**XVI$^{th}$ Hvar Astrophysical Colloquium**

# International Study of Earth-affecting Solar Transients ISEST 2018 Workshop

**24 - 28 September 2018, Hvar, Croatia**

**Figure on the cover:** Bow figurine from the Hvar galley that was engaged in the naval battle of Lepanto on 7 October 1571 when the galley fleet of the Holy League defeated the Ottoman fleet.

# XVI$^{\text{th}}$ Hvar Astrophysical Colloquium
# International Study of Earth-affecting Solar Transients
# ISEST 2018 Workshop
# 24 - 28 September 2018, Hvar, Croatia

The XVI$^{\text{th}}$ Hvar Astrophysical Colloquium "International Study of Earth-affecting Solar Transients ISEST 2018 Workshop" is organized by Hvar Observatory, Faculty of Geodesy, University of Zagreb. The meeting is held under the auspices of the Hvar Town Council and Croatian Astronomical Society. The Colloquium is sponsored by the Ministry of Science, Education and Sports, Republic of Croatia, Scientific Committee on Solar Terrestrial Physics (SCOSTEP) and the International Association of Geomagnetism and Aeronomy (IAGA).

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Isabell Piantschitsch (Uni. Graz)
Ivica Skokić (Hvar Obs.)
Davor Sudar (Hvar Obs.)
Toni Visković (Hvar Obs.)

CONFERENCE MEETING PLACE: Hotel Amfora - Hvar Grand Beach Resort, Hvar, Croatia

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## PROGRAMME:

### Sunday, September 23, 2018

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| 18:00 – 19:00 | Registration |

### Monday, September 24, 2018

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| 8:15 – 9:00 | Registration |
| 9:00 – 9:30 | Opening words:<br>Katija Vučetić (Hvar), Bojan Vršnak (SOC), Jaša Čalogović (LOC) |

*ISEST WG reports* chairperson: **M. Temmer**

| | |
|---|---|
| 9:30 – 10:20 | J. Zhang: Global Evolution of CMEs from the Sun to the Earth *(Plenary talk)* |
| 10:20 – 10:40 | J. Zhang: Working Group 1 (Data) - Progress Report |
| 10:40 – 11:00 | B. Vršnak: Working Group 2 (Theory) - Progress Report |
| 11:00 – 11:20 | D. Odstrcil: Working Group 3 (Simulation) - Progress Report |

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| 11:20 – 11:50 | coffee – break |

*ISEST WG reports* chairperson: **J. Zhang**

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|---|---|
| 11:50 – 12:10 | D. Webb: Working Group 4 (Campaign events) - Progress report |
| 12:10 – 12:30 | S. Patsourakos: Working Group 5 (Bs Challenge) - Progresses Report |
| 12:30 – 12:50 | O. Malandraki: Working Group 6 (Solar Energetic Paticles) - Progress Report |
| 12:50 – 13:10 | M. Temmer: Working Group 7 (MiniMax24) - Progress Report |

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| 13:10 – 15:30 | lunch – break |

*Data & Observation related to solar-terrestrial phenomena (WG1 (data), WG5 (Bs challenge) and related abstracts from the General session on Sun & Heliosphere)* chairperson: **J. Zhang**

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|---|---|
| 15:30 – 16:00 | L. Green: Observations of magnetic flux ropes in the solar atmosphere: what next? *(Invited)* |
| 16:00 – 16:20 | N. Srivastava: Evolution of coronal cavities leading to CMEs |
| 16:20 – 16:40 | R. Liu: Identifying the source complexity of a complex ejecta |
| 16:40 – 17:00 | A. Veronig: Which factors of an active region determine whether a strong flare will be CME-associated or not? |

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| 17:00 – 17:30 | coffee – break |

*Data & Observation related to solar-terrestrial phenomena (WG1 (data), WG5 (Bs challenge) and related abstracts from the General session on Sun & Heliosphere)* chairperson: **A. Veronig**

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| 17:30 – 17:50 | T. Mrozek: The catalogue of solar failed eruptions |
| 17:50 – 18:10 | T. Kaltman: Features of spectral-polarization dynamics of flare active regions by microwave observations |
| 18:10 – 18:30 | D. Sokoloff: Can superflares occur on the Sun? A view from dynamo theory |
| 18:30 – 19:00 | Open discussion |

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| 19:30 | Welcome reception |

**Tuesday, September 25, 2018**

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| *Data & Observation related to solar-terrestrial phenomena (WG1 (data), WG5 (Bs challenge) and related abstracts from the General session on Sun & Heliosphere)* chairperson: **S. Patsourakos** | |
| 9:00 – 9:30 | C. Kay: The Effects of Uncertainty on Deflection, Rotation and Bs predictions *(Invited)* |
| 9:30 – 9:50 | K. Dissauer: What can we learn from coronal dimmings about the early evolution of Earth-directed CMEs? |
| 9:50 – 10:10 | A. Ruzmaikin: Clustering of Coronal Mass Ejections |

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| 10:10 – 10:40 | coffee – break |

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| *Data & Observation related to solar-terrestrial phenomena (WG1 (data), WG5 (Bs challenge) and related abstracts from the General session on Sun & Heliosphere)* chairperson: **B. Heber** | |
| 10:40 – 11:10 | T. Nieves-Chinchilla: Unraveling the internal magnetic configuration of the ICMEs *(Invited)* |
| 11:10 – 11:30 | S. Benella: On the role of the topology of magnetic clouds on galactic cosmic-ray Forbush decreases at energies above 70 MeV |
| 11:30 – 11:50 | A. Melkumyan: Statistical analysis of Forbush decreases observed during past five solar cycles and associated to coronal mass ejections or coronal holes |
| 11:50 – 12:10 | S. Hofmeister: The dependence of high-speed stream peak velocities and of the Kp index on the positions of their source coronal holes on the Sun |
| 12:10 – 12:40 | Open discussion |

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| 12:40 – 15:00 | lunch – break |

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| *Data & Observation related to solar-terrestrial phenomena (WG1 (data), WG5 (Bs challenge) and related abstracts from the General session on Sun & Heliosphere)* chairperson: **J. Zhang** | |
| 15:00 – 15:30 | P. Hess: Preparing for the Future of Heliospheric Observations *(Invited)* |
| 15:30 – 15:50 | M. Dosa: Long-term periodicities in the heliospheric magnetic flux density and the effects on planetary space weather |
| 15:50 – 16:10 | Y. Yan: Solar Radio Imaging-Spectroscopy and Heliospheric Imager |

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| 16:10 – 16:40 | coffee – break |

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| *Simulations and theoretical aspects of solar-terrestrial phenomena (WG2 (theory), WG3 (simulation) and related abstracts from the General session on Sun & Heliosphere)* chairperson: **F. Shen** | |
| 16:40 – 17:10 | C. Shen: Interaction between multiple CMEs and its impact on space weather *(Invited)* |
| 17:10 – 17:30 | T. Amerstorfer: Ensemble prediction of a solar storm arrival at Earth using heliospheric images |
| 17:30 – 17:50 | J. Čalogović: DBEM web application for heliospheric propagation of CMEs |
| 17:50 – 18:10 | M. Dumbović: Forbush decrease model for expanding CMEs (ForbMod) |
| 18:10 – 18:40 | Open discussion |

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| 19:00 – 20:30 | Poster Session |

## Wednesday, September 26, 2018

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| *Simulations and theoretical aspects of solar-terrestrial phenomena (WG2 (theory), WG3 (simulation) and related abstracts from the General session on Sun & Heliosphere)* chairperson: **B. Vršnak** | |
| 9:00 – 9:30 | D. Odstrcil: Near Real-Time Simulation of Heliospheric Space Weather *(Invited)* |
| 9:30 – 9:50 | F. Shen: Three-dimensional MHD simulation of solar wind using a new boundary treatment: Comparison with in-situ data at Earth |

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| 9:50 – 10:20 | coffee – break |

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| *Simulations and theoretical aspects of solar-terrestrial phenomena (WG2 (theory), WG3 (simulation) and related abstracts from the General session on Sun & Heliosphere)* chairperson: **D. Odstrcil** | |
| 10:20 – 10:40 | I. Myshyakov: Influence of the Magnetic Decay Index Spatial Distribution on the Kinematics of the Solar Eruptive Prominence |
| 10:40 – 11:00 | I. Piantschitsch: Simulation of fast-mode MHD waves interacting with low density regions such as coronal holes |
| 11:00 – 11:20 | A. Afanasev: Numerical simulations of coronal loop kink oscillations excited by different driver frequencies |
| 11:20 – 11:50 | Open discussion |

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| 11:50 – 14:30 | lunch – break |

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| *Parker Solar Probe and Solar Orbiter* chairperson: **M. Temmer** | |
| 14:30 – 15:15 | R. Pinto: Modeling and data analysis tools to support science at the Parker Solar Probe and Solar Orbiter era (including the hands-on-session) *(Invited)* |
| 15:15 – 15:35 | E. Dickson: STIX Software Development at Graz |
| 15:35 – 15:55 | B. Heber: GEANT4 simulation of the Helios E6 - Proton contamination of relativistic electron measurements |
| 15:55 – 16:25 | Open discussion |

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| 18:00 | Group visit to fortress "Španjola" |

## Thursday, September 27, 2018

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| *Solar energetic particles (WG6 (SEPs) and related abstracts from the General session on Sun & Heliosphere)* chairperson: **O. Malandraki** | |
| 9:00 – 9:30 | C. Cohen: Solar Energetic Particles: Origin, Acceleration, and Transport *(Invited)* |
| 9:30 – 9:50 | M. Riazantseva: The features of plasma turbulence associated with solar transients |
| 9:50 – 10:10 | V. Zharkova: Acceleration of particles in 3D magnetic islands with low plasma density and their diagnostics in the heliosphere |
| 10:10 – 10:30 | J. Guo: Challenges of Space Weather and space radiation predictions for human explorations to Mars |

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| 10:30 – 11:00 | coffee – break |

| *Event studies using solar-terrestrial data & modeling (WG4 (campaign events) and related abstracts from the General session on Sun & Heliosphere)* chairperson: **D. Webb** | |
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| 11:00 – 11:30 | M. Jin: Sun-to-Earth Modeling of Coronal Mass Ejections with a Global MHD Model: Facilitating Physical Understanding and Space Weather Forecasting *(Invited)* |
| 11:30 – 11:50 | J. I. Campos Rozo: Solar photospheric plasma and magnetic field dynamics: modelling of the temporal evolution of flow motions |
| 11:50 – 12:10 | I. Dammasch: Multi-instrument observations of an X9.3 flare |
| 12:10 – 12:30 | S. Heinemann: Coronal Hole and Active Region Interaction observed through a CME-HSS Interaction |
| 12:30 – 13:00 | Open discussion |

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| 13:00 – 17:00 | lunch – break |

| *Event studies using solar-terrestrial data & modeling (WG4 (campaign events) and related abstracts from the General session on Sun & Heliosphere)* chairperson: **N. Srivastava** | |
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| 17:00 – 17:30 | C. Scolini: Observation-based Sun-to-Earth simulations of geo-effective Coronal Mass Ejections with EUHFORIA *(Invited)* |
| 17:30 – 17:50 | T. Tsvetkov: Dynamic properties of prominence eruptions observed by AIA and LASCO |
| 17:50 – 18:10 | T. Podladchikova: CME acceleration and EUV wave kinematics for September 10th 2017 event |
| 18:10 – 18:30 | J. Seibezeder: Evolution of plasma parameters during the early acceleration phase of the June 13 2010 CME event |
| 18:30 – 19:00 | Open discussion |

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| 20:00 | Conference dinner |

**Friday, September 28, 2018**

| *ISEST WG reports* chairperson: **M. Temmer** | |
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| 10:00 – 10:20 | J. Zhang: Working Group 1 (Data) - Summary Report |
| 10:20 – 10:40 | B. Vršnak: Working Group 2 (Theory) - Summary Report |
| 10:40 – 11:00 | F. Shen: Working Group 3 (Simulation) - Summary Report |

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| 11:00 – 11:30 | coffee – break |

| *ISEST WG reports* chairperson: **B. Vršnak** | |
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| 11:30 – 11:50 | D. Webb: Working Group 4 (Campaign events) - Summary Report |
| 11:50 – 12:10 | S. Patsourakos: Working Group 5 (Bs Challenge) - Summary Report |
| 12:10 – 12:30 | O. Malandraki: Working Group 6 (Solar Energetic Paticles) - Summary Report |
| 12:30 – 12:50 | J. Zhang: Conclusion & future plans |

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| 12:50 – 13:00 | Closing words (B. Vršnak) |

## LIST OF POSTERS:

E. Asvestari *et al.*: ASSESSING EUHFORIA USING MULTI-SPACECRAFT CORONAL MASS EJECTION ENCOUNTERS

M. Brüdern *et al.*: THE DETERMINATION OF SOLAR ENERGETIC PARTICLE ANISOTROPIES BASED ON FOUR-SECTOR MEASUREMENTS

W. Caicedo Tez *et al.*: A STUDY ON THE RELATIONSHIP BETWEEN X-RAY EMISSION, WHITE LIGHT AND MAGNETIC FIELD CHANGES DURING SOLAR FLARES

J. Čalogović *et al.*: PHOTOSPHERIC AND CHROMOSPHERIC OBSERVATIONS AT HVAR OBSERVATORY

J. Čalogović *et al.*: THE POSSIBLE IMPACT OF COSMIC RAYS ON EXTRATROPICAL CYCLONE FREQUENCY AND STRENGTH OVER NORTH ATLANTIC

A. Deres *et al.*: DIAGNOSTIC OF TRANSVERSE TEMPERATURE DISTRIBUTION IN CORONAL FANS, USING 3-MIN OSCILLATIONS

D. Galsdorf *et al.*: THE GROUND LEVEL EVENT ON SEPTEMBER 10, 2017

N. Gopalswamy *et al.*: IMPLICATIONS OF THE FRED MODEL TO UNDERSTANDING THE INTERPLANETARY COUNTERPART OF THE 2015 JUNE 21 CME

