EP 7: Sun and Heliosphere II

Time: Thursday 14:00–17:45 Location: ELP 6: HS 2

EP 7.1 Thu 14:00 ELP 6: HS 2

New results on solar energetic electron events obtained from combined in-situ and remote-sensing observations from Solar Orbiter — •Alexander Warmuth and Frederic Schuller — Leibniz-Institut für Astrophysik Potsdam (AIP)

We present the first statistical results on energetic electron events obtained by joint observations of remote-sensing and in-situ instruments on Solar Orbiter. We use the Energetic Particle Detector (EPD) to measure the properties of the electrons (time profile, anisotropy, inferred injection time at the source, etc.), as well as to determine the composition of the associated energetic ions. X-ray observations from the Spectrometer/Telescope for Imaging X-rays (STIX) constrain the energetic electrons in the solar flare in terms of timing, spectrum, and location. Type III radio bursts detected by the Radio and Plasma Waves (RPW) instrument are used to link the nonthermal X-ray peaks to the interplanetary electron beams. Finally, the Extreme Ultraviolet Imager (EUI) provides context on the flare evolution. We have compiled a large sample of 330 events obtained during the first 2.5 years of the Solar Orbiter mission, which covers a wide range of radial distances ranging from as close as 0.3 au to 1 au. For the first time, this allows us to study the relationship between energetic electron events and associated flares as a function of heliocentric distance. This is crucial to constrain particle propagation effects.

EP 7.2 Thu 14:15 ELP 6: HS 2

Separating fundamental and harmonic emission in LOFAR solar type III radio burst images — •Christian Vocks[1], Mario Bisi[2], Bartosz Dabrowski[3], Diana Morosan[4], Peter Gallagher[5], Andrzej Krankowski[3], Jasmina Magdalenic[6], Gottfried Mann[1], Christophe Marque[6], Barbara Matyjasiak[7], Hanna Rothkaehl[7], and Pietro Zucca[8] — [1]Leibniz-Institute for Astrophysics Potsdam (AIP), Germany — [2]RAL Space, United Kingdom — [3]University of Warmia and Mazury, Olsztyn, Poland — [4]University of Helsinki, Finland — [5]DIAS, Dublin, Ireland — [6]Royal Observatory of Belgium, Brussels, Belgium — [7]Polish Academy of Sciences, Warsaw, Poland — [8]ASTRON, Dwingeloo, Netherlands

LOFAR spectroscopic imaging observations of solar type III radio bursts during an M class flare show distinct compact sources with variations in their positions and intermittent dual structures. These are interpreted as fundamental and harmonic emission, with the one or other being dominant at times. Sources of fundamental emission at one observed frequency, and harmonic emission from a coronal region with plasma frequency of half the observed frequency, can be clearly separated. Thus, it is possible to yield separate lightcurves, and to compare the flux evolution of fundamental - harmonic pairs, e.g. 35 MHz and 70 MHz. Both fundamental and harmonic emission should originate simultaneously from the same coronal source region. Variations in burst onset times and apparent source position then provide information on transport effects, like scattering and refraction, of radio waves in the solar corona.

EP 7.3 Thu 14:30 ELP 6: HS 2

The alignment of STEREO-A and Earth: A unique opportunity to improve solar energetic proton forecasting capabilities — •B. Heber[1], D. Banys[2], J. Berdermann[2], H. Dröge[1], M. Hörlöck[1], A. Kollhoff[1], P. Kühl[1], O. Malandraki[3], J. Martens[1,2], A. Posner[4], and H. Sierks[5] — [1]Christian Albrechts Universität, Kiel, Germany — [2]German Aerospace Center, Institute for Solar-Terrestrial Science — [3]National Observatory of Athens, Greek — [4]NASA, USA — [5]Max-Planck Institute for Solar System Research, Germany

A major impact on human and robotic space exploration activities is the sudden and prompt occurrence of solar energetic ion events. The fact that near relativistic electrons (1 MeV electrons have 95% of the speed of light) travel faster than ions (30 MeV protons have 25% of the speed of light) and are always present in Solar Energetic Particle (SEP) events can be used to forecast the arrival of protons from SEP events with real-time measurements of near relativistic electrons. The Relativistic Electron Alert System for Exploration (REleASE) forecasting scheme uses this effect to predict the proton flux. In 2023 and 2024, STEREO is approaching the Earth from a behind position, soon passing Earth inside its orbit and thereafter moving ahead of Earth. STEREO thus offers several unique opportunities during this passage to test the accuracy and extent of the REleASE system as is, and to enhance REleASE beyond its current capabilities.

