inefficient. In this contribution I'll illustrate the diagnostic possibilities of radio spectral imaging with applications to the tracing of magnetic structures where energetic particles propagate, and the role of different acceleration processes in solar eruptive events.

- **Yulia Kartavykh**: “Modeling of energetic particle transport and acceleration by a blast wave propagating in a spiral magnetic field”

  Abstract: We consider a blast wave propagating in a spiral magnetic field and apply the focused transport approach to model the time profiles of protons, initially accelerated in a solar flare. During their propagation particles are changing their energy due to adiabatic losses in the expanding solar wind as well as due to diffusive shock acceleration because of different speed of fluid on both sides of the shock front. Because of the oblique geometry of the propagating shock front the particles experience adiabatic reflection, which results to the shift of the intensity maximum in time profiles from the moment of shock passage and appearing of more complicated structures. To verify our approach we model the events of 2 October 1998 and 6 April 2000 observed by Wind spacecraft. Finally we investigate the effect of shock parameters and plasma turbulence on the structures at the shock front as well as their development with radial distance.

- **Seve Nyberg**: “Modeling of particle acceleration at shocks”

  Abstract: By current understanding, large gradual solar energetic particle (SEP) events are caused by shock waves driven by coronal mass ejections (CMEs). While analytical solutions of particle distribution functions around shocks exist for one-dimensional steady-state theory,time-dependent and/or multi-dimensional systems cannot generally be solved analytically, motivating investigation of numerical models. We will showcase the self-consistent proton acceleration and Alfvén wave generation model SOLar Particle Acceleration in Coronal Shocks (SOLPACS) [Afanasiev et al. 2015] and a Monte Carlo simulation modeling electron acceleration by stochastic shock drift acceleration (SSDA). We evaluate the significance of energetic particle injection in self-consistent proton acceleration modeling by comparing simulation results to observations, outline ideas for improving the accuracy and performance of self-consistent numerical models of particle acceleration in shocks, and inspect capabilities of SSDA in accelerating electrons and forming an electron beam.
  This research has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101004159 (SERPENTINE).

- **Silvina Guidoni (remote):** “TBD”

- **Ian Richardson:** “Solar Energetic Particle Transport in the Corona and Heliosphere”

  Abstract : Observational evidence for various mechanisms of particle tr ansport in the heliosphere and corona will be discussed with a particular emphasis on multi spacecraft observations of widespread SEP events.

- **Nicolas Wijsen (remote):** “Modelling the transport of energetic particles in the inner heliosphere”

  Abstract : Solar Energetic Particles (SEPs) pose significant challenges for space weather forecasting and the safety of space missions in interplanetary space. Understanding the transport mechanisms and dynamics of these energetic particles is crucial for accurate predictions and risk assessment. In this talk, we provide an overview of some of the modelling approaches used to study SEP transport in the inner heliosphere, focusing mostly on our work using the EUHFORIA and PARADISE models. We demonstrate how these models have been used to simulate suprathermal particle enhancements near corotating interaction regions (CIRs) and capture the characteristics of gradual SEP events observed under complex solar wind conditions. Additionally, we discuss future advancements of these models.

- **Christina Cohen:** “SEP events from PSP mission”

- **Hamish Reid:** “TBD”

Wednesday 28th June, morning:

- **Silvio Cerri (remote) :** "Cosmic-ray transport (in the Galaxy): a micro-physics perspective"

  Abstract: The origin and propagation of cosmic rays (CRs), as well as their interaction with the turbulent medium through which they propagate, is one of the clearest intersection between astro-particle physics and plasma astrophysics, where indeed plasma processes play a crucial role. More than a century after the discovery of cosmic radiation, our understanding of the processes responsible for CR transport are still under debate, lacking of a self-consistent theory. The theory of CR transport still relies mostly on a phenomenological model of pitch-angle scattering on Alfvénic turbulence, adopting a naive picture of spatially isotropic and homogeneous diffusion through the whole Galaxy. Although such simplified approach was considered adequate to reproduce available CR data for long time, this picture and its predictions have been seriously challenged both by theoretical arguments (i.e., the anisotropy of Alfvénic turbulence, which makes this type of cascade very inefficient at scattering CRs) and by recent direct and indirect high-precision measurements (i.e., significative anomalies in the CR fluxes at Earth and a systematic hardening of the CR-proton spectrum towards the Galactic center inferred from gamma-ray emission that cannot fit within the above picture).
  In this talk, I will briefly review these observational and theoretical arguments that challenge the standard phenomenological picture, and then I will present some recent studies that employ advanced transport models and global CR-transport simulations to possibly explain some of the above-mentioned observational features. Finally, I will use these examples to draw an analogy with what can be done for CR transport in the Heliosphere, paying particular attention on the recent insights about turbulence theories that we obtained in the past decades thanks to space missions and numerical simulations.

- **Luigi Tibaldo :** "Galactic cosmic rays: observational probes and challenges to standard models"

  Abstract: Cosmic rays (CRs) are energetic particles first observed around the Earth with energies ranging from MeV to above 10^20 eV and with approximately isotropic arrival *directions. A most remarkable change of the power-law spectral slope occurs around 10^15 eV, the so-called knee of the CR spectrum. Below the knee, the standard paradigm holding since the sixties asserts that the particles originate in the Milky Way, very likely from shock acceleration in supernova remnants, and diffuse on turbulent magnetic fields in a kpc-sized halo encompassing the disk of the Galaxy for durations exceeding several Myr. After a quick overview of observational probes of Galactic cosmic rays, I will discuss how recent measurements pose challenges to standard Galactic cosmic-ray models. Are supernova remnants the only or main sources of Galactic cosmic rays? Are discrepancies observed between observations and predictions from standard models due to missing details or do they require fundamental paradigm changes?*

- **Alexandre Marcowith:** "Energetic particle acceleration at astrophysical shocks"

  Abstract: Astrophysical shocks are in most of cases collisionless and are expected to be able to inject and accelerate particles up to high energies because of their high Mach numbers and the possibility they have to strongly amplify magnetic field fluctuations up to a fraction of the kinetic energy of the plasma ram pressure. Particle acceleration at astrophysical shocks now comes to a mature age thanks to recent results obtained by different simulations combining particle-in-cell and/or magnetohydrodynamics. I will describe recent observation which support particle acceleration and magnetic field amplification, then describe some relevant simulation results. I will try to address some common interests between space and astrophysical plasmas in this particular field.