B. Heber *et al.*: NEUTRON MONITOR MEASUREMENTS ON THE GERMAN RESEARCH VESSEL POLARSTERN

L. Holzknecht *et al.*: IN-SITU DENSITY OF (I)CMES VERSUS CME 3D GEOMETRY AND MASS DERIVED FROM REMOTE SENSING DATA

K. Jiřička, M. Karlický: VERY RARE BURSTS OBSERVED IN THE 0.8-2.0 GHZ SOLAR RADIO SPECTRA

A. Kirin: REFLECTION OF COSMIC RAYS AT MHD SHOCKS

M. Köberle *et al.*: EXTREME SOLAR ENERGETIC ELECTRON EVENTS OBSERVED BY ULYSSES COSPIN/KET

A. Kollhoff *et al.*: INTERPRETATION OF INCREASED SOLAR ENERGETIC PARTICLE FLUX MEASUREMENTS WITH SEPT ABOARD THE STEREO SPACECRAFT AND CONTAM

D. Korda, M. Švanda: COMBINED HELIOSEISMIC INVERSION FOR 3D VECTOR FLOWS AND SOUND-SPEED PERTURBATIONS

K. Krikova *et al.*: DYNAMICS AND MAGNETIC PROPERTIES IN CORONAL HOLES USING HIGH-RESOLUTION MULTI-INSTRUMENT SOLAR OBSERVATIONS

V. Krupar *et al.*: STATISTICAL STUDY OF TYPE II AND TYPE III BURSTS OBSERVED BY STEREO/WAVES

M. Kuhar *et al.*: NUSTAR DETECTION OF X-RAY HEATING EVENTS IN THE QUIET SUN

P. Kühl *et al.*: SOLAR ENERGETIC PARTICLE EVENTS WITH PROTONS ABOVE 500 MEV BETWEEN 1995 AND 2015 MEASURED WITH SOHO/EPHIN

O. Kühner *et al.*: DEPENDENCY OF FORMATION HEIGHTS OF DIFFERENT HINODE SOT/BFI SPECTRAL BANDS ON MBP MODEL CHARACTERISTICS

E. Kupriyanova *et al.*: TO THE ANALYSIS OF THE NON-STATIONARY QUASI-PERIODIC PULSATIONS IN A SOLAR FLARE

A. Lara *et al.*: STATISTICAL ANALYSIS OF SUCCESSIVE CORONAL MASS EJECTIONS AND THEIR SPATIO-TEMPORAL ASSOCIATION

C. Munteanu *et al.*: MAGNETOSPHERIC EFFECTS OF RECURRENT COROTATING INTERACTION REGIONS OBSERVED BETWEEN JANUARY AND APRIL 2008

D. Odstrcil *et al.*: LAUNCHING HYDRODYNAMIC AND MAGNETIC CME-LIKE STRUCTURES INTO THE OPERATIONAL HELIOSPHERIC SPACE WEATHER MODELS

D. Odstrcil *et al.*: CONSTRAINING THE CONE FREE-MODEL PARAMETERS IN THE WSA-ENLIL-CONE HELIOSPHERIC MODEL BY THE UPDATED CME DRAG MODEL

W. Pötzi *et al.*: EVALUATION OF THE NEW KANZELHÖHE OBSERVATORY FLARE DETECTION ALGORITHM WITH AN EVENT BASED VERIFICATION SYSTEM

M. Rodari *et al.*: 3D RECONSTRUCTION AND INTERPLANETARY EXPANSION OF A 2010 APRIL 3RD CME

J. Saqri *et al.*: PLASMA DIAGNOSTICS AND FORMATION OF CORONAL HOLES

M. Švanda, T. Výboštoková: IS THE CZECH POWER GRID AFFECTED BY SPACE-WEATHER EVENTS?

Ż. Szaforz, M. Tomczak: QUASI-PERIODIC PULSATIONS WITH LARGE PERIODS

M. Temmer *et al.*: STATISTICAL STUDY ON CORONAL HOLE EVOLUTION AND APPLICATION FOR SOLAR WIND SPEED FORECASTING

O. Troshichev *et al.*: MAGNETOSPHERE RESPONSE TO SPACE WEATHER EVENTS: RELATIONSHIPS BETWEEN PC, AE AND SYMH INDICES

Ts. Tsvetkov *et al.*: FIRST YEAR RESULTS OF THE BULGARIAN-RUSSIAN PROJECT ON THE ORIGIN OF SOLAR ENERGETIC PARTICLES

D. Utz *et al.*: LONG TIME TRENDS OF MBP CHARACTERISTICS

S. Vennerstrom *et al.*: MULTI-SPACECRAFT INVESTIGATION OF CHARACTERISTICS AND EVOLUTION OF CO-ROTATING STREAM INTERACTION REGIONS

# ISEST WG reports

## GLOBAL EVOLUTION OF CMES FROM THE SUN TO THE EARTH [plenary talk]

Jie Zhang

*Department of Physics and Astronomy, George Mason University, 4400 University Dr., MSN 3A3, Fairfax, VA 22031, USA*

In this presentation, the four-year-long activity of the ISEST program will be summarized. The program consists of six working groups and one long-term campaign activity. It holds workshops every year in different continents. It has a persistent WIKI website for ISEST events and catalogs. The program results in a special topical collection in the Journal of Solar Physics and a spin-off book. The presentation will then discuss the progress in tracking and understanding the global evolution of CMEs from the Sun to the Earth, including (1) the full kinematic evolution from the surface of the Sun to 1 AU, and (2) the full multiple-component structure of CMEs. The efforts on the prediction of CME arrivals will be also discussed.

## WORKING GROUP 1: DATA - PROGRESS REPORT

Jie Zhang

*Department of Physics and Astronomy, George Mason University, 4400 University Dr., MSN 3A3, Fairfax, VA 22031, USA*

The Working Group 1 – Data is targeted with the following tasks. (1) Identify all Earth-affecting solar transient events, CMEs and CIRs, during the STEREO era. (2) Track selected events from the Sun to Earth, and fully measure, characterize and quantify their evolutional properties from the Sun to Earth. The report will summarize the existing event catalogs and provide a report on the progress that has been in the recent year.

## WORKING GROUP 2: THEORY - PROGRESS REPORT

Bojan Vršnak[1], Yuming Wang[2] *et al.*

[1]*Hvar Observatory, Faculty of Geodesy, University of Zagreb, Croatia*
[2]*University of Science and Technology of China, Hefei 230026, China*

The overall aim of WG2 is to advance our comprehension of the physical background of Earth-affecting solar transients. The main goals are: i) to improve our understanding of the structure and evolution of CMEs, including magnetic flux ropes and driven shocks, as well as their origin; ii) to improve comprehension of coronal/heliospheric dynamics of CMEs, including the interaction with ambient solar wind and interplanetary magnetic field, causing deceleration/acceleration and deflections; iii) to get a better insight into how long does the Lorentz force dominate over the aerodynamic drag force, including the estimation of the drag parameter and/or the dimensionless drag coefficient; iv) to improve our capability in modelling and forecasting the southward magnetic field component (Bs) inside a CME; v) to compare the theoretical results with observations, e.g., 1AU transit time, impact speed, impact magnetic field, etc. The WG2-related scientific results obtained in the period after the Jeju/Korea meeting are presented.

## WORKING GROUP 3: SIMULATION - PROGRESS REPORT

Fang Shen[1], Dusan Odstrcil[2] et al.

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We report the progress and the future plan of the Simulation Working Group of the ISEST project. The scientific goals of this working group are to (1) provide global context for the ICMEs investigated by the ISEST team (e.g. WG1, WG4); (2) investigate processes of the CME initiation, heliospheric propagation, and CMEs interaction; (3) develop tools to assist collaboration of numerical modelers, theoreticians, and observers. The working group will use existing 3D MHD models including ENLIL, COIN-TVD, CESE, H3DMHD, EUHFORIA, SWMF and other model from Michigan group.

## WORKING GROUP 4: CAMPAIGN EVENTS - PROGRESS REPORT (OVERVIEW OF VARSITI ISEST/MINIMAX24 WORKING GROUP 4 STUDIES ON CAMPAIGN EVENTS)

David Webb[1] and Nariaki Nitta[2]

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The goal of the ISEST (International Study of Earth-affecting Solar Transients) project as part of the Variability of the Sun and Its Terrestrial Impact (VarSITI) program is to understand the origin, evolution and propagation of solar transients through the space between the Sun and Earth, and to improve our prediction capability for space weather. A goal of ISEST Working Group 4 (Campaign Events) is to study a set of well-observed Sun-to-Earth events to develop an understanding of why some events are successfully forecast (textbook cases), whereas others become problem or failed forecasts. WG4 has studied about 15 events in detail. In a recent paper (Webb and Nitta, Sol. Phys., 2017) we studied six cases during the rise of Solar Cycle 24 that highlight forecasting problems, and were chosen to illustrate some key problems in understanding the chain from cause to geoeffect.

## WORKING GROUP 5: BS CHALLENGE - PROGRESS REPORT

Spiros Patsourakos

*University of Ioannina, Physics Department, Greece*

The presence of intense and long-duration southward magnetic fields (Bs) in Interplanetary Coronal Mass Ejections (ICMEs) upon impact to the magnetosphere, is arguably the most important factor in producing geomagnetic storms. Unfortunately, we currently lack routine direct observations of the magnetic field vector near the Sun. Therefore, we have to mostly rely on indirect methods to infer this important parameter, which is a key element in schemes aiming to predict the CME magnetic field at 1 AU. WG5 aims to characterize the near-Sun magnetic fields of CMEs, and to eventually predict their magnetic field distribution at 1 AU. With this talk, we will supply a report of research related to WG5 activities, and outline possible avenues of future research.

## WORKING GROUP 6: SOLAR ENERGETIC PATICLES - PROGRESS REPORT

Olga E. Malandraki

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Solar Energetic Particles (SEPs) constitute an important contributor to the characterization of the space environment. They are emitted from the Sun in association with solar flares and Coronal Mass ejection (CME)-driven shock waves. SEP radiation storms may have durations from a period of hours to days or even weeks and have a large range of energy spectrum profiles. These events pose a threat to modern technology strongly relying on spacecraft and are a serious radiation hazard to humans in space, and are additionally of concern for avionics and commercial aviation in extreme circumstances. The main objective of the Working Group on SEPs (WG6) of the VarSITI/ISEST project, directly aligned with the ISEST science objectives, is the improvement of our understanding of the origin, acceleration and transport of energetic particles in the heliosphere, in association with CMEs and Corotating Interaction Regions (CIRs) propagation and evolution. In this talk, recent activities of the WG6 will be reported.

## WORKING GROUP 7: MINIMAX24 - PROGRESS REPORT (WG7 UPDATE ON THE MINIMAX24 WORKING GROUP)

Manuela Temmer

*Institute of Physics, University of Graz, Austria*

MiniMax24 coordinates international observations and acts as long-term campaign providing daily updates on solar and geospace events. The MiniMax24 email list is also a "come-into-contact platform" with a broad range of experts and serves as hub for the solar and heliospheric physics community. A team of young researchers and seniors provide in a daily email information on non-flare as well linking to flare targets. Main focus are high-speed solar wind streams and filaments, both important information for Space Weather. As the platform is huge and reaches a lot of international colleagues, not only the VarSITI program but also the forecasters themselves increase their visibility. An update and outlook on the MiniMax24 effort is given.

# Data & Observation related to solar-terrestrial phenomena (WG1-data, WG5-Bs challenge and related abstracts from the General session on Sun & Heliosphere)

## OBSERVATIONS OF MAGNETIC FLUX ROPES IN THE SOLAR ATMOSPHERE: WHAT NEXT? [invited]

Lucie Green

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There is increasing observational support for the existence of magnetic flux ropes in the atmosphere of the Sun before their eruption as a CME. The identification of flux ropes can be made using soft X-ray and EUV emission structures, with supporting evidence provided by the photospheric evolutionary sequence that drives the flux rope formation and also vector magnetic field data in some cases. Non-linear force-free models that reconstruct the coronal magnetic field using vector magnetic field data as their boundary condition have also been able to reproduce the flux ropes inferred using observations. Thus enabling a more detailed study of the rope properties and stability conditions. This talk will review observational studies of flux ropes, looking at the physical processes by which they form in the solar atmosphere and the timescales over which these processes take place. Given the apparent wealth of flux rope observations, we ask what next for observational studies? How can we extract more quantitative information about the flux rope properties to further our knowledge of CME processes, and how can we better use observations of flux ropes as the starting point for predicting their space weather consequences?

## EVOLUTION OF CORONAL CAVITIES LEADING TO CMES

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The initiation mechanism of coronal mass ejections (CMEs) remains among the most elusive topics in solar physics. The initiation and triggering of CMEs can be observed in the lower coronal regions by observing the coronal cavities. These appear as dark features and are believed to be the density depleted cross sectional view of the magnetic flux ropes where the magnetic field strength attains a much higher value compared to the background corona. These cavities may last for days or even weeks and evolve as the dark core part of the CME during the eruptive phase. In order to understand the pre-eruptive stability conditions for quiescent cavities and the triggering mechanisms for those structures to erupt, it is important to study the morphological evolution of the coronal cavities. When the CME reaches at 1 AU, the associated dark cavity seen close to the Sun arrives as a magnetic cloud and for the Earthward directed CMEs, it may cause severe geo-magnetic storms depending on the orientation of the embedded magnetic field. We study the evolution of cavity in lower corona using SWAP EUV imager observations which provide an extended (54 arc-minute) field of view that enables to capture the evolution of the erupting cavities upto 1.7-1.9 solar radii. This fills the observational gap between 1 to 2 solar radii which is well known as the regime where the main initial acceleration of the CME occurs . In this study, we report on evolution of several observed coronal cavities from pre-eruptive to eruptive phase with an objective to understand the initiation mechanism of associated CMEs

## IDENTIFYING THE SOURCE COMPLEXITY OF A COMPLEX EJECTA

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The solar corona is frequently disrupted by coronal mass ejections (CMEs), whose core structure is believed to be a flux rope made of helical magnetic field. This has become a "standard" picture, but it remains elusive how the flux rope forms and evolves toward eruption. While one-third of the ejecta passing through spacecraft demonstrate a flux-rope structure, the rest have complex magnetic fields. Are they originating from a coherent flux rope, too? Here we investigate the source region of a complex ejecta, focusing on a flare precursor with definitive signatures of magnetic reconnection, i.e., nonthermal electrons, flaring plasma, and bidirectional outflowing blobs. Aided by nonlinear force-free field modeling, we conclude that the reconnection occurs within a system of multiple braided flux ropes with different degrees of coherency. The observation signifies the importance of internal tructure and dynamics in understanding CMEs and in predicting their impacts on Earth.

