EP 12: Sun and Heliosphere

Time: Friday 11:00–14:00 Location: EP-H1

Invited Talk EP 12.1 Fri 11:00 EP-H1

Linking Solar Eruptions and Energetic Particles through Observations and Modeling — •Frederic Effenberger — Ruhr-Universität Bochum, Bochum, Germany

Cosmic rays and energetic particles constitute one of the fundamental components of space plasmas and our Heliospheric environment. However, the relation between different energetic particle populations accelerated in the solar atmosphere and detected in interplanetary space is not well established. Observational studies during the last years demonstrated the still poorly understood existence of a connection between solar flare signatures of accelerated particles at the Sun and the corresponding solar energetic particles (SEPs) detected at 1 AU. It is thus important to make progress towards answering the question: Under which circumstances do these two observations point to the same population of accelerated particles? Here, we will discuss recent progress concerned with this issue. We illustrate the potential for observations and simultaneous modeling of the escaping and precipitating electron populations to constrain the plasma properties of the flaring region and interplanetary medium. In particular, with the recently launched Parker Solar Probe and Solar Orbiter missions, which explore the Sun from a close distance and with unprecedented detail, new insights into these questions can be expected. We emphasize the importance of such studies for the fundamental understanding of physical processes in space plasmas and for our space weather forecasting capabilities.

EP 12.2 Fri 11:30 EP-H1

Determining Pitch-Angle Diffusion Coefficients for Electrons in Whistler Turbulence — •Felix Spanier[1], Cedric Schreiner[2,3], and Reinhard Schlickeiser[4,5] — [1]Institut für Theoretische Astrophysik, Universität Heidelberg, Albert-Ueberle-Strasse 2, 69120 Heidelberg — [2]Centre for Space Research, Northwest-University, Potchefstroom 2520, South Africa — [3]Max-Planck-Institute for Solar System Research, Justus-von-Liebig-Weg 3, 37077 Göttingen, — [4]Institut für Theoretische Physik IV, Ruhr-Universität Bochum, Universitätsstrasse 150, 44801 Bochum, Germany — [5]Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel, Leibnizstr. 15, 24118 Kiel

Transport of energetic electrons in the heliosphere is governed by resonant interaction with plasma waves, for electrons with sub-GeV kinetic energies specifically with dispersive modes in the whistler regime.

We have performed Particle-in-Cell simulations of kinetic turbulence using parameters similar to those found in the heliosphere. Test-particle electrons are injected into the simulation. The pitch-angle diffusion coefficients of these test particles were analyzed using a novel method.

An analytical model for electron transport in left- and right-handed is derived and the numerical results are compared to this model.

EP 12.3 Fri 11:45 EP-H1

On Compressible Turbulence in the Inner Heliosheath — •Horst Fichtner[1], Jens Kleimann[1], Peter Yoon[2], Klaus Scherer[1], Sean Oughton[3], and Eugene Engelbrecht[4] — [1]Institut für Theoretische Physik IV, Ruhr-Universität Bochum, 44780 Bochum, Germany — [2]Institute for Physical Science and Technology, University of Maryland, College Park, USA — [3]Department of Mathematics and Statistics, University of Waikato, Hamilton 3240, New Zealand — [4]Centre for Space Research, North-West University, Potchefstroom, 2522, South Africa

Measurements made with the Voyager 1 spacecraft indicate that significant levels of compressive fluctuations exist in the so-called inner heliosheath, i.e. the region between the solar wind termination shock and the heliopause. Here we extend previous studies of the mirror-mode instability to the whole inner heliosheath. Employing quasilinear theory combined with results from a global magnetohydrodynamic model of the heliosphere allows for a computation of the time evolution of the temperature anisotropy and the energy density of the magnetic fluctuations related to the mirror mode. We demonstrate the likely presence of the latter in the inner heliosheath. Furthermore, we compute the associated, locally generated density fluctuations. The results can serve as inputs for future models of the transport of compressible fluctuations in this outermost region of the heliosphere.

Invited Talk EP 12.4 Fri 12:00 EP-H1

Solar Orbiter: two years of operations and first results — •Frederic Schuller, Alexander Warmuth, and Gottfried Mann — Leibniz Institute for Astrophysics (AIP) Potsdam, Germany

The Solar Orbiter spacecraft was launched in February 2020 and will remain the most significant observatory for solar physics research in the next decade. During the cruise phase, which ended in November 2021, several crucial activities took place, starting from the commissioning of the various instruments until the testing and validation of all possible observing modes. We will provide an overview of the mission and describe the regular operations, focussing on the day-to-day work of the STIX instrument team. Then, we will highlight some technical improvements that were achieved during the early phase of the mission. Finally, we will briefly present initial scientific results obtained so far, whereas the nominal phase has only just started.