EP 7.4 Thu 14:45 ELP 6: HS 2

Solar Energetic Proton forecasting with REleASE during STEREO-A's flyby of Earth — •Henrik Dröge[1], Bernd Heber[1], Alexander Kollhoff[1], Patrick Kühl[1], Olga Malandraki[3], and Arik Posner[2] — [1]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, Germany — [2]NASA/HQ, Washington, DC 20546, USA — [3]National Observatory of Athens, Athens, Greece

Solar Energetic Particle (SEP) events can pose a significant radiation hazard for human and robotic space exploration acivities. Therefore SEP forecasting systems are needed to support operations. The REleASE system (A. Posner, 2007) utilizes the fact that near relativistic electrons (1 MeV electrons have 94% of the speed of light) travel faster than ions (30 MeV protons have 25% of the speed of light) and are always present in hazardous SEP events. Their early arrival can be used to forecast the expected proton flux. Originally REleASE uses realtime data from SOHO/EPHIN near Earth. Since the instrument is aging we recently adapted the method to STEREO-A/HET and used the period from June to November, 2023 when STEREO-A passed the Earth to compare the REleASE forecasts from the different instruments.

EP 7.5 Thu 15:00 ELP 6: HS 2

Measurements of ultra-relativistic electrons during solar energetic particle events - Results from the Ulysses Kiel Electron Telescope — •Carlotta Jöhnk, Bernd Heber, and Marlon Köberle — Christian-Albrechts-Universität zu Kiel, Germany

Solar energetic particle (SEP) events are increases of ions and electrons caused by solar activity namely flares and coronal mass ejections. While the most energetic ion population is well studied, SEP events accelerating electrons above 20 MeV have only been reported from measurements by ISEE III in the 1980s and the Kiel Electron Telescope (KET).

The KET aboard Ulysses launched in 1990 and measured the electron flux in the energy range from 4 MeV to above 6 GeV. Here we report on observations of ultra-relativistic electrons and show spectra of electron events during solar cycle 22 and 23 until the end of 2008. The maximum electron energy exceeded 100 MeV during the August 16, 2001 SEP event.

EP 7.6 Thu 15:15 ELP 6: HS 2

Charge sign dependence of recurrent Forbush Decreases in 2016 — •Lisa Romaneehsen, Johannes Marquardt, and Bernd Heber — Christian-Albrechts-Universität zu Kiel, Germany

This study investigates the periodicities of cosmic rays attributed to corotating interaction regions (CIRs) using AMS-02 data from late 2016 to early 2017. These data enable the first-time examination of recurrent Forbush decrease amplitudes induced by CIRs, considering rigidity and charge sign dependence. The findings from the Lomb-Scargle algorithm and Superposed Epoch Analysis were compared. Results reveal that the rigidity dependence of proton decreases attributed to the northern coronal hole aligns with existing literature, while that of the southern coronal hole does not. The amplitude of the Helium modulation exceeds that of protons, in line with previous observations. For positrons statistical limitation prevent definitive conclusions. In comparison to the positively charged ions the modulation behavior of electrons can not be understood in the current paradigma of modulation by diffusion barriers.