## WHICH FACTORS OF AN ACTIVE REGION DETERMINE WHETHER A STRONG FLARE WILL BE CME-ASSOCIATED OR NOT?

Christian Baumgartner, Julia K. Thalmann, Astrid M. Veronig

*Institute of Physics & Kanzelhöhe Observatory, University of Graz, Austria*

We study how the magnetic field determines whether a strong flare launched from an active region (AR) will be eruptive or confined, i.e. associated with a coronal mass ejection (CME) or not. 44 flares of GOES class >M5.0 that occurred during 2011 to 2015 were analyzed in SDO data. We used 3D potential magnetic field models to study their location within the host AR (using the flare distance from the flux-weighted AR center, $d_{FC}$) and the strength of the overlying coronal field (via decay index n). We also present a first systematic study of the orientation of the coronal magnetic field changing with height, using the orientation phi of the flare-relevant polarity inversion line as a measure. We analyzed all quantities with respect to the size of the underlying active-region dipole field, defined by the distance between the flux-weighted opposite-polarity centers, $d_{PC}$. We find that flares originating from the periphery of an AR dipole field ($d_{FC}$ / $d_{PC}$ > 0.5) are predominantly eruptive. Flares originating from underneath the AR dipole field ($d_{FC}$ / $d_{PC}$ 60 Mm). In confined events, the flare-relevant field adjusts its orientation quickly to that of the underlying dipole field with height (delta phi > 40° between the surface and the apex of the active-region dipole field), in contrast to eruptive events where it changes more slowly. The critical height for torus instability discriminates best between confined ($h_{crit}$ > 40 Mm) and eruptive flares ($h_{crit}$ < 40 Mm). It discriminates better than delta phi, implying that the decay of the confining field plays a stronger role in the eruptive/confined character of a flare than its orientation at different heights.

## THE CATALOGUE OF SOLAR FAILED ERUPTIONS

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Failed eruptions are a type of solar eruptive events which after initial increase of height are abruptly stopped. Even strongest X-class flares may be accompanied by failed eruptions. Few observations show that active regions with specific magnetic configuration may produce many CME-less solar flares. Therefore, forecasts of geoeffective events based on active region properties have to take into account probability of failed eruption occurence. From observational point of view failed eruptions were observed, and analysed occasionally. Present observations of SDO/AIA give a chance for deep statistical analysis of such events which may lead to understanding the mechanisms responsible for confinement. Therefore, we developed automated algorithm which can recognize moving structures in AIA images. We searched 4 years of AIA database, and we found more than 10 000 dynamic events. Among them around 700 were failed eruptions of various types. The catalogue will be available on-line, and it will contain basic information about eruption kinematics, properties of accompanying flare, decay index of magnetic field in the active region etc. The catalogue and preliminary results will be presented and discussed.

## FEATURES OF SPECTRAL-POLARIZATION DYNAMICS OF FLARE ACTIVE REGIONS BY MICROWAVE OBSERVATIONS

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The dynamic development of solar flare leads to influence on space weather in a number of different ways through the energetic particle fluxes and coronal mass ejection. It is important to trace the development of flare activity of solar active regions from the beginning of energy accumulation to the explosive release and to the subsequent slow cooling of the flare coronal plasma. The microwave observations track dynamic of emission at the levels of the high transition region and of the low corona.In this contribution, we present a study of spectral-polarization changes in some flare productive active regions close to time of radio bursts and CME. For this purpose, the microwave data of 3-18 GHz observations with RATAN-600 were used. A number of events (x-ray flares, radio bursts and CME) within the time frame of the observations of RATAN-600 were investigated. Observational data registered the spectral-polarization dynamics along with the changes in the spatial structure. The analysis of observational scans allowed to localize the source of the increased emission by a one-dimensional coordinate. We have determined the frequencies at which the effect of the burst was most powerful at different moments of the burst development. Since the frequencies of microwave emission are strongly linked with the strength of the magnetic field, and, accordingly, with the heights of the emitting layers, these received data should allow to clarify the topology and the scenario of the events development.

## CAN SUPERFLARES OCCUR ON THE SUN? A VIEW FROM DYNAMO THEORY

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Recent data from the *Kepler* mission has revealed the occurrence of superflares in sun-like stars which exceed by far any observed solar flares in release of energy. Radionuclides data do not provide evidences for occurrence of superflares on the Sun over the past eleven millennia. Stellar data for a subgroup of superflaring *Kepler* stars are analysed in an attempt to find possible progenitors of their abnormal magnetic activity. A natural idea is that the dynamo mechanism in superflaring stars differs in some respect from that in the Sun. We search for a difference in the dynamo-related parameters between superflaring stars and the Sun to suggest a dynamo-mechanism as close as possible to the conventional solar/stellar dynamo but capable of providing much higher magnetic energy. Dynamo based on joint action of differential rotation and mirror asymmetric motions can in principle result in excitation of two types of magnetic fields. First of all, it is well-known in solar physics dynamo waves. The point is that another magnetic configuration with initial growth and further stabilisation is also possible for excitation. For comparable conditions, magnetic field strength of second configuration is much larger rather of the first one just because dynamo do not spend its efforts for periodic magnetic field inversions but use its for magnetic field growth. We analysed available data from the *Kepler* mission concerning the superflaring stars in order to find tracers of anomalous magnetic activity. Starting from the recent paper [1]), we find that anti-solar differential rotation or anti-solar sign of the mirror-asymmetry of stellar convection can provide the desired strong magnetic field in dynamo models. We confirm this concept by numerical models of stellar dynamos with corresponding governing parameters. We conclude that the proposed mechanism can plausibly explain the superflaring events at least for some cool stars, including binaries, subgiants and, possibly, low-mass stars and young rapid rotators.

## THE EFFECTS OF UNCERTAINTY ON DEFLECTION, ROTATION AND BS PREDICTIONS [invited]

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Understanding the effects of coronal mass ejections (CMEs) requires knowing not only if and when they will impact, but also their properties upon impact. Of particular importance is the strength of a CME's southward magnetic field component (Bs). Kay et al. (2013, 2015) have shown that the simplified analytic model ForeCAT can be used to reproduce the deflection and rotation of CMEs. Kay et al. (2017) introduced FIDO, which uses the position and orientation from ForeCAT to simulate magnetic field profiles. FIDO reproduces the in situ observations on roughly hourly time scales, suggesting that the combination of ForeCAT and

FIDO could be extremely useful for predictions of Bs. However, as with all models, both ForeCAT and FIDO are sensitive to their input parameters, which may not be precisely known for actual predictions. We explore the sensitivity of both models using ensembles with small changes in the initial latitude, longitude, and orientation of the erupting CME. Additionally, thus far ForeCAT has only been run using a Potential Field Source Surface (PFSS) magnetic background driven by a synoptic map. We explore the effects of different magnetic backgrounds - the Schatten Current Sheet model and synchronic maps. We find that the changes in deflection and rotation resulting from the uncertainty in the initial parameters tend to exceed the changes from different magnetic backgrounds. The range in the in situ profiles tends to scale with the range in the deflection and rotation.

## WHAT CAN WE LEARN FROM CORONAL DIMMINGS ABOUT THE EARLY EVOLUTION OF EARTH-DIRECTED CMES?

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Coronal dimmings are observed as localized regions of reduced emission in the EUV and soft X-rays, interpreted as density depletions due to mass loss during the CME expansion. They contain crucial information on the evolution and early propagation phase of CMEs low in the corona. For a set of 62 dimming events, characteristic parameters, describing their dynamics, morphology, magnetic properties and the brightness evolution are derived, statistically analyzed and compared with basic flare and CME quantities. We use optimized multi-point observations, where the on-disk dimming evolution is studied in high-cadence SDO/AIA filtergrams and SDO/HMI line-of-sight magnetograms, while STEREO/EUVI, COR1 and COR2 data is used to measure the associated CME kinematics close to the limb with low projection effects.For 60% of the events we identified core dimmings, i.e. potential footpoints of the erupting CME structure. These regions contain 20% of the magnetic flux covering only 5% of the total dimming area. The majority of the total dimming area consists of secondary dimmings mapping overlying fields that are stretched during the eruption and closed down by magnetic reconnection, thus adding flux to the erupting structure via magnetic reconnection. This interpretation is supported by the high correlation between the magnetic fluxes of secondary dimmings and flare reconnection fluxes ($c = 0.63 \pm 0.08$), the balance between positive and negative magnetic fluxes ($c = 0.83 \pm 0.04$) within the total dimmings and the fact that for strong flares (>M1.0) the flare reconnection and secondary dimming fluxes are roughly equal.The area of the total dimming, i.e. including both core and secondary dimmings, its total brightness and the total unsigned magnetic flux show the highest correlations with the flare fluence ($c > 0.7$) and the CME mass ($c > 0.6$). Their corresponding time derivatives, describing the dimming dynamics, strongly correlate with the GOES flare class ($c > 0.6$). Events where high-cadence observations from STEREO are available show a moderate correlation between the area growth rate of the dimming and the maximum speed of the CME.

## CLUSTERING OF CORONAL MASS EJECTIONS

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We investigate the Heliospheric presence and origin of extreme Coronal Mass Ejections (very fast CMEs), a class of the hazardous extreme events affecting the Earth and near-Earth space environment. Feynman and Gabriel (2000) identified a distinction between CME eruption that causing high-energy particles associated with spacecraft damage.Our previous studies showed that extreme CMEs are not rare events, although their statistics is strongly non-Gaussian. They often come in groups (clusters) supporting a folk's proposition that 'trouble never comes alone'. In this talk will focus on the solar causes of extremely fast CMEs associated with solar active regions. These studies will follow up and confirm earlier studies of ours (Feynman and Ruzmaikin, 2006) and others. Using solar observations we will investigate the formation of active regions, their distribution in spatial and time scales, their clustering and evolution over the 11-year solar cycle. We will investigate how active regions form the basic sources for the extreme CMEs.

## UNRAVELING THE INTERNAL MAGNETIC CONFIGURATION OF THE ICMES [invited]

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In Heliophysics, a flux rope could be defined as a confined magnetized plasma within magnetic field lines wrapping around an axis in a twisting but not necessarily a monotonic way. This is a picture of an unidealized structure in which the magnetic field lines may not be neat or helically well-organized, and possibly the global axis can be visualized as a writhed structure. Indeed, this intuitive description of heliospheric flux ropes is an attempt to link the current in situ, imaging observations and theory perspectives.

Interplanetary coronal mass ejections (ICMEs) sometimes haul a flux rope (FR) embedded moving away from the sun the larger amount of magnetic energy, flux and helicity than any other heliospheric structure. Furthermore, its passage through the interplanetary medium may heat, accelerate or alter the trajectory of any particle in such space. Thus, for a proper forecast, it is critical to learn about how such structure can be described locally but also globally. Currently, the debate about the CME/ICME global 3D morphology, magnetic field configuration, and the implications in terms of the heliospheric evolutionary physical processes is open. In spite of the significant advances with STEREO mission, we have still a very limited understanding of the global heliospheric third dimension and this is not aided by the restricted in situ information of a single spacecraft crossing a large structure. In addition, traditional FR models are limited to describe an ideal flux rope structure.

In this presentation, I will revisit the ICMEs observed for more than 20 years by Wind at 1 AU to better understand the status of the internal magnetic field of ICMEs and to explore in situ signatures to identify clues to develop a more accurate and reliable in situ analytical models. I will also present the new analytical flux rope model that represent an effort to reconcile the in-situ with the remote imaging views by adding flexibility in the internal magnetic configuration and complexity in the geometry.

## ON THE ROLE OF THE TOPOLOGY OF MAGNETIC CLOUDS ON GALACTIC COSMIC-RAY FORBUSH DECREASES AT ENERGIES ABOVE 70 MEV

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Several Interplanetary Coronal Mass Ejections (ICMEs) were recorded at L1 Lagrangian point during the flight time of the LISA Pathfinder (PF) mission, from 2016 February 18 to 2017 July 18. The particle detector aboard LISA PF allowed for the monitoring of the GCR intensity at energies above 70 MeV n-1 with a statistical uncertainty of 1% on one-hour binned data. The transit of shock, sheath and magnetic cloud (MC) regions are identified and MC characteristics and topology are investigated the Grad-Shafranov reconstruction technique. The relationship between the topology of MCs and the features of the observed FDs is discussed.

## STATISTICAL ANALYSIS OF FORBUSH DECREASES OBSERVED DURING PAST FIVE SOLAR CYCLES AND ASSOCIATED TO CORONAL MASS EJECTIONS OR CORONAL HOLES

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We represent statistical analysis of Forbush decrease (FD) parameters and related solar wind characteristics for FDs observed during solar cycles 20 - 24 as well as for FDs caused by interplanetary disturbances (ICMEs) from coronal mass ejections or by high-speed streams from coronal holes. The results obtained for various phases of solar activity and for FDs associated to two different types of solar sources are compared. The Forbush Effects and Interplanetary Disturbances (FEID) database created and maintained in IZMIRAN was used. We selected 3464 non–overlapped FDs out of the FEID database (since the beginning of solar cycle 20) and we picked out 207 FDs associated to coronal mass ejections and 350 FDs associated to coronal holes within this group (since 1997). Each event was characterized by maximum (during FD) values of solar wind velocity and interplanetary magnetic field strength as well as by FD parameters: FD magnitude, FD decrease rate, maximum of equatorial component of cosmic ray anisotropy (for the particles with rigidity 10 GV). In the FEID database, FD parameters have been obtained by the data from worldwide neutron monitor network using the global survey method developed in IZMIRAN. We carried out distribution analysis and correlation analysis and computed the linear regression models for all listed above parameters. The results obtained reveal that the statistical properties of FD parameters and their connection with interplanetary phenomena depend on the type of FDs (associated to coronal mass ejections or to coronal holes) as well as on the solar activity phase.