EP 12.5 Fri 12:30 EP-H1

MHD avalanches in truly curved coronal arcades: proliferation and heating — •Jack Reid[1], James Threlfall[2], and Alan W. Hood[1] — [1]University of St Andrews, St Andrews, Fife, United Kingdom — [2]Abertay University, Dundee, United Kingdom

MHD avalanches involve small, narrowly localized instabilities spreading across neighbouring areas in a magnetic field. Cumulatively, many small events release vast amounts of stored energy. Straight cylindrical flux tubes are easily modelled, between two parallel planes, and can support such an avalanche: one unstable flux tube causes instability to proliferate, via magnetic reconnection, and an ongoing chain of like events. True coronal loops, however, visibly curve between footpoints on the same solar surface. With 3D MHD simulations, we verify the viability of MHD avalanches in the realistic, curved geometry of an arcade. MHD avalanches thus amplify instability in strong astrophysical magnetic fields and disturb wide regions of plasma. Contrasting with the behaviour of straight cylindrical models, a modified ideal MHD kink mode occurs, more readily and preferentially upwards. Instability spreads over a region far wider than the original flux tubes and their footpoints. Sustained heating is produced in a series of ‘nanoflares’, collectively contributing substantially to coronal heating. Overwhelmingly, viscous heating dominates, generated in shocks and jets produced by individual small events. Reconnection is not the greatest contributor to heating, but rather facilitates those processes that are. Localized and impulsive, heating shows no strong spatial preference, except a modest bias away from footpoints, towards the apex.

EP 12.6 Fri 12:45 EP-H1

Quasi-discontinuous solar wind models — •Lukas Westrich — Institut für theoretische Physik IV, Ruhr-Universität Bochum, Deutschland

Recently Shergelashvili et al. (2020) developed a new class of discontinuous solar wind solutions. They considered a case of quasi-adiabatic radial expansion with a jump in the flow velocity, density, and temperature but a continuous Mach number at the critical point and derived analytical solutions. Therefore, they proposed a localized external heating source without actual modeling. After a brief discussion of this concept, I will present continuous numerical solutions, more similar to the classical Parker solar wind model, but with quasi-adiabatic radial expansion with an explicitly formulated localized heating source. This kind of solutions can reproduce the analytically derived solutions without discontinuous jumps in the physical properties.

EP 12.7 Fri 13:00 EP-H1

Solar Surface Stereoscopy with Solar Orbiter's Polarimetric Helioseismic Imager — •Amanda Romero Avila, Bernd Inhester, Johann Hirzberger, and Sami Solanki — Max Planck Institute for Solar System Research

A compound method for a stereoscopic analysis of the height variations in the solar photosphere is presented. This method allows to estimate relevant quantities (i.e. the Wilson depression) and to study structures in the solar photosphere and within sunspots. We will demonstrate the feasibility of the method using simulated Stokes I continuum observations derived from a radiative transfer model using the plasma properties of a MHD simulation of the solar surface. The large scale variations in our method are estimated by shifting and correlating two signals of the same region as observed from two different view directions. This result is then introduced as an initial height estimate in a least squares optimization algorithm in order to reproduce smaller scale structures. This method has been developed to be applied to the high resolution images of the PHI instrument on board Solar Orbiter or similar instruments on other Sun-observing spacecraft. It will allow to perform direct stereoscopic studies of solar surface observations in different wavelengths of the solar spectrum. Preliminary results, advantages and limitations, applications and particular considerations for PHI data will be discussed.