EP 7.7 Thu 15:30 ELP 6: HS 2

Quasi-Discontinuous Solar Wind Models — •Lukas Westrich[1,2], Horst Fichtner[1], and Bidzina Shergelashvili[1,2] — [1]Ruhr-Universität Bochum, Institute for theoretical physics IV — [2]Ilia State University, Faculty of Natural Sciences and Medicine, Tbilisi, Georgia

In this talk the heating of the solar wind above the Heliobase will be examined. Based on the discontinuous solar wind solutions from Shergelashvili et al. (2020) we developed new quasi-discontinuous so-

lar wind models. First we will present the basic concept of discontinuous solar wind solutions and the quasi-discontinuous solar wind models, which is basically the assumption of a localized heating source above the Heliobase in a case of 1D quasi- adiabatic radial expansion of the solar wind. Furthermore, we will discuss the differences and the similarities of these. These models contain high gradients in the physical properties. Therefore, after an discussions of the characteristics of these solutions we will examine, how heat conduction could weaken those. It will be shown, that heat conduction is not strong enough to flatten the basic flow structure. As a result, the idea behind these models, that a damping of plasma waves near the trans-sonic point could produce such solar wind structures, is still reasonable.

EP 7.8 Thu 15:45 ELP 6: HS 2

Impact of diffusion models on the spectra obtained by diffusive shock acceleration — •Dominik Walter, Horst Fichtner, Yuri Litvinenko, and Frederic Effenberger — Ruhr-Universität-Bochum

The process of shock acceleration has long been a topic in astrophysics. A very prominent point of discussion is the shock spectrum, which has prooved quite universal over the last decades. In recent years, however, there have been modifications made to the diffusive behaviour of the acceleration process, some of which seem to alter said shock spectrum. Mentioned modifications are based on e.g. fractional or nonlinear diffusion approaches. This presentation will give a few examples and discuss, when a change of the spectral behaviour is to be expected and why.

30 min break

EP 7.9 Thu 16:30 ELP 6: HS 2

Energetic particle transport modelling with PARADISE — •Edin Husidic[1,2], Nicolas Wijsen[1], Stefaan Poedts[1,3], and Rami Vainio[2] — [1]Centre for mathematical Plasma Astrophysics, KU Leuven, Leuven, Belgium — [2]Department of Physics and Astronomy, University of Turku, Turku, Finland — [3]Institute of Physics, University of Maria Curie-Skłodowska, Lublin, Poland

Solar energetic particles (SEPs) constitute high-energy charged particles originating from solar eruptive phenomena. In particular, protons with energies ranging from tens of MeV to a few GeV per nucleon, pose a significant threat to satellites and astronauts. The intensities of SEPs are substantially influenced by the large-scale solar wind configuration, incorporating structures like coronal mass ejections (CMEs) or stream interaction regions (SIRs), which perturb the interplanetary (IP) magnetic field and ultimately affect the transport of SEPs. Despite decades of research, the precise acceleration mechanisms remain not fully known. Numerical models capable of simulating SEP events have proven to be valuable tools in the study of the transport and acceleration of SEPs. Here, we share recent findings derived with the energetic particle transport code PARADISE. The code utilises realistic background solar wind configurations as input, derived from magnetohydrodynamic (MHD) models such as EUHFORIA or the Icarus test case of the MPI-AMRVAC framework. By employing a stochastic approach to solve the focused transport equation, PARADISE obtains SEP intensities in the inner heliosphere. The presented studies focus on particle acceleration at IP shocks associated with CMEs and SIRs.

EP 7.10 Thu 16:45 ELP 6: HS 2

Solar energetic particle transport, gamma ray flares and intermittent turbulence — •Frederic Effenberger, Jeremiah Lübke, Julien Dörner, Horst Fichtner, and Rainer Grauer — Theoretische Physik, Ruhr-Universität Bochum, Germany

The detailed understanding and ultimately the ability to forecast solar energetic particle (SEP) events is critical in our efforts to mitigate space weather risks. I will discuss current issues in SEP modelling and observations with a particular focus on non-thermal particle sources in solar flares and CME shocks, and cross-field transport effects due to solar wind structures and field line random walk. Of particular interest are coherent features in the solar wind turbulence that can influence particle transport behaviour. Synthetic fields to study particle transport are typically generated from superpositions of Fourier modes with a prescribed power spectrum and uncorrelated random phases, bringing the advantage of covering a wide range of turbulence scales at manageable computational effort. However, almost all of these models to date only account for second-order Gaussian statistics and thus fail to include intermittent features. We have developed a novel method to account for this shortcoming based on a minimal Lagrangian map approach. We investigate the particle transport properties by solving a large number of particle orbits in these synthetic turbulence realisations and specifically look for non-diffusive regimes and non-standard energy dependences resulting from the intermittency of the generated fields. Applications to SEP transport and the production of gamma rays from solar events will be discussed.