## THE DEPENDENCE OF HIGH-SPEED STREAM PEAK VELOCITIES AND OF THE KP INDEX ON THE POSITIONS OF THEIR SOURCE CORONAL HOLES ON THE SUN

Stefan Hofmeister[1], Astrid Veronig[1], Manuela Temmer[1], Susanne Vennerstrom[2], Bernd Heber[3], Bojan Vršnak[4]

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The peak velocities of high-speed solar wind streams are linearly dependent on the areas oftheir solar source regions, coronal holes. We revise this relationship in a comprehensive study of 115 events in the time-range from 2010/08 to 2017/03, and analyse the properties of the solar source coronal holes, the corresponding high-speed solar wind streams at 1 AU, and for a subset their geomagnetic consequence, using remote-sensing and in-situ data from the satellites SDO, ACE, STEREO-A, STEREO-B, and the Kp index.Thereby, we find a further distinct dependence of the high-speed stream peak velocities as measured by the satellites and of the Kp index on the co-latitudes of the solar source coronal holes,that is the latitudinal angle between the coronal hole and the measuring satellite. High-speed streams arising from coronal holes located near the ecliptic result in the highest peak velocities and Kp index per coronal hole area, and they linearly decrease with increasing co-latitudes of the source coronal holes up to co-latitudes of $\sim 60°$. By adding the coronal hole co-latitudes as a further parameter to the high-speed stream peak velocity – coronal hole area relationship, the Spearman's correlation coefficient between predicted and measured high-speed stream peak velocities increases from cc=0.50 to cc=0.72.We interpret this as an effect of the three-dimensional propagation of high-speed streams inthe heliosphere: when the source coronal hole is located in the ecliptic directly looking towardsthe measuring satellite, then the satellite is passing the central part of the corresponding high-speed stream measuring the highest plasma velocities of the high-speed stream. Whereas,when the source coronal hole is located at higher solar latitudes, the satellite is passing thelatitudinal flank of the high-speed stream, measuring much lower plasma velocities.We conclude that the latitudinal angle between the source coronal hole on the Sun and the measuring satellite is an estimate on the position of the satellite in the high-speed stream. Therefore, the co-latitude is an important parameter for the forecast of high-speed stream parameters near the Earth and their related geomagnetic storms.

## PREPARING FOR THE FUTURE OF HELIOSPHERIC OBSERVATIONS [invited]

Hess Phillip

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Despite the relatively low activity of solar cycle 24, much progress was made over the last decade in understanding the initiation and propagation of coronal mass ejections (CMEs) because of new, powerful observations from missions such as STEREO and SDO. STEREO has proven particularly useful for studying CME evolution in the heliosphere and estimating the physical forces governing CME motion. However, the period towards the end of solar cycle 24 when STEREO was behind the Sun and not transmitting data revealed that many of the tools that were developed to capitalize on the insights of the STEREO era are completely dependent on these observations. As we prepare for both new observations from the next

generation of missions as well as a potential future without comprehensive heliospheric observations, it is vital to develop a theoretical understanding of CMEs that can be used to model events even with limited data availability.

## LONG-TERM PERIODICITIES IN THE HELIOSPHERIC MAGNETIC FLUX DENSITY AND THE EFFECTS ON PLANETARY SPACE WEATHER

Melinda Dosa, Geza Erdõs

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Long-term datasets were used to analyse solar wind parameters and their eventual correlation. Significant recurrent enhancements of the heliospheric magnetic flux were observed during the declining phase of past solar cycles. These flux enhancements are associated with co-rotating interaction regions (CIRs), lasting several years. The recurrence period equals the equatorial rotation period of the Sun. The same, long lasting recurring features can be observed in the deviation angle of the solar wind velocity vector from the radial direction. However, the deviation angle is small, in the order of few degrees, which cannot account for the observed flux increases. Magnetic sector patterns show similar long lasting recurrences, but the rotation periods are different. The consequence of the different rotation periods and the eventual topological constraints is discussed. The longitudinal variation of the magnetic flux during the declining phase of the solar cycle has impact on the modulation of cosmic rays as well as on the frequency and intensity of planetary space weather events.

## SOLAR RADIO IMAGING-SPECTROSCOPY AND HELIOSPHERIC IMAGER

Yihua Yan[1,2] & MUSER Team

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Solar eruptive phenomena have great impact in the heliosphere and may cause severe space weather. Radio bursts are prompt indicators of the various solar activities including flares and coronal mass ejections (CMEs). Radio technique can detect radio emissions tracking solar eruptive processes all the way from the Sun through interplanetary space to the Earth space. To address the processes how solar eruptive events generate and propagate into interplanetary space, it is important to have imaging-spectroscopy observations covering metric to decametric frequency range. The Mingantu Spectral Radioheliograph (MUSER) in 400 MHz to 15GHz with high spatial resolution, high time resolution, and high frequency resolution has been established in recent years that will play an important role in space weather. The plan to extend MUSER with a new array covering $\sim$40-400 MHz with about 180 LPDA elements and a design for IPS observations at MUSER site with additional sub-stations will be presented.

# Simulations and theoretical aspects of solar-terrestrial phenomena (WG2-theory, WG3-simulation and related abstracts from the General session on Sun & Heliosphere)

## INTERACTION BETWEEN MULTIPLE CMES AND ITS IMPACT ON SPACE WEATHER [invited]

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The interaction between multiple CMEs has been widely reported and studied in recent years. Most of these researches focused on two key problems. The first one is the physical process of the interaction process. In this talk, we will introduce our recent works about the physics of the interaction between multiple CMEs, including observational analysis and MHD simulations. The second problem is the space weather effect of such interaction. The interaction between multiple CMEs might significant influence the space weather effect of them. In recent, we made a statistical analysis about the geoeffectivenss of multiple CMEs interaction structures especially the shock-ICME complex structures. We also studied the enhancement of the geoeffectiveness of a shock-ICME structure quantitively. We will exhibit these results in this talk. In addition, we will make some brief discussions about the effect of CMEs' interaction on producing SEP events.

## ENSEMBLE PREDICTION OF A SOLAR STORM ARRIVAL AT EARTH USING HELIOSPHERIC IMAGES

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Predicting space weather disturbances at Earth is still a difficult undertaking. Especially the arrival times and speeds of the drivers of the strongest geomagnetic storms, namely coronal mass ejections (CMEs), can only be predicted with an accuracy of almost one day (+/-10h). One reason for that may be the limited observational possibilities of coronagraphs, which are mainly used for these predictions. We present the prediction tool ELEvoHI, which is based on heliospheric imager observations that provide the possibilityto observe CMEs along their way from the Sun to Earth from the side. ELEvoHI includes an ellipse shaped CME front and accounts for the influence of the ambient solar wind on the propagation of the solar transient. The model is executed in an ensemble mode, performing hundreds of predictions based on various shape-related input parameters for each CME. In this way, we gain a frequency distribution of the arrival time and speed at the target of interest, e.g. Earth. In our recent study, we found a promising new approach to restrict these ensemble predictions to the most likely ones and to reduce the prediction error by a sufficient amount.

## DBEM WEB APPLICATION FOR HELIOSPHERIC PROPAGATION OF CMES

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Forecasting of coronal mass ejections (CMEs) arrival is one of the major tasks for operational space weather services. The Drag-based Model (DBM) with CME cone geometry is an analytical model that predicts the CME arrival time and speed at Earth or any other target in the solar system. It is based on the equation of motion that depends on the CME launch speed, background solar wind speed and drag parameter gamma which is derived empirically. The main advantage of DBM is very short computational time (<< 1s) compared to the numerical models (e.g. ENLIL). Recently developed Drag-Based Ensemble Model (DBEM) takes into account the variability of model input parameters by making an ensemble of n different input parameters to calculate a distribution and significance of DBM results. Using such approach, DBEM can determine the most likely CME arrival times and speeds, quantify the prediction uncertainties and calculate the forecast confidence intervals. To provide the real-time CME forecast to various users worldwide, DBEM web on-line application was developed. Using a simple web interface, user can enter all input parameters and uncertainties to get CME arrival time and speed distributions in very short time, where up to 100 000 DBM runs can be performed in less than one minute.

## FORBUSH DECREASE MODEL FOR EXPANDING CMES (FORBMOD)

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Forbush decreases (FDs) in the galactic cosmic ray flux can be used as one of the "signatures" of an ICME passage. An analytical diffusion-expansion FD model (ForbMod) was developed that is based on the widely used approach of an initially empty, closed magnetic structure (i.e. flux rope) that fills up slowly with particles by perpendicular diffusion. Remote CME observations and 3D reconstruction is used to constrain initial and boundary conditions. CME evolutionary properties are taken into account by incorporating the flux rope expansion. Several options of flux rope expansion are regarded as competing mechanism to diffusion, which can lead to different FD characteristics, and forward modelling is used to analyse flux rope expansion and further constrain the model. In testing the model, a number of spacecraft and planetary observation is utilised, including those by the Radiation Assessment Detector aboard the Mars Rover Curiosity. This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 745782.

## NEAR REAL-TIME SIMULATION OF HELIOSPHERIC SPACE WEATHER [invited]

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We have developed the WSA-ENLIL-Cone modeling system that enables faster-than-real time simulations of corotating and transient heliospheric disturbances. This 'hybrid' system does not simulate origin of coronal mass ejections (CMEs) but uses appearance in coronagraphs, fits geometric and kinematic parameters and launches a CME-like structure into the solar wind computed using WSA coronal model. This modeling system is implemented at NASA based multiagency Community Coordinated Modeling Center (CCMC) to provide Run-on-Request service to community, and it is the first numerical model transitioned into operation at NOAA and NASA. In this presentation, we introduce the recent enhancement of this modeling system and we will focus on improving the solar wind and CME initialization, and on predicting gradual solar-energetic particles (SEPs) events. We simulated over 1600 CMEs in 2011-2017 to validate and calibrate the new modeling system, and we will present results of a calibration study as well as examples of selected events. We will also compare numerical results with remote white-light observations, with in-situ measurements of plasma parameters, and with detection of solar energetic particles (SEPs) at various spacecraft.

## THREE-DIMENSIONAL MHD SIMULATION OF SOLAR WIND USING A NEW BOUNDARY TREATMENT: COMPARISON WITH IN-SITU DATA AT EARTH

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Three-dimensional (3D) magnetohydrodynamics (MHD) numerical simulation is an important tool in the prediction of solar wind parameters. In this study, we improve our corona interplanetary total variation diminishing (COIN-TVD) MHD model by using a new self-consistent boundary treatment, which is suitable for all phases of solar cycles. In the computational domain of this model, a six-component grid system is employed, the ideal MHD equations are solved by using the total variation diminution (TVD) Lax-Friedrich scheme, and the divergence of magnetic fields is eliminated by a diffusion method. This model uses synoptic magnetogram maps from the Global Oscillation Network Group (GONG) as the input data. The empirical WSA relation is used to assign solar wind speed at the lower boundary, while temperature is specified accordingly based on its empirical relation with the solar wind speed. Magnetic field intensity and slow wind density at the boundary are obtained from observational data in the immediate past Carrington rotations, assuming the persistency of these two parameters in a short time period. There are only five free parameters for the boundary conditions, which should be tuned to simulate the solar wind for different phases of solar cycle. We find that the number of multipole components included in the spherical harmonic expansion in the potential field source surface (PFSS) model, Lmax, has the most influence on the solar wind speed distribution, and two free parameters in the WSA model also have obvious effect on the speed distribution. This model is applied

to simulate the background solar wind from year 2007 to 2017, and we compare the modeling results with the observational data in the OMNI database. Visual inspection shows that our model can capture the time patterns of solar wind parameters well at most times. Statistical analysis shows that the simulated solar wind parameters, including speed, density, temperature, and magnetic field strength and direction, are all in good agreement with the observations. This study demonstrates that the improved IN-TVD (interplanetary total variation diminishing) model with a new self-consistent boundary treatment can be used for predicting all solar wind parameters near the Earth, including magnetic fields which have been systematically underestimated in current operational models.

## INFLUENCE OF THE MAGNETIC DECAY INDEX SPATIAL DISTRIBUTION ON THE KINEMATICS OF THE SOLAR ERUPTIVE PROMINENCE

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Theoretical studies of magnetic flux rope instabilities, designed to explain filament eruptions, indicate that the loss of equilibrium may develop in the case when surrounding magnetic field decreases sufficiently rapidly with height. The magnetic decay index, a parameter indicating whether external magnetic field had a configuration that may lead to a certain type of flux rope instability, is a useful instrument for predicting the behavior of filaments. In our study we perform potential extrapolation to obtain spatial distribution of the magnetic decay index in the coronal space, identified with the eruptive prominence. Analysis of time dependent height profile of the prominence revealed, that it had lost its equilibrium at the height where computed magnetic decay index exceeded value 1.5, which is specific for the torus instability.

## SIMULATION OF FAST-MODE MHD WAVES INTERACTING WITH LOW DENSITY REGIONS SUCH AS CORONAL HOLES

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We use a 2.5D numerical magnetohydrodynamical (MHD) code for studying the interaction between a fast-mode MHD wave and a coronal hole (CH). We observe that these interactions lead to wave-like features, such as reflected and transmitted waves (secondary waves), but also to stationary features at the CH boundary. We find a correlation between the CH density and the amplitudes of the secondary waves as well as the peak values of the stationary features. Moreover, we compare the lifetime of the stationary features and the phase speed of the secondary waves to observations. Both effects obtained in the simulation, the formation of stationary fronts at CH boundaries and the evolution of secondary waves, support the theory that coronal waves are fast-mode MHD waves.

# NUMERICAL SIMULATIONS OF CORONAL LOOP KINK OSCILLATIONS EXCITED BY DIFFERENT DRIVER FREQUENCIES

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We study the problem of plasma heating and analyse the propagation of magnetohydrodynamic kink waves in a coronal loop. Recently, it has been shown that the plasma mixing effect due to the Kelvin-Helmholtz instability occurring at the loop boundaries contributes significantly to the temperature distribution inside a loop. Using the MPI-AMRVAC code, we perform three-dimensional numerical simulations of the propagation of magnetohydrodynamic kink waves in a gravitationally stratified magnetic flux tube. The waves are driven by transverse displacements of the tube footpoint. We consider different driver frequencies and analyse the distribution of plasma internal energy and temperature with height to understand the efficiency of that mechanism for coronal loop heating. We study the response of a coronal tube to perturbations of different frequencies, determining the tube eigenspectrum, which is of importance for analysis of a broad-band footpoint driver. We compare our results with the previous ones to reveal the effects of different driver frequencies and plasma stratification on heating of coronal loops by kink waves.