EP 12.8 Fri 13:15 EP-H1

A new global nonlinear force-free coronal magnetic-field extrapolation code implemented on a Yin Yang grid — •Argiris Koumtzis and Thomas Wiegelmann — Max Planck Institute for Solar System Research

The solar magnetic field dominates and structures the coronal plasma and detailed insights are important to understand almost all physical processes. While direct routine measurements of the coronal magnetic field are not available, we have to extrapolate the photospheric vector field measurements into the corona. To do so, we developed a new code that performs state-of-the-art nonlinear force-free magnetic field extrapolations in spherical geometry. Our new implementation is based on an optimization principle and is able to reconstruct the magnetic field in the entire corona, including the polar regions. Because of the nature of the finite-difference numerical scheme used in the past, extrapolation close to polar regions was computationally inefficient. In the current code, the so-called Yin Yang grid is used. Both the speed and accuracy of the code is improved compared to previous implementations. We tested our new code with a well known semi-analytical model (Low and Lou solution). This new Yin and Yang implementation is timely because the Solar Orbiter mission is expected to provide reliable vector magnetograms also in the polar regions within the following years. Thus, this code can be used in the future when these synoptic magnetograms are available to model the magnetic field of the solar corona for the entire Sun including the polar regions.

EP 12.9 Fri 13:30 EP-H1

Automatic computation of magneto-hydro-static equilibria from magnetograms and EUV-images — •Thomas Wiegelmann and Maria Madjarska — MPS, Göttingen

We present a newly developed tool that models the magnetic field in the solar atmosphere and matches individual field lines with observed structures with enhanced emission in EUV images. Presently, for quiet Sun regions, we can only measure the photospheric line-of-sight magnetic field, as accurate horizontal field measurements are not available. The photospheric magnetic-field measurements are extrapolated into the upper photosphere, chromosphere and corona with a magneto-hydro-static model. Free model parameters are then optimized with a downhill simplex method by comparing magnetic field lines quantitatively with the enhanced emission of various structures recorded in EUV images. The tool can be employed to obtain the magnetic and plasma properties of these structures above the photosphere. This could help to achieve a better understanding of the solar atmosphere and will help the constrain of the modelling of atmospheric structures.

EP 12.10 Fri 13:40 EP-H1

Coronal Magnetic Field Extrapolation Using a Specific Family of Analytical 3D Magnetohydrostatic Equilibria - Practical Aspects — •Lilli Nadol and Thomas Neukirch — University of St Andrews, Scotland, UK

With current observational methods it is not possible to determine the magnetic field in the solar corona accurately. Hence, coronal magnetic field models have to rely on extrapolation methods using photospheric magnetograms as boundary conditions. In recent years, due to the increased resolution of observations and the need to resolve non-forcefree lower regions of the solar atmosphere, there have been efforts to use magnetohydrostatic (MHS) field models instead of force-free extrapolation methods. Although numerical methods to calculate MHS solutions can deal with non-linear problems more accurately, analytical 3D MHS equilibria can also be used as a numerically "cheaper" method.

We discuss a family of analytical MHS equilibria that allows for a transition from a non-force-free to a force-free region. The solution involves hypergeometric functions. While routines for the calculation of these are available, this can affect the speed and accuracy of the calculations. We look into the asymptotic behaviour of this solution in order to approximate it through exponential functions to improve the numerical efficiency. We present an illustrative example by comparing field line profiles, density and pressure differences between the exact solutions and the asymptotic solution.

EP 12.11 Fri 13:50 EP-H1

Confined and Subsequent Full Flux Rope Eruption as a Model for Homolous Solar Events — Alshaimaa Hassanin[1], •Bernhard Kliem[2], Norbert Seehafer[2], and Tibor Török[3] — [1]Department of Astronomy, Space Science & Meteorology, Faculty of Science, University of Cairo, Egypt — [2]Institute of Physics and Astronomy, University of Potsdam, Germany — [3]Predictive Science Inc., San Diego, CA 92121, USA

We present the first numerical model of a sequence of a confined and a full eruption (i.e., a coronal mass ejection, CME). The first eruption results from the helical kink instability of a sufficiently twisted magnetic flux rope; it remains confined because the flux rope does not reach the critical height for onset of the torus instability. A two-step reconnection process reforms a flux rope with subcritical twist near the position of the original flux rope. The full eruption develops as a result of converging motions imposed at the photospheric boundary, which drive flux cancellation. In this process, a part of the positive and negative sunspot flux converge toward the polarity inversion line, reconnect, and cancel each other. Flux of the same amount as the canceled flux transfers to the flux rope, increasing its free magnetic energy. With sustained flux cancellation and the associated progressive weakening of the magnetic tension of the overlying flux, we find that a flux reduction of $\approx 9\%$ leads to the ejective eruption. These results demonstrate that homologous eruptions, eventually leading to a coronal mass ejection, can be driven by flux cancellation.