- **Joe Giacalone:** "The Acceleration of Heliospheric Energetic Particles at the Termination Shock and in the Heliosheath"

  Abstract : I will present recent science results on the acceleration of heliospheric energetic particles - interstellar pickup ions, termination shock particles, and anomalous cosmic rays - at the solar-wind termination shock and in the inner heliosheath region which separates the heliopause and termination shock. I will also give a brief overview of the physics of the outer heliosphere.

- Illya Plotnikov "Relativistic shocks physics" (??)

Wednesday 28th June, afternoon:

- **Laura Rodriguez-Garcia:** "Following a CME from the Sun to the inner heliosphere: The 2013 August 19 event "

  Abstract: Late on 2013 August 19, a coronal mass ejection (CME) erupted from an active region located near the far-side central meridian from Earth's perspective. The event were remotely observed by the STEREO-A, STEREO-B, and SOHO spacecraft. The interplanetary counterpart (ICME) was intercepted by MESSENGER near 0.3 au and by both STEREO-A and STEREO-B near 1 au, which were separated from each other 78° in heliolongitude. Taking this event as a basis, we review some of the different methods available to study the evolution from the Sun to the heliosphere of CMEs and the corresponding interplanetary counterparts (ICMEs). We use solar disk observations to estimate the magnetic flux-rope type to compare with in situ measurements at different locations. Some models as the graduated cylindrical shell model (GCS) or the elliptical cylindrical analytical model (EC-model) are also utilized.

- **Alexis Rouillard:** *TBD*

- **Manon Jarry:** " CME/shock - SEP event of Sep 5th 2022" *(TBC)*

- **Athanasios Kouloumvakos: "**The Multi-Spacecraft high-energy solar particle event of 28 October 2021"

- **Andrew Dimmock:** "Backstreaming Ions Observed by Solar Orbiter"

  Abstract : The Mach number of interplanetary shocks are typically between 1 and 3, which is low compared to planetary bow shocks and most astrophysical shocks. However, on 30 October 2021, Solar Orbiter measured a shock with an Alfven Mach number above 6, which can be considered high in this context. Our study examines particle observations for this shock, which provide clear evidence of ion reflection. The magnetic and electric field observations contain complex electromagnetic structures near the shock, and we investigate

how they are connected to ion dynamics. The ion velocity distribution functions show clear evidence of particle reflection in the form of backstreaming ions several minutes upstream. The shock structure has complex features at the ramp as well as whistler precursors. The backstreaming ions may be modulated by the complex shock structure and the whistler waves are likely driven by gyrating ions in the foot. Suprathermal ions up to 20 keV were observed but shock-accelerated particles with energies above this were not.

- **Domenico Trotta:** "Kinetic simulations of collisionless shocks propagating in turbulent plasmas"

  Abstract: The interaction between shock and turbulence is an important pathway to energy conversion and particle acceleration in the heliosphere and in a large variety of remote astrophysical systems. Through kinetic modelling of such an interaction, it is possible to address how particles are accelerated from the thermal plasma. In this talk, I will discuss the key results of a variety of modelling efforts recently performed, in both two- and three-dimensional geometries. Finally, the results will be put in the context of novel in-situ observations of energetic particles at heliospheric shocks, and the importance of novel multi-spacecraft missions will be discussed.

- **Domenico Trotta (alternative):** "Observations of interplanetary shocks with Solar Orbiter"

  Abstract: Interplanetary (IP) shocks are important sites of particle acceleration in the Heliosphere and can be observed in-situ utilizing spacecraft measurements. Such observations are crucial to address important aspects of energy conversion for a variety of astrophysical systems.
  From this point of view, Solar Orbiter provides observations of interplanetary shocks at different locations in the inner heliosphere with unprecedented time and energy resolution in the suprathermal (usually above 50 keV) energy range. We present a comprehensive identification of such shocks, highlighting their typical parameters and performing a preliminary comparison of the shocks observed at low heliocentric distances with observations in the near-Earth environment.

- **Heli Hietala**: "Candidates for downstream jets at interplanetary shocks"

  Abstract: Localised dynamic pressure enhancements - jets - are regularly observed downstream of the Earth's bow shock. They drive enhanced particle acceleration, larger amplitude magnetic field variations and reconnecting current sheets. Various shock simulations have also exhibited jets, suggesting that they are not unique to Earth.
  In this study, we search for similar dynamic pressure pulses downstream of interplanetary shocks observed by the Wind spacecraft using SerPyShock tools. We discuss how the jet selection criteria are adapted for such conditions. The interplanetary shocks where we have found jet candidates feature foreshock activity, a favourable condition for jet formation according to bow shock studies. We examine the properties of the candidate jets and compare them to those reported for magnetosheath jets. Widening the range of environments where downstream jets are observed can shed light on their dynamics and formation mechanisms. (authors: H. Hietala, D. Trotta, A. Fedeli, L. B. Wilson III, L. Vuorinen, J. T. Coburn).