## Session 3: Parker Solar Probe and Solar Orbiter

### MODELING AND DATA ANALYSIS TOOLS TO SUPPORT SCIENCE AT THE PARKER SOLAR PROBE AND SOLAR ORBITER ERA [invited]

R. F. Pinto, and the IRAP-CDPP team

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The quasi-steady background solar wind flow is a key component of space weather, being the source of corotating density structures that perturb planetary atmospheres and affect the propagation of impulsive perturbations (such as CME). Moreover, fast and slow wind streams develop different places in the solar atmosphere, reflecting the global distribution of the coronal magnetic field during solar cycle. I will present different numerical models and tools that aim at providing robust predictions of the physical properties of the time-evolving surface and coronal magnetic field, and of the structure of the solar wind. Such new tools and models are expected to operate equally well on past data and on short-term forecasts, and should provide quantitative means to test theories on the structure and heating processes of the solar corona and wind back to the community. I will also present ongoing efforts carried out within the ESA Modeling and Data Analysis Working Group (MADAWG) to develop tools and methods that automatically estimate the magnetic connectivity between the solar surface and any point in interplanetary space, the paths and propagation delays of plasma and energetic particles, and that establish connections between remote observations of the solar surface and corona, and in-situ measurements of the solar wind. These are key points for the exploitation of the Solar Orbiter and Parker Solar Probe missions and to establish synergies between them.

### STIX SOFTWARE DEVELOPMENT AT GRAZ

Ewan Dickson[1], Astrid Veronig[1], Richard Schwartz[1,2], László Etesi[3], Gordon Hurford[3], Nicky Hochmuth[3], Samuel Krucker[3] and STIX Software Team

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STIX (Spectrometer Telescope for Imaging X-rays) is the Hard X-ray instrument on Solar Orbiter. STIX aims to study the acceleration of solar electrons and their propagation into interplanetary space. We are involved in the development of the software for the operation of STIX and the analysis of its data. As STIX is an indirect sensing instrument and bandwidth is severely limited, software for on board operations, data reduction and user analysis is critical to meeting any science goals. The ground analysis software will provide tools for scientists to analyse STIX data, in terms of spectroscopy, imaging and imaging-spectroscopy. At Graz we are mainly focused on tasks related to the spectroscopy and calibration, such as using low-latency background spectra, and variations in the spectra from detector to detector, as well as more detailed simulations of the detector response, including radiation damage and rate dependent effects. This aims to provide the correct calibration for each detector and pixel. Here we are also involved in simulations in support of the flight software, particularly for the flare detection and location modules.

# GEANT4 SIMULATION OF THE HELIOS E6 - PROTON CONTAMINATION OF RELATIVISTIC ELECTRON MEASUREMENTS

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HELIOS A and HELIOS B were launched on December 10, 1974 and January 15, 1976, respectively. The two almost identical space probes were sent into ecliptic orbits around the Sun. The Kiel experiment, E6 is one of three particle detectors aboard HELIOS that allows to study the flux of energetic particles in the energy range from 1.3 MeV/nucleon to above 1000 MeV/nucleon for ions and from 0.3 to 8 MeV for electrons. A GEANT 4 simulation has been set up to calculate the response functions for protons and electrons in the energy range from 1 to 60 MeV and from 50 keV to 10 MeV, respectively. Due to the detector design there is substantial contamination of protons in the electron measurements that is quantified in this contribution. A method for correcting the electron time flux profiles will be presented and applied to a set of solar energetic particle events.

# Solar energetic particles (WG6-SEPs and related abstracts from the General session on Sun & Heliosphere

## SOLAR ENERGETIC PARTICLES: ORIGIN, ACCELERATION, AND TRANSPORT [invited]

C.M.S. Cohen

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Solar energetic particles (SEPs) have been measured in space for more than 45 years, mostly from near Earth, but as close as 0.3 AU and at the 'backside' of the Sun (relative to Earth). Occasionally the same SEP event has been measured by multiple spacecraft spaced widely around the Sun. Through the combination of such measurements, theoretical work and increasingly complex models, great strides have been made in understanding where and how SEPs are energized and their passage through the inner heliosphere. Yet, many questions regarding the details remain, which hamper our understanding of the observed variation of the characteristics of SEP events (including composition, spectra, and intensity-time profiles) as well as limit our ability to predict when SEP events will occur with any significant lead time. This talk will review what we think we know, as well as what remains confusing regarding SEP event origin, acceleration and transport as illustrated by observations.

## THE FEATURES OF PLASMA TURBULENCE ASSOCIATED WITH SOLAR TRANSIENTS

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The solar wind plasma propagates unevenly in space and can be characterized by high level of turbulence and intermittency. The structures of different spatial scales form the cascade where the energy injects at large scales (the scale of sources or integral scale), transforms to the inertial scale (the scale of MHD structures) and then dissipates at the smallest scales, which leads the heating and acceleration of the particles. The development of solar wind turbulence is limited by natural boundaries of different solar transients. Velocity shear near these boundaries can have a significant effect on the formation of a turbulent cascade, especially in the dissipation range and in the transition region between inertial and dissipation range. As a result, observed turbulent spectra can differ from ones in traditional models. In this study we investigate properties of plasma turbulence spectrum in different large scale solar wind streams associated with solar transients (interplanetary coronal mass ejections (ICMEs including EJECTA and magnetic clouds (MCs)), compression regions before EJECTA or MC (SHEATHs) and corotating interaction regions between fast and slow streams (CIRs)) and compare them with the same properties in the steady slow and fast solar wind. We use plasma measurements during years 2011-2017 at BMSW instrument on board of Russian astrophysical mission SPEKTR-R. The high time resolution (up to 31 ms) of the spectrometer allows us to analysis the wide spectrum range including the proton scales structures. The determination of large scale solar wind types is presented in our catalogue (ftp://ftp.iki.rssi.ru/pub/omni/catalog/). It is shown that the properties of plasma fluctuation spectra are weakly dependent of local plasma parameters, but strongly affected by the large scale solar wind types. The regions of MCs and SHEATHs before MCs are most influence on the formation of spectra shape. In these cases the strong turbulence with the

most steep spectra is observed. The abnormal steepening of spectra at kinetic scale is also typical for these cases, which can indicate the more effective dissipation processes which occur in these areas. The spectrum corresponding to the traditional turbulent models as a rule can be observed only in rather steady solar wind streams.

## ACCELERATION OF PARTICLES IN 3D MAGNETIC ISLANDS WITH LOW PLASMA DENSITY AND THEIR DIAGNOSTICS IN THE HELIOSPHERE

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In this talk we present electron and ion trajectories, density, energy spectra and pitch angle distributions simulated in 3D reconnecting current sheets with magnetic islands of different types using particle-in-cell (PIC) and test particle approaches. Magnetic islands are shown to be the most effective accelerators of particles. We demonstrate specifics of acceleration of electrons and protons entering current sheets from the opposite sides of current sheet in coalescent and squashed magnetic islands. We show that accelerated electrons are ejected via X-nullpoints forming electron clouds.between magnetic islands often observed in in-situ observations in the heliosphere.

## CHALLENGES OF SPACE WEATHER AND SPACE RADIATION PREDICTIONS FOR HUMAN EXPLORATIONS TO MARS

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Space agencies such as ESA, NASA, the Chinese space agency and even private sectors have already launched human deep space exploration programs to the Moon and Mars. It requires a very timely and thorough study to better understand the space weather conditions and effects for such human deep space activities in order to further develop mitigation strategies against the associated radiation risks.In the long-term, there is the omnipresent radiation induced by Galactic Cosmic Rays (GCRs) which are modulated by solar activities. Continuous exposure to the background GCRs may increases the chance of long term health consequences, such as onset of cancer, cardiovascular diseases, skin atrophy, eye cataract, leukemia, anemia, leucopenia and malfunctions of the central nervous system.In the short-term, intense solar energetic particles (SEPs) can be considered as mightily re- lated to deterministic radiation effects which are of great concern for space exploration. Acute radiation syndrome (ARS) or sickness or poisoning or toxicity is induced after a whole body exposure to high doses of radiation between at the Gy [J/kg] level. Such events, despite of being rather infrequent, could result in severe damage to humans and equipment and lead to failure of the entire mission and therefore should be detected and mitigated as immediately as possible.Under different shielding environment, the intensity and composition of the GCRs/SEPs may vary due to the interactions of primary particles (of different energies and charges) with the surrounding material (such as the spacecraft and the planetary atmosphere) and the generation of secondaries. Habitable shelters on the Moon and Mars with regolith shielding could provide sufficient protection against such radiations. However the situation of a transit spacecraft in deep space or an astronaut carrying out extra-vehicle or planetary surface activities may be much more severe, especially during the onset of a solar particle event (SPE). This is because an SPE generally have a sudden and sporadic nature and can be very intense, dynamic and vary drastically in time and location. Therefore radiation and particle enhancement measured near Earth (such as the onset time and intensity) may be completely different from of that detected elsewhere in the heliosphere such as on the surface Mars.Three major factors should be taken into account for evaluating the solar energetic particle radiation environment at different locations in the heliosphere (where the deep space exploration activities may take place): (1) the acceleration process at the Sun which are often related to the flare eruptions and associated shocks, (2) the properties of the accelerated particles injected into the open magnetic field which are connected to the missions (that can be very differently connected compared to Earth), and (3) the atomic and nuclear interaction of particles with the local shielding environment (such as the spacecraft or the Martian atmosphere). Taking into consideration of these 3 factors, we will show our recent study of the September 2017 event which is seen on the surface of both Earth and Mars as well as at STEREO-A (a spacecraft surrounding the Sun at 1 AU). These three locations have a heliospheric longitudinal separation of more than 240 degrees apart and they all saw the SPE with different time profiles, intensities and particle spectra. We highlight the utmost importance of utilizing multi-spacecraft in-situ and remote sensing observations of the Sun and the heliosphere to better understand such dynamic events and their dynamic effects across the heliosphere in particular at locations where human explorations may take place.

# Event studies using solar-terrestrial data & modeling (WG4-campaign events and related abstracts from the General session on Sun & Heliosphere)

## SUN-TO-EARTH MODELING OF CORONAL MASS EJECTIONS WITH A GLOBAL MHD MODEL: FACILITATING PHYSICAL UNDERSTANDING AND SPACE WEATHER FORECASTING [invited]

Meng Jin[1,2]

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Coronal Mass Ejections (CMEs) are one of the major sources of destructive space weather. However, our understanding of CMEs and their propagation in the heliosphere is limited by the insufficient observations. First-principles-based numerical models play a vital role in interpreting observations, testing theories, and providing forecasts. By modeling realistic CME events using the newly developed Alfven Wave Solar Model (AWSoM) together with the data-driven Eruptive Event Generator by Gibson-Low (EEGGL), we demonstrate that many of the observed features can be reproduced near the Sun, in the heliosphere, and at the Earth, which illustrates the new capability to predict the long-term evolution of CMEs in interplanetary space. Furthermore, through several case studies (e.g., 2011 March 7, 2014 September 1, 2017 September 10 etc.), we emphasize how the unique information provided by the model (e.g., time-varying shock parameters, dynamical field line connectivities, plasma evolutions) could facilitate our understanding of fundamental processes of solar and heliophysics.

## SOLAR PHOTOSPHERIC PLASMA AND MAGNETIC FIELD DYNAMICS: MODELLING OF THE TEMPORAL EVOLUTION OF FLOW MOTIONS

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The photospheric dynamics are dominated by the emergence of convective flow patterns organized in different structures which correspond to the so-called granulation, meso-granulation, and super-granulation depending on the spatial and temporal scales. Our study of the dynamics within the phostosphere or the visible surface of the Sun makes use of continuum images as well as Line-of-Sight (LOS) magnetograms during the emergence of Active Region (AR) 11190 on 11-April-2011. The velocity fields are calculated using Local Correlation Tracking (LCT) techniques. Due to the nature of the velocity flow fields, the best suitable statistical distribution that describes such motions is a Rayleigh distribution. However, in the moments of strong and newly magnetic flux elements appearance, the dynamics within the FOV change creating the necessity to model the velocity flow fields by using a mixture of two different statistical distributions. The main distribution is still fit well by a Rayleigh

distribution, which is related to the quiet background flows and the general behavior in the region of interest, whereas the second component describes the rapid and violent changes within the FOV. The proposed model shows in general a strong correlation between the plasma motions and the movements of the detected magnetic elements, whereas during the strong and rapid magnetic flux emergence the correlation starts to break down with an apparent faster movement of magnetic elements for short periods of time.

## MULTI-INSTRUMENT OBSERVATIONS OF AN X9.3 FLARE

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The radiometer LYRA on PROBA2 observed the X9.3 flare of 06 Sep 2017, the strongest flare of this solar cycle. We found flare signatures in all four spectral channels of LYRA: channel 1 ("Lyman-alpha", 120-123nm), channel 2 ("Herzberg continuum", 190-222nm), as well as EUV and SXR in channel 3 and 4, and in GOES. This was the first detection of solar flare emission by channel 2 of LYRA. The flare radiation is consistent with the hydrogen Balmer continuum emission produced by an optically thin chromospheric layer heated up to 10000 K.

## CORONAL HOLE AND ACTIVE REGION INTERACTION OBSERVED THROUGH A CME-HSS INTERACTION

Stephan G. Heinemann[1], Manuela Temmer[1], Karin Dissauer[1], Charlie Farrugia[2], Thomas Wiegelmann[3], Astrid M. Veronig[1], Stefan J. Hofmeister[1], M. Dumbović[1]

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Understanding the evolution of coronal holes (CH) is a key towards a better understanding of solar wind high-speed streams and consequently their Space Weather effects. The goal is to examine in a thorough study, using stereoscopic remote sensing observations as well as in-situ data and modeling efforts, the evolution of a CME launched from an active region which is spatially close to a coronal hole. Due to the different regimes of open and closed field lines, the CME deviates significantly from a radial propagation direction. From this active region a C7.7 flare event occurred on June 21, 2011 together with an associated CME that was Earth-directed. Using SDO data and magnetic field modeling we examine the surface properties of this event. A reconstruction of the CME has been done using multi viewpoint observations from SOHO, SDO, STEREO-A and STEREO-B. To conclude the picture we investigate in-situ data at around 1 AU and geomagnetic indices near Earth. The influence of the HSS on the CME structure can already be observed from remote sensing white-light data as well as from in-situ data. By understanding the interactions and the relations between CHs and CMEs, we are able to conclude and advance the forecast of space weather effects. To improve the forecast capabilities is in great demand in the space weather community and this study is another step in reaching this goal.