EP 7.11 Thu 17:00 ELP 6: HS 2

Structured Synthetic Turbulence and Solar Energetic Particle Transport — •Jeremiah Lübke[1], Frederic Effenberger[2], Mike Wilbert[1], Horst Fichtner[2], and Rainer Grauer[1] — [1]Institute for Theoretical Physics I, Ruhr-University Bochum, Universitätsstr. 150, 44801 Bochum — [2]Institute for Theoretical Physics IV, Ruhr-University Bochum, Universitätsstr. 150, 44801 Bochum

Turbulence is ubiquitous in the solar wind, however its impact on the transport of solar energetic particles is poorly understood, since global simulations of the heliosphere are not able to resolve the turbulent length scales properly. This issue can be mitigated by employing synthetic turbulence, which is usually modelled as scale-invariant "smart noise" via sums of waves with a prescribed power spectrum and random uncorrelated phases. We present a novel model for synthetic turbulence, which is more faithful to the complex intermittent character of realistic turbulence, which is dominated by low-curvature coherent structures and high-curvature intense scattering sites. The model is a combination of a log-normal cascade and the multiscale minimal Lagrangian mapping approach. We investigate the resulting vector fields with regard to structure function scaling, fieldline geometry and energetic particle transport properties. Magnetohydrodynamic simulations of turbulence are consulted for comparison. We find that energetic particle diffusion is significantly enhanced by a combination of extended coherent structures and intense high-curvature scattering sites. Finally, applications to specific phenomena in the heliosphere, such as CME sheath turbulence, are discussed.

EP 7.12 Thu 17:15 ELP 6: HS 2

Linear theory of oblique plasma instabilities for reguarlized Kappa-distributions — •Dustin Lee Schröder[1], Horst Fichtner[1], and Marian Lazar[1,2] — [1]Ruhr-Universität Bochum, Bochum, Deutschland — [2]KU Leuven, Löwen, Belgien

A linear plasma solver is employed to investigate proton firehose and electron firehose instabilities for oblique propagation directions in the context of regularized Kappa-distributions.

EP 7.13 Thu 17:30 ELP 6: HS 2

Flux rope formation prior to CME onset by confined precursor flares—a statistical study — •Bernhard Kliem — University of Potsdam, Institute of Physics and Astronomy

I present a statistical study of flare ribbons in confined eruptions which precede a major ejective eruption (coronal mass ejection, CME), using the complete sample of CMEs associated with $>$ M5.0 flares in 2011–2015 and source distance from Sun center of < 50 deg (32 events, from Baumgartner et al. 2018). Ribbons of precursor events within 12 hr from the onset of the CME-associated (eruptive) flare are compared with the ribbons of the main event to assess a potential contribution of the precursor events to the buildup of a flux rope prior to CME onset. It is found that 26 CMEs (81%) have one or several precursors with bright ribbons that cover a part of the ribbons in the main event, hence, clearly contribute to the buildup of the flux rope that later erupts and drives the CME. Two further events (6%) develop such ribbons during an enhancement that is part of the event's slow-rise phase, i.e., also prior to CME onset. Two CMEs only possess precursors with weak, very short, or very transient ribbons, indicating at least a minor contribution to the buildup of the flux rope erupting in the CME, and the final two events do not show any such indication. Of the last four events, however, three are characterized by a large ribbon separation from their onset, suggesting a high-lying flux rope that may have formed at earlier times. Overall, a significant role of flare reconnection for the buildup of a flux rope prior to CME onset is indicated for the great majority (88%) of the considered CME sample.