## OBSERVATION-BASED SUN-TO-EARTH SIMULATIONS OF GEO-EFFECTIVE CORONAL MASS EJECTIONS WITH EUHFORIA [invited]

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Coronal Mass Ejections (CMEs) and their Interplanetary counterparts (ICMEs) are the primary source of space weather disturbances at Earth. The key ICME parameters responsible for driving strong geomagnetic storms are the dynamic pressure and the magnetic field Bz component at Earth, for which reliable predictions are not possible by means of traditional, over-simplified cone CME models. In order to overcome with such limitations, the newly developed EUHFORIA heliospheric model has been recently integrated with a magnetised flux rope CME model that allows to model the IMF components associated to ICMEs to a higher degree of accuracy. In this work we present a Sun-to-Earth comprehensive analysis of a selected set of Earth-directed CME events, with the aim of testing the space weather predictive capabilities of the new flux rope CME model compared to those of an over-simplified cone CME model. In particular, we focus on the quantification of the prediction performances in terms of (1) solar wind parameters at L1, and (2) CME geo-effectiveness estimated by means of global geomagnetic activity indices associated to the ICME-driven geomagnetic storm.We first discuss the determination of the CME input parameters based on remote-sensing observations. For each event, we reconstruct the CME kinematical and geometrical parameters by means of single- and multi- spacecraft reconstruction methods based on coronagraphic CME observations. The magnetic field-related parameters of the flux ropes are estimated based on imaging observations of the photospheric and low coronal source region of the eruption. We then simulate the events with EUHFORIA, using both a cone and a flux-rope CME model in order to compare the effect of the different CME kinematical and magnetic input parameters on simulation results at L1. We compare simulation outputs with in-situ observations of the ICMEs and we use them as input for the prediction of global geomagnetic activity indices, comparing our predictions with actual data records. We quantify the forecasting capabilities of such kind of approach by means of forecast verification metrics and we discuss its future improvements.

## DYNAMIC PROPERTIES OF PROMINENCE ERUPTIONS OBSERVED BY AIA AND LASCO

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Different kind of prominence eruptions are often observed all over the solar disk. Detailed analyses have been carried out for 304 A Solar Dynamics Observatory/Atmospheric Imaging Assembly observations. To track their behaviour (up to 1.3 solar radii) during eruptions we observed multiple events since 2010. To expand our research and to follow the rising of a filament on higher altitudes (up to 6 solar radii), we added Solar and Heliospheric

Observatory/Large Angle and Spectrometric Coronagraph C2 data if the studied prominence was visible in LASCO field of view. Obtained height-time profiles of the eruptions show quasi-periodic velocity fluctuations. Reasons causing oscillations in the material movement are discussed.

## CME ACCELERATION AND EUV WAVE KINEMATICS FOR SEPTEMBER 10TH 2017 EVENT

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On September 10th 2017 a large solar eruption, accompanied by an X8.2 solar flare, from NOAA active region 12673 was observed on the Sun's western limb by the new Solar Ultraviolet Imager (SUVI) on the GOES-16 spacecraft. We present a method to identify the CME bubble shape and to determine its radial and lateral acceleration. The large field of view of SUVI allows us to study the early impulsive CME acceleration up to 2 solar radii. The CME bubble reveals afast evolution and strong overexpansion. The radial propagation of the CME revealed a peak value of the acceleration of about 4.8 km/s2, whereas the lateral expansion reached a peak value of 8.9 km/s2. The EUV wave associated with this eruption was observed by SUVI and STEREO-A, which had a separation angle with Earth of 128°, and the common field of view of both spacecraft was 52°. SUVI images above the solar limb reveal the initiation of the EUV wave by the accelerating flanks of the CME bubble, followed by detachment and propagationof the wave with a speed of 1100 km/s. Above the limb, the wave front can be observed as high as 0.7 solar radii. The EUV wave shows a global propagation over the full SUVI disk as well as into the STEREO-A field-of-view, and can be followed up to distances of about 1727 Mm from the source region. We study the propagation and kinematics of the direct as well as the various reflected and refracted EUV wave components on the solar sphere, finding speeds in the range from 370 to 1010 km/s. Finally, we note that this EUV wave is also distinct as itreveals propagation and transmission through a polar coronal hole.

## EVOLUTION OF PLASMA PARAMETERS DURING THE EARLY ACCELERATION PHASE OF THE JUNE 13 2010 CME EVENT

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We investigate the Coronal Mass Ejection (CME) from June 13, 2010 to gain deeper insight into the evolution of plasma parameters, i.e. plasma temperature and density. The CME structure and its early evolution is studied by combining data from six different EUV channels of SDO/AIA and applying the Differential Emission Measure (DEM) technique by Hannah and Kontar (2012). With this approach, we are able to calculate temperature and density maps of the CME structure as it propagates outward. We evaluate the evolution of

the CME front and derive, where and when the CME shock develops and de-couples from the driver.The reconstructed density maps show that the CME shock wave starts to decouple low in the corona ($\sim$130 Mm above solar surface). The maximum relative amplitude in both plasma parameters occurs at a distance of $\sim$105 Mm, respectively, with a maximum compression ratio of $\sim$1.3. We find that the CME shock front propagates with a velocity of $\sim$600 km/s, while the CME driver is significantly slower with $\sim$380 km/s.

# Poster abstracts

## ASSESSING EUHFORIA USING MULTI-SPACECRAFT CORONAL MASS EJECTION ENCOUNTERS

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Coronal Mass Ejections are one of the primary drivers of space weather and modelling the evolution of their internal magnetic field configuration as they propagate in the interplanetary space is an essential part of space weather forecasting. EUHFORIA is a data-driven physics-based model, tracing the evolution of CMEs and CME-driven shocks through realistic background solar wind conditions. A recent key advancement in EUHFORIA was the incorporation of a magnetic flux rope (spheromak) to model Interplanetary CMEs (ICMEs). This provides the advantage of modeling not only the hydrodynamic structure of CMEs, but also their magnetic field configuration. In this work we assess this new aspect of EUHFORIA by comparing the output of the model to in-situ observations. We focus on two events in which the CME is encountered by at least two well-separated spacecraft and exhibits flux rope signatures in both. In one of the events the CME was observed in-situ by two radially aligned spacecraft during the time of the flux rope passage. In the second event, the CME was observed by two longitudinally separated spacecraft at the time of the event. The choice of these candidates will allow us to comprehensively evaluate the accuracy and utility of the employed flux rope modelling approach, not only in terms of radial evolution of the CMEs but also in modelling different parts of the propagating structure.

## THE DETERMINATION OF SOLAR ENERGETIC PARTICLE ANISOTROPIES BASED ON FOUR-SECTOR MEASUREMENTS

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The Solar Electron and Proton Telescope (SEPT) aboard the two three axis stabilized STEREO spacecraft provides four different viewing directions for energetic electrons and ions allowing to study their pitch angle distribution. The variation of the magnetic field can cause different pitch-angle coverage which strongly alters the determination of the angular energetic particle distribution and especially the anisotropy. Here we systematically study the possible pitch angle sampling of the instrument that can occur during solar energetic particle events. Synthetic pitch angle distributions are computed from energetic particle transport models allowing a precise determination of the omnidirectional intensity and anisotropy. These values are used as a reference for our study. In the next step we determine the intensity values of the model solution at the pitch angle values covered by SEPT for a

given magnetic field vector and apply different methods to calculate the omnidirectional intensity and anisotropy for these cases. These results are compared to the reference values allowing to estimate in a systematic way the conditions that are needed in order to calculate reliable omnidirectional intensities and anisotropies. This work can also be applied to the Electron Proton Telescope (EPT) instrument aboard Solar Orbiter that utilizes the same measurement principles.

## A STUDY ON THE RELATIONSHIP BETWEEN X-RAY EMISSION, WHITE LIGHT AND MAGNETIC FIELD CHANGES DURING SOLAR FLARES

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During solar flares it has been observed that the photospheric magnetic field changes significantly, abruptly and permanently. We investigated the possible spatial and temporal correlation between permanent changes of magnetic field, emission in white light and X-rays, during 5 solar flares. These highly energetic events occurred during the current solar cycle 24. The energy range of the flares contains events from low energetic to very energetic, according to the GOES classification. The behavior of the emission of hard X-rays (HXR) and the magnetic fields is analyzed using data from the RHESSI and SDO / HMI satellites. We study the probability that the photospheric magnetic field will change due to particle injection in the lower layers of the solar atmosphere. This study would contribute to the statistics that relate these processes during flares.

## PHOTOSPHERIC AND CHROMOSPHERIC OBSERVATIONS AT HVAR OBSERVATORY

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The double solar telescope at Hvar Observatory consists of two refractors, one with 217 mm objective diameter used for photospheric observations, and the second one with 130 mm objective used for chromospheric observations. The aim of the Hvar solar telescope is to produce high-resolution and high-cadence imaging of active regions on the Sun, using a field of view of about 11 arcmin for the photosphere and 7 arcmin for the chromosphere. The Pulnix TM-4200GE 12-bit 4 megapixel CCD cameras recording seven frames per second together with the software that automatically selects the sharpest frames during the periods of good seeing, allow to study the rapid changes on the Sun in great detail. High-cadence ground-based observations are an important tool to identify and study solar flares, filaments and other solar phenomena that are associated with coronal mass ejections (CME) and their propagation towards Earth. Aiming to improve the space weather forecasts by using ground-based observations, we present the catalogue of Hvar solar telescope observations in the last solar cycle 24. A future expansion of this catalogue will be used for a comparison with ALMA- SSALMON observations.

## THE POSSIBLE IMPACT OF COSMIC RAYS ON EXTRATROPICAL CYCLONE FREQUENCY AND STRENGTH OVER NORTH ATLANTIC

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The mechanism based on the global electric circuit (GEC) flowing vertically from the ionosphere to the Earth's surface could potentially provide the link between the solar modulated energetic particles and Earth's weather and climate. Cosmic ray (CR) induced atmospheric ionization modulates the vertical current density (Jz) and introduces the changes in GEC that could alter the microphysical properties of the clouds. Due to the complexity and scale of the GEC and its feedbacks, possible implications and importance of this mechanism are still mostly unknown. One of the possible feedbacks to GEC alteration could be the process of storm invigoration and occurrence of extratropical cyclones. Using 6-hourly sea level pressure (SLP) fields from the ERA-Interim data, extratropical cyclones are identified by tracking their low-pressure centers. Daily timescale super-positional epoch (composite) analysis is performed to analyze the frequency and strength of cyclones during the short-term reductions in CR flux or so-called Forbush decrease events in the last three solar cycles (1979 - 2015). In order to test the significance of the results the robust Monte Carlo significance testing were employed to avoid the possible false positives that may be obtained with standard statistical tests (e.g. t-test). We don't find a significant response in the frequency or strength of extratropical cyclones to changes in CR flux during the whole analysis period.

## DIAGNOSTIC OF TRANSVERSE TEMPERATURE DISTRIBUTION IN CORONAL FANS, USING 3-MIN OSCILLATIONS

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Slow MHD waves can be applied for the diagnostics of transverse temperature distribution in coronal fans. The interpretation of the EUV observations of coronal structures is a challenging task. Since the coronal EUV emission is optically thin, any EUV imaging instrument (like SDO/AIA) measures emission integrated along the line of sight. To establish the transverse temperature distribution, we model numerically the propagation of slow MHD waves in coronal fans with different temperature distribution: hotter interior – colder background, and colder interior – hotter background. MHD simulations were performed in 2D case by using of Lare2D code. To compare our numerical results with observations, we applied the FoMO forward modeling code to the simulation data. The FoMO code was used to create synthetic SDO/AIA images at 171 Å and 193 Å from temperature, density and velocity distributions produced by the MHD simulations. As a next step, we calculated apparent delays between bright ness oscillations seen in 171 Å and 193 Å synthetic data. We found that the delays can be either positive (the wave firstly appears in 171 Å) or negative for both

"cold interior" and "hot interior" models, but its dependence upon the distance from the foot-point of the fan is more informative. The apparent delay between oscillations observed in 171 and 193 Å channels decreases with the distance for the "cold interior" model and increases for the "hot interior". We calculated the delays for real observation of 3 minutes oscillations in coronal fans associated with the sunspots of active regions NOAA 11711, 11582 and found that the spatial distribution of the apparent delay is consistent with the hot "interior model" for both cases.

## THE GROUND LEVEL EVENT ON SEPTEMBER 10, 2017

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Ground level events (GLEs) are the most energetic solar particle events (SEPs). On September 10, 2017 at 15:35 UT a X8.2 X-ray flare from the active region 2673 (S09, W91) was detected that peaked at 16:06 UT. The event was accompanied by a coronal and IP type II radio burst starting at 15:49 UT followed by IP type III radio bursts starting at 15:53 UT and a coronal mass ejection. The event onsets of near relativistic electrons have been detected at 16:06 UT and 21:38 UT at SOHO and STEREO A, respectively. In contrast to observations close to the Earth no strong SEP anisotropies have been observed at STEREO A. The neutron monitor network (NMN) recorded the second GLE for solar cycle 24 with an onset at 16:10 UT at Fort Smith. DOSIS 3d aboard the international space station showed an increase in the dose rate at low cutoff rigidities. The Electron Proton Helium INstrument on board SOHO measured protons with energies of more than 700 MeV. The analysis of the NMN indicates that the interplanetary field direction pointed to areas over South America. The biggest increase of 12% was measured by DOMC with an onset time of 17:03 UT. Data observed at Earth and the longitudinal structure in the inner heliosphere will be discussed.

## IMPLICATIONS OF THE FRED MODEL TO UNDERSTANDING THE INTERPLANETARY COUNTERPART OF THE 2015 JUNE 21 CME

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The 2015 June 21 CME originated from NOAA AR 12371 located close to the disk center (N12E13). There was a series of five halo CMEs on June 18, 19, 21, 22, and 25. All except the June 19 CME were from AR 12371; the June 19 CME originated from a filament channel eruption to the south of the disk center. There were also two episodes of large-scale disturbances in the region surrounding AR 12371 (especially to the south and west) that did not have associated CMEs probably because they were not wide enough to become halos. All halo CMEs from AR 12371 were associated with type II bursts over a wavelength wide range. Of these the 2015 June 21 CME produced a large geomagnetic storm and an intense solar energetic particle event. One of the puzzling aspect of this event is that the interplanetary CME was extremely complex. At the Sun, the CME was fit to a flux rope using the Graduated Cylindrical Shell (GCS) model. The flux rope was of high inclination, consistent with the twin dimming observed including the south-pointing axial field. We were

also able to use the FRED model (Flux Rope from Eruption Data) that yields a large axial magnetic field strength. However, in-situ observations indicate a short-duration flux rope followed by an extended interval that may not be related to the flux rope. The flux rope size and the magnetic field strength are not compatible with the coronal flux rope. We provide a plausible explanation to the in-situ observations and the associated geomagnetic storm.

## NEUTRON MONITOR MEASUREMENTS ON THE GERMAN RESEARCH VESSEL POLARSTERN

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Neutron monitors and muon telescopes are ground-based devices to measure the variation of galactic cosmic ray intensities. Since their measurements are influenced by the variable Earth magnetic field and the atmospheric conditions close to its position a detailed knowledge of the instrument sensitivity with geomagnetic latitude (rigidity) and atmospheric pressure is essential. The rigidity dependence is determined experimentally by utilizing several so called latitude scans. The Polarstern is currently one of the most sophisticated polar research vessels in the world that spends almost 310 days a year at sea. Between November and March it usually sails to and around the waters of the Antarctic, while the northern summer months are spent in Arctic waters. In other words the vessel scans twice a year the rigidity range below the atmospheric threshold and above 10 GV. One mini neutron monitor, constructed by the North West University campus Potchefstroom, and muon telescope, constructed by DESY Zeuthen, are measuring the variation of galactic cosmic rays with respect to the position of the vessel. In this presentation the measurements of the neutron moinitor over the last years are presente

## IN-SITU DENSITY OF (I)CMES VERSUS CME 3D GEOMETRY AND MASS DERIVED FROM REMOTE SENSING DATA

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Using stereoscopic data from STEREO-SECCHI instruments COR1, and COR2, we derive the de-projected mass and its evolution for a sample of coronal mass ejections (CMEs). A significant mass increase can be found of the order of 2% − 6%, most prominent over the distance range 10Rs-15Rs. At a distance of about 20Rs it can be assumed that the CME mass evolution more or less ceases and that a final mass is reached (cf., Bein et al., 2013). By applying the forward fitting model (Thernisien et al., 2006, 2009) on COR2 data, for some well observed events out of this sample, we obtain the geometry of the CMEs and their volume. Working under the assumption that the CME undergoes self-similar expansion and combining it with solar wind density assumptions, we will have a look at the CME mass development and derive the CME density (plasma composition of 90%H and 10%He) for the distance of 1AU. The results are compared to in-situ proton density data measured for the associated flux ropes. From this we may draw important conclusions on the possible CME mass increase in interplanetary space.

## VERY RARE BURSTS OBSERVED IN THE 0.8-2.0 GHZ SOLAR RADIO SPECTRA

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Besides typical and known radio bursts there are also very rare bursts that are up to now not commonly known and explained. In more than twenty years of observations in the 0.8-2.0 GHz frequency range by the Ondrejov solar radio spectrograph, we found several such very rare bursts. In this paper six examples of them are presented and described.

## REFLECTION OF COSMIC RAYS AT MHD SHOCKS

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CME-driven shocks cause a decrease in cosmic ray flux. This effect is called Forbush decrease (Fd). We assume a linearly changing magnetic field component inside the shock and write the corresponding equations of motion. Solving equations numerically and varying different parameters, such as kinetic energy and velocity components of the particle, or the change of magnetic field component and shock width, gives us pitch angles for which particles are reflected. Integrating over velocity space gives the amplitude of Forbush decrease for a given change of magnetic field.

## EXTREME SOLAR ENERGETIC ELECTRON EVENTS OBSERVED BY ULYSSES COSPIN/KET

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The Ulysses mission launched in October 1990 has successfully made in-situ observations of the south and north polar regions of the Sun (up to 80.2) during different phases of the solar cycle. The COsmic and Solar Particle INvestigation KielElectron Telescope (COSPIN/KET) on-board Ulysses measured protons and a-particles in the energy range from $\sim$4 to $>$2000 MeV/n and electrons in the range from $\sim$3 to $>$300 MeV in different energy channels. Energy spectra of 55 solar energetic electron (SEE) events in the energy range from 10 to 100 MeV have been published utilizing data from the MEH aboard ISEE3. Here we present the observation of Ulysses SEE events that show a significant electron flux increase at energies above 10 MeV. Due to the Ulysses orbit we observe only events at distances beyond 1 AU and at different heliolatitudes. In addition the interpretation of COSPIN/KET electron energy spectra is difficult because of the instrument background that is caused partially by proton interactions with the spacecraft. Therefore a detailed simulation of the COSPIN/KET has been developed and will be presented here allowing us to determine reliable electron energy spectra.

## INTERPRETATION OF INCREASED SOLAR ENERGETIC PARTICLE FLUX MEASUREMENTS WITH SEPT ABOARD THE STEREO SPACECRAFT AND CONTAMINATION

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Among others, shocks are known to be accelerators of energetic charged particles. However, many questions regarding the acceleration efficiency and the required conditions are not fully understood. In particular, the acceleration of electrons by shocks is often questioned. Recurrent energetic particle events are caused by the passage of Corotating Interaction Regions (CIRs) that have been extensively analyzed by different instrumentation close to Earth. Measurements of the Solar Electron and Proton Telescope aboard the Solar TErrestrial RElations Observatory are utilized in the solar heliospheric community to investigate electron events. Due to its measurement principle, the magnet foil technique, ions can contribute to the electron channel. This effect is well known. During recurrent energetic particle events the averaged helium to proton ration is enhanced to more than 10%. The energy per nucleon spectra are nearly the same for protons and helium. Although the electron intensity profile is influenced by an ion contamination during the shock crossings it is not obvious that electrons are not enhanced during such periods. Computation using a GEANT4 simulation of the SEPT instrument resulted in response function for ions and electrons. These response functions have been utilized to analyze the recurrent energetic particle event that was measured by STEREO B on August 9, 2011. Assuming a constant helium to proton ratio and energy spectra described by a Band function we found that electron and ion measurement can be explained by the contribution of helium and protons with an helium to proton ratio of about 16%. Thus no electron enhancements are needed to explain the SEPT measurements.

## COMBINED HELIOSEISMIC INVERSION FOR 3D VECTOR FLOWS AND SOUND-SPEED PERTURBATIONS

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We introduce an improved methodology of the time-distance helioseismology which allows us to invert for a full 3D vector of plasma flows and the sound-speed perturbations at once. Additionally, by this methodology one also can derive the mean value of the vertical component of the plasma flows and the cross-talks between the plasma flows and the sound-speed perturbations. The methodology is validated using forward-modelled travel times from a snapshot of fully self-consistent simulation of a convection.
We demonstrate that we are able to recover flow and sound-speed perturbations exactly as expected. We also show the sensitivity of our methodology to entire vertical velocity, not only to its variations as in other methodologies available. The cross-talk from both the vertical flow component and the sound-speed perturbation has only a negligible effect

for inversions for horizontal flow components. The inversions for the vertical component of the vector flows or for the sound-speed perturbations are affected by cross-talk from the horizontal components and needs to be minimised in order to retrieve valid results. It seems, that there is a nearly constant cross-talk between the vertical component of the vector flows and sound-speed perturbations.

## DYNAMICS AND MAGNETIC PROPERTIES IN CORONAL HOLES USING HIGH-RESOLUTION MULTI-INSTRUMENT SOLAR OBSERVATIONS

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Using high-resolution solar observations from the Hinode Instruments SOT/SP, EIS and XRT as well as IRIS from a coronal hole on the 26th of September 2017, we are investigating the dynamics within the coronal hole. Further satellite data support is given by full disc images from SDO with the AIA and HMI instruments. EIS and IRIS data provide us crucial information about the plasma and energy flow from the sun's chromosphere into the corona using the EUV and UV spectra and images. Investigating the magnetic configuration as well as the dynamics and changes within the coronal hole by using the SOT/SP data gives us crucial insides about the physical processes leading to the corresponding changes in the higher atmosphere. We compare the Hinode data with AIA and HMI data to get a firm comprehensive picture about the connection from high resolved photospheric fields and its dynamic with the higher layers. In this poster contribution we will outline the state of the art of this investigation and give an overview of the further steps necessary. The data were obtained during a recent GREGOR campaign with the joint support of IRIS and Hinode (HOP 338)

## STATISTICAL STUDY OF TYPE II AND TYPE III BURSTS OBSERVED BY STEREO/WAVES

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Type II and type III radio bursts are produced by electron beams of accelerated at shock waves ahead of coronal mass ejections, and at reconnection sites of solar flares, respectively. We performed a statistical analysis of type II and type III radio bursts observed by Solar TErrestrial RElations Observatory (STEREO)/Waves instruments (125 kHz - 16 MHz) between May 2007 and September 2014. We have found that type II radio bursts are preferably observed at higher frequencies, when compared to type III radio bursts. The flux density of type II bursts is statistically frequency independent, while the flux density of type III bursts is larger for the lower frequencies. We investigate exponential rise and decay times of type III radio bursts to study a role of scattering by density inhomogeneities in the solar wind.

## NUSTAR DETECTION OF X-RAY HEATING EVENTS IN THE QUIET SUN

Matej Kuhar, Säm Krucker and the NuSTAR solar team

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We present the first imaging spectroscopy X-ray observations of three quiet Sun flares during the two NuSTAR solar campaigns on 2016 July 26 and 2017 March 21. Their X-ray spectra is well described with isothermal fits with temperatures in the range 3.2-4.1 MK, while their energies are in the range $(2\text{–}6)\times10^{2}6$ erg. While their spectra did not reveal a clear sign of a nonthermal component above $\sim$5 keV, the energy in a hidden nonthermal component is still comparable to the thermal energy estimates of the detected flares. Their GOES classes fall between 1/1000 and 1/100 A class level, making them 8 orders of magnitude fainter in SXR flux than the largest solar flares. We also discuss the possibilities of joint NuSTAR-ALMA observations of quiet Sun flares to detect their nonthermal signals.

## SOLAR ENERGETIC PARTICLE EVENTS WITH PROTONS ABOVE 500 MEV BETWEEN 1995 AND 2015 MEASURED WITH SOHO/EPHIN

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The Sun is an effective particle accelerator producing solar energetic particle (SEP) events during which particles up to several GeVs can be observed. Those events observed at Earth with the neutron monitor network are called ground level enhancements (GLEs). In this work, SEP events with protons accelerated to above 500 MeV have been identified using data from the Electron Proton Helium Instrument (EPHIN) aboard the Solar and Heliospheric Observatory (SOHO) between 1995 and 2015. The compiled list of 42 SEP events is discussed based on the fitted spectral slopes and absolute intensities with special emphasis on whether or not an event has been observed as GLE. Furthermore, a correlation between the derived intensity at 500 MeV and the observed increase in neutron monitor count rate has been found for a subset of events.

## DEPENDENCY OF FORMATION HEIGHTS OF DIFFERENT HINODE SOT/BFI SPECTRAL BANDS ON MBP MODEL CHARACTERISTICS

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It is well-known that the formation height of spectral filters within the solar atmosphere depends on the atmospheric parameters itself. This means that the spectral line formation within small-scale magnetic fields is different compared to the quiet surrounding Sun. Of

special interest for us is the formation height of the Hinode broadband filters as we hope, to measure via the size distribution of small-scale features the height evolution and thus the scale-height parameter of small-scale flux tubes. To do so, we constructed an atmospheric model of the Sun with the MPI-AMRVAC simulation tool with emphasis on Magnetic Bright Points (MBPs). Along vertical cuts through this atmosphere we derived the electron density, the hydrogen population numbers for the first five bound levels and the proton and helium population numbers (using Boltzmann and Saha equations). With these parameters together with the temperature and velocity fields we used the MULTI3 code from Uppsala to derive the non LTE population levels and hence the response functions leading ultimately to the formation heights of the Hinode SOT/BFI spectral bands – blue, red, green continuum, G-Band, CA II H. We investigated the behavior of the formation heights of these lines in answer to varying input parameters of our atmospheric model.

## TO THE ANALYSIS OF THE NON-STATIONARY QUASI-PERIODIC PULSATIONS IN A SOLAR FLARE

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The quasi-periodic pulsations (QPP) are a frequently observed feature of the time profiles of a solar flare emission. The QPP are widely studied during the last decades and are still poorly understood. For example, a special attention should be given to a distinct class of the QPP signals with non-stationary parameters. The non-stationarity appears as a variation of the oscillation amplitude, period, or phase with time. It can also be associated with the presence of different kinds of slowly varying trends. Such features could be caused by the variations of the physical parameters in the flare site or as a superposition of several physical processes ongoing simultaneously, including power-law distributed background noise. A serious challenge in the detection and analysis of QPP is that the current analytical methods imply the stationary or slowly varying parameters of the signal. In this respect, the corresponding techniques should be appropriately tuned to adequately address the non-stationary nature of QPP. In this study, we reveal and analyze the non-stationary QPP observed in the solar flare 2013-11-10. The pulsations are seen to have the apparent time scales varying from 15 s to 50 s. We attempt to formulate an empirical criterion for QPP's non-stationarity which would allow us to distinguish between the real signals and artefacts. We also investigate the question of whether the non-stationary QPP are seen in different wavebands and how their parameters vary within the observational spectral waveband and the height range in the solar atmosphere. The periodic properties are analyzed using a unique combination of the analytical methods, such as the autocorrelation, Fourier periodogram, wavelet, and the EMD analyses. Impacts of the flare trend and different kinds of noise are considered. The analysis is based on the data obtained by Konus-Wind, RHESSI, NoRH, NoRP, GOES.This study was supported by RFBR according to the research project No. 17-52-10001.

## STATISTICAL ANALYSIS OF SUCCESSIVE CORONAL MASS EJECTIONS AND THEIR SPATIO-TEMPORAL ASSOCIATION

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We study the waiting time (WT) of 28590 Coronal Mass Ejections (CMEs). We found that the WT, i.e., the time elapsed between two consecutive events is lower than 25 hrs for 97% off events and is lower than 5 hrs for 59% of events. The WT definitely does not follow an exponential nor a gamma distribution, which represent stationary and time dependent stochastic processes, respectively. Although, the fitting process is better when we consider a Pareto distribution (non-Poisson statistics) during different phases of the solar cycle. In this way, the mean WT is $\sim 6$ hrs for the whole period, and $\sim 9$ and $\sim 4$ hrs during minimum and maximum, respectively. The possible correlation between consecutive CMEs is supported by the fact that a large number of consecutive events have a Position Angle difference within a range of 30°, implying that CMEs tend to occur in similar source regions. Furthermore, analyzing the speed distribution of the leading and trailing CMEs we found significant speed differences between these groups of CMEs. Finally, We found a limit relationship between the WT and the speed of consecutive events, this is important in terms of space weather, because it establishes that a high speed CME must be preceded by another CME within a short WT. In particular, the probability of having an extreme CME $\sim 3000$ km/s) is low (p $\sim 10^{-6}$) for WT of one hr, and it drops by one order of magnitude when the WT increases to 32 hrs.

## MAGNETOSPHERIC EFFECTS OF RECURRENT COROTATING INTERACTION REGIONS OBSERVED BETWEEN JANUARY AND APRIL 2008

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We investigate the geoeffectiveness of corotating interaction regions (CIRs) observed between January and April 2008. We use SOHO-EIT images to search for persistent coronal holes around the solar equator and OMNI datasets to study the corotating interaction regions at 1 AU. When the plasma and magnetic field compression regions, characteristic for leading edges of CIR events, are associated with southward turnings of the interplanetary magnetic field (IMF), recurrent geomagnetic storms and substorms are triggered. The geomagnetic variability related to the storm activity is described with the AE and SYM-H indices. During the targeted time interval, we selected 8 CIR events presumably generated by two persistent coronal holes observed on the Sun. Thus, the dataset consists of two groups of 4 CIR events which can be analyzed comparatively. We find that each group triggers geomagnetic storms and substorms, with one set of CIR being overall more geoeffective than the other. From a closer inspection we determined that the two CIR groups were characterised by different IMF polarities: for the first group of CIRs the IMF is positive while it is preponderantly negative for the second one. The latter is the most geoeffective. This result can be explained by the Russel-McPherron effect, which predicts that, around the spring equinox, a negative

polarity IMF (in the GSE coordinate system) gives rise to a southward component of the IMF (in the GSM coordinate system), which in turn increases the geoeffectiveness of the associated CIR. We also performed a spectral analysis of the entire period of 4 months and found dominant periodicities of about 13.4 and 9.6 days in all datasets that describe the recurrent magnetospheric effects of the CIR events studies here.

## LAUNCHING HYDRODYNAMIC AND MAGNETIC CME-LIKE STRUCTURES INTO THE OPERATIONAL HELIOSPHERIC SPACE WEATHER MODELS

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Operational heliospheric space weather models require simulations of coronal mass ejections (CMEs) much faster than real time for all observed events. The WSA-ENLIL-Cone model uses the white-light appearance of CMEs in coronagraphs, fits the geometric and kinematic parameters, launches simple hydrodynamic structures into the background solar wind, and simulates the propagation and interaction by a 3-D magnetohydrodynamic (MHD) code. We introduce the "cone" and "spheromak" models for launching hydrodynamic and magnetic structures, respectively. Selected CME events, characterized by excellent observations from Sun to Earth, are used for numerical simulations of transient disturbances. We compare the numerical heliospheric results with remote white-light observations and with in-situ measurements of plasma parameters at Earth and STEREO spacecraft. Launching of spheromaks is less realistic than the launching of flux ropes but it enables easier and more practical operational predictions and utilization of existing tools. We present improvements over the hydrodynamic cone model and discuss its predictive application to estimate strength and duration of the Bs events.

## CONSTRAINING THE CONE FREE-MODEL PARAMETERS IN THE WSA-ENLIL-CONE HELIOSPHERIC MODEL BY THE UPDATED CME DRAG MODEL

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There has been significant progress in observations, theory, and modeling of coronal mass ejections (CMEs) in recent years; however, modeling their origination on the Sun and at the same time forecasting their specific impact on the Earth is still in the research phase. The operational WSA-ENLIL-Cone model does not address the specifics of the initiation process of CMEs; it takes the resulting CME observed in coronagraphs, determines its geometric and kinematic representation, and launches a corresponding hydrodynamic ejecta into the heliospheric computational domain, where it evolves as it interacts with the background solar wind. To further improve the prediction accuracy of CME arrival time, we explore a possibility to specify the ejecta density and radial extent, as essential physical quantities

determining the CME driving momentum (just as angular width and velocity), not as the model-free parameter but as quantities constrained by remote white-light observations of the CME acceleration/deceleration within 20 Rs. We use the Graduated Cylindrical Shell (GCS) model to fit the CME geometric and kinematic parameters to determine the ejecta direction, angular extent, and initial speed. Then we determine a 3-D trajectory of the CME leading edge and use the updated CME drag-based model to calculate the density within a spheroidal ejecta. Finally, we use the WSA-ENLIL-Cone model for simulations of the CME propagation in the inner heliosphere.

## EVALUATION OF THE NEW KANZELHÖHE OBSERVATORY FLARE DETECTION ALGORITHM WITH AN EVENT BASED VERIFICATION SYSTEM

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The flare detection algorithm, that was developed for the Space Situational Awareness program of the European Space Agency (ESA/SSA), was updated in September 2017. The old system has been in operation since mid-2013. In order to evaluate the new algorithm all data back to 2014 was reprocessed using the new algorithm. The standard procedure for verification measures yields strongly biased values, therefore we introduce a new event-based method. The timeline of the H$\alpha$ observations is divided into positive events (flaring period) and negative events (quiet period), independent of the length of each event. In total, 329 positive and negative events were detected between 2014 and 2016. The hit rate for the new algorithm reached 96% (just five events were missed) and a false-alarm ratio of 17%. This is a significant improvement of the algorithm, as the original system had a hit rate of 85% and a false-alarm ratio of 33%. The true skill score and the Heidke skill score both reach values of 0.8 for the new algorithm; originally, they were at 0.5.

## 3D RECONSTRUCTION AND INTERPLANETARY EXPANSION OF A 2010 APRIL 3RD CME

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We analyse selected CME event using ultraviolet and coronagraphic images from spacecraft at different vantage points (SDO, SOHO, STEREO-A and STEREO-B). We perform a 3D reconstruction of both the flux rope and shock of the events using the Graduated Cylindrical Shell (GCS) model and calculate CME kinematic parameters (velocity, acceleration). The obtained results are fitted with empirical models describing the expansion of CMEs in the heliosphere and compared with in situ measurements. Finally, we relate the event with a decrease in the Galactic Cosmic Ray Flux, known as Forbush decrease, detected by near-Earth spacecraft (SOHO/EPHIN) and terrestrial detectors (neutron monitor), and perform the analysis using the analytical diffusion-expansion Forbush decrease model ForbMod.

## PLASMA DIAGNOSTICS AND FORMATION OF CORONAL HOLES

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We investigate the evolution of a well-observed, long-lived, low-latitude coronal hole (CH) over 10 solar rotations in the year 2012. For this we apply a DEM reconstruction technique using SDO/AIA EUV data in different wavelengths. We analyse the plasma parameters during the different phases of the CH evolution, namely growing, maximum and decaying phase, to derive how the density and temperature change as the CH increases/decreases in size during its evolution. We further look for signatures of interchange reconnection in the DEM during phases of rapid CH growth taking advantage of AIA's high temporal and spatial resolution. To this aim we look at the EM evolution of pixels around the CH boundary. The results are compared to changes in the solar wind plasma and magnetic field parameters measured in-situ by the ACE spacecraft.

## IS THE CZECH POWER GRID AFFECTED BY SPACEWEATHER EVENTS?

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The effects of geomagnetic storms on transmission networks in the region of Central Europe has largely been questioned and disputed by professionals from the industry. We statistically study the occurrence rates of failures in the Czech power grids, as provided by the grid operators, in periods of increased geomagnetic activity and compare them to the periods of the identical length of decreased activity. We critically discuss the possibility of the increase of failure rates due to the effects of spaceweather at low geomagnetic latitudes.

## QUASI-PERIODIC PULSATIONS WITH LARGE PERIODS

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One of the significant manifestation of the solar corona variability are so-called quasi-periodic pulsations (QPPs). QPPs are characteristic, fast and impulsive changes visible sometimes on light curves of solar flares. Subsequent maxima of QPPs are recorded in fairly regular intervals, while the amplitude of the individual pulses of radiation can change in time. Although we observe QPPs from half a century, we still cannot identify the underlying physical mechanism responsible for QPPs. We investigated a set of solar flares with QPPS which were simultaneously observed on both RHESSI and GOES light curves. We focused on the events with quite large periods of oscillations- of order of few minutes. Example of such event is a flare of 21 April 2013, that occurs in small magnetic arcade and shows oscillations with period of about 420 s. We suggest that QPPs of those flares can be caused by the external modulation of the reconnection process with the new emerging flux.

## STATISTICAL STUDY ON CORONAL HOLE EVOLUTION AND APPLICATION FOR SOLAR WIND SPEED FORECASTING

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The evolution of coronal holes (CHs), which are the sources of high speed solar wind streams, play an important role in the persistence of the solar wind structure in interplanetary space. Forecasting tools that are based on persistence models, e.g., for the in-situ solar wind speed, might be less reliable during times when CHs undergo strong changes. To assess the speed uncertainty in persistence models, we perform a statistical study on the CH area evolution from combined EUV observations (STEREO versus SoHO/SDO) and the response of that evolution in the in-situ measured solar wind speed (STEREO versus ACE). By comparing the extracted fractional CH area in each spacecraft, we derive a relation between expanding CH areas and increase in the solar wind speed. In comparison, there is no consistent trend found for decaying CHs to be related to solar wind streams of decreasing speed. These results can be applied to modify solar wind speed forecasting models when monitoring EUV data and CH evolution from different vantage points. For expanding CHs we give an uncertainty estimate in the forecasted speed which leads to an improvement of the hit/miss rate in the prediction of solar wind high speed streams. The obtained results support a future L5 mission and show the importance and valuable contribution using multi-viewpoint data. This study is supported by the FFG/ASAP program under grant no. 859729 (SWAMI).

## MAGNETOSPHERE RESPONSE TO SPACE WEATHER EVENTS: RELATIONSHIPS BETWEEN PC, AE AND SYMH INDICES

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The index of the polar cap magnetic activity (PC index) is regarded as a proxy of the solar wind energy input into the magnetosphere (Resolution of XII IAGA Assembly, 2013), unlike to AL and Dst indices, which characterize the energy realized in magnetosphere in form of substorms and magnetic storms. This assertion is based on examination of relationships between the PC-index and the solar wind parameters, on the one hand, and relationships between the PC evolution and development of the magnetospheric disturbances (AL and Dst-indices), on the other hand. Relationships between the 30-min smoothed PC and SymH indices examined for 430 magnetic storms [Troshichev and Sormakov, 2017] showed that magnetic storms can be classified, by features of the PC evolution, as classic, pulsed and composite magnetic storms. The classic and pulsed storms are related, correspondingly, to such solar drivers as Coronal Mass Ejections (CME) and Stream Interaction Regions (SIR), whereas the composite storms are produced by joint action of these drivers. The relationships between PC, AE and SymH indices in course of magnetic storms under conditions of the impulse solar wind impact on the magnetosphere is examined. In this case the delay times $\Delta$T between the PC index leap and the corresponding response in SymH are clearly reduced in proportion to the growth rate of the interplanetary electric field EKL. Reason of the $\Delta$T reduction is sharp enhancement of the DCF currents flowing along the magnetopause, their close through the field-aligned current (FAC) system across the polar cap ionosphere and

appropriate sharp increase of magnetic activity in the polar cap (PC index). The PC and SymH response to different types of the impulse SW events is examined.

## FIRST YEAR RESULTS OF THE BULGARIAN-RUSSIAN PROJECT ON THE ORIGIN OF SOLAR ENERGETIC PARTICLES

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We present and discuss the first year results of the space weather collaboration between scientists from Bulgaria and Russia which aims is to identify the individual contribution of flares and coronal mass ejections (CMEs) to the resultant flux of solar energetic particles (SEPs). The investigation of the solar origin of SEPs is based on observations from space-based missions SOHO/ERNE, GOES, SDO combined with together with the Russian satellites (SONG/CORONAS-F and Relek/Vernov) and ground-based instruments in the wide range of the electromagnetic spectrum from X-ray and EUV to radio emission. The relationship of SEP events with other solar activity phenomena (prominences, active regions, radio bursts, etc.) is also explored. The research obtained in this study is supported by the project "The origin of solar energetic particles: solar flares vs. coronal mass ejections", co-funded by the Russian Foundation for Basic Research with project No. 17-52-18050 and the National Science Fund of Bulgaria under contract No. DNTS/Russia 01/6 (23-Jun-2017).

## LONG TIME TRENDS OF MBP CHARACTERISTICS

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In this contribution we will have a look on magnetic bright points (MBPs) from the point of view of long time changes over time periosds in the range of the solar sunspot cycle. MBPs are small-scale solar magnetic field features visible in the photosphere. Their field strength reaches normally well beyond 1 kG and they are very variable and dynamic on time scales ofjust a few minutes. Due to their strong magnetic field, which resembles in shape the ideal concept of vertical flux tubes, as well as their dynamic behaviour, they are of special interest forwave triggering and propagation processes and thus for the coronal heating problem.On the other hand these small-scale structures appear brighter on the solar photosphere and thus their long time behaviour in respect of number, size, and intensity is of great importancefor the total solar irradiance variability and thus also for climate change studies. In the current contribution we want to have a detailed look in exactly these

parameters over the timeperiod from end of 2006 until spring 2017 when unfortunately the Hinode SOT/BFI and NFI CCD cameras failed and thus no more data could be taken. The analysis of the available data shows that both quantities, size and number of MBPs, varies with the solar cycle but temporally shifted to the sunspot cycle. These and more results anddetails will be discussed and outlined in the presentation.

## MULTI-SPACECRAFT INVESTIGATION OF CHARACTERISTICS AND EVOLUTION OF OF CO-ROTATING STREAM INTERACTION REGIONS

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We examine statistically the occurrence and physical characteristics of Co-rotating Stream Interaction Regions (CIRs/SIRs) observed to precede high-speed streams in the heliosphere. The study is based on magnetic field and plasma data observed in L1 and by the NASA STEREO A and STEREO B satellites. We investigate how the physical characteristics relates to the associated high-speed stream and also to the phase of the solar cycle. We further investigate the recurrence pattern and geoefficiency of the CIRs, and assess to which extent a dual space-craft approach will improve the predictability of the SIRs in L1.