2nd China-Europe Solar Physics Meeting

Advances in Solar and Heliospheric Physics

6 - 10 May 2019, Hvar, Croatia
Over the last three decades, solar physicists in both Europe and China have worked together on a large variety of topics in various ways, yielding fruitful achievements and success. In order to broaden the collaborations and to exchange scientific results between Chinese and European solar physicists, the series China-Europe solar physics meetings was introduced every 2 or 3 years in China and Europe alternatively. Following the success of the first meeting held in China (CESPM 2017, Kunming, Yunnan) we are organising the 2nd meeting in Hvar aiming to strengthen the collaboration between European and Chinese scientists, in particular among young scientists. We believe it will not only help development of solar physics in China and Europe, but will greatly contribute to the development of solar physics world-wide as well.

The 2nd CESPM is organized by Hvar Observatory, Faculty of Geodesy, University of Zagreb. The meeting is held under the auspices of the Hvar Town Council and Tourist Board and Croatian Astronomical Society. The Colloquium is sponsored by the Ministry of Science and Education, Republic of Croatia, the European Physical Society (EPS) and Galaxies (MDPI journal). Additionally we want to acknowledge all supporters of poster prizes: EPS poster prize grant, Springer Nature / Solar Physics and Elsevier.
SCIENTIFIC ORGANIZING COMMITTEE:

Cheng Fang, Nanjing University (co-chair)
Eduard P. Kontar, University of Glasgow (co-chair)
Mingde Ding, Nanjing University
Li Feng, Purple Mountain Observatory
Manolis K. Georgoulis, Academy of Athens
Jun Lin, Yunnan Astronomical Observatory
Hardi Peter, Max Planck Institute for Solar System Research
Brigitte Schmieder, LESIA, Paris Observatory
Jean-Claude Vial, Institut d’Astrophysique Spatiale, Orsay
Bojan Vršnak, University of Zagreb
Jingxiu Wang, National Astronomical Observatories

LOCAL ORGANIZING COMMITTEE:

Jaša Čalogović, Hvar Observatory (co-chair)
Domagoj Ruždjak, Hvar Observatory (co-chair)
Bojan Vršnak, Hvar Observatory (co-chair)
Eleanna Asvestari, University of Graz
Karin Dissauer, University of Graz
Mateja Dumbović, University of Graz
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Isabell Piantschitsch, University of Graz
Ivica Skokić, Hvar Observatory
Davor Sudar, Hvar Observatory
Toni Visković, Hvar Observatory

CONFERENCE MEETING PLACE:

Hotel Amfora - Hvar Grand Beach Resort, Hvar, Croatia

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PROGRAMME:

Sunday, May 5, 2019

| 18:00 – 19:00 | Registration |

Monday, May 6, 2019

| 8:00 – 9:00   | Registration |
| 9:00 – 9:45   | Opening words |

**Session 1** chairperson: **Eduard Kontar**

| 9:45 – 10:15  | Sami Solanki: Ground- and space-based solar instruments in Europe (Invited talk) |
| 10:15 – 10:45 | Weiqun Gan: Ground- and space-based solar instruments in China (Invited talk) |
| 10:45 – 11:15 | Coffee break |

**Session 2** chairperson: **Cheng Fang**

| 11:15 – 11:45 | Huaning Wang: Prediction of solar cycle 25: progress and challenges (IT1.1) |
| 11:45 – 12:00 | Melinda Nagy: How ‘rogue’ active region emergences affect the variation of the solar cycle? (O1.1) |
| 12:00 – 12:15 | Qi Hao: Statistical Analysis of Filament Features during Solar Cycles 20–24 by Computer Automated Detection Method (O1.2) |
| 12:15 – 15:00 | Lunch break |

**Session 3** chairperson: **Huaning Wang**

| 15:00 – 15:15 | Olena Podladchikova: Automated EUV Wave Catalogue For Solar Cycle 23 And 24: EUV Global Wave Rotation Sense Follows Hale Magnetic Cycle (O1.3) |
| 15:15 – 15:30 | Shangbin Yang: Magnetic helicity butterfly diagram of solar cycles: breaking the symmetry and braking the activity (O1.4) |
| 15:30 – 16:00 | Peng-Fei Chen: Formation, Dynamics, and Magnetic Configurations of Solar Filaments (IT2.1) |
| 16:00 – 16:15 | Zhongquan Qu: FASOT, an instrument to reveal the magnetic coupling between solar photosphere and chromosphere (O2.1) |
| 16:15 – 16:30 | Yang Su: New results from the DEM diagnostic of solar coronal structures (O2.2) |
| 16:30 – 17:00 | Coffee break |

*Poster session 1*

| 17:00 – 18:30 | Posters from topics 1-3 |

<p>| 19:00 | Welcome reception |</p>
<table>
<thead>
<tr>
<th>Time</th>
<th>Session 4 chairperson: Brigitte Schmieder</th>
<th>Session 5 chairperson: Li Feng</th>
<th>Session 6 chairperson: Hardi Peter</th>
<th>Poster session 2</th>
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<tbody>
<tr>
<td>9:00 – 9:30</td>
<td>Elena Khomenko: Simulations of partially ionised chromosphere: progress and challenge (IT2.2)</td>
<td>Hardi Peter: Hot and cool structures in active region cores running in parallel (O2.7)</td>
<td>Hamish Reid: New look at the radio fine structures with LOFAR and beam-plasma interactions in the solar corona (IT3.1)</td>
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<tr>
<td>9:30 – 9:45</td>
<td>Robertus Erdelyi: Vortices in the Lower Solar Atmosphere - Automated Swirl Detection Algorithm (ASDA) (O2.3)</td>
<td>Guiping Ruan: Bi-directional plasma jet observed in an active region (O2.8)</td>
<td>Nicolina Chrysaphi: CME-driven Type II solar radio burst with LOFAR and radio-wave scattering (O3.1)</td>
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</tr>
<tr>
<td>9:45 – 10:00</td>
<td>Iain Hannah: Small X-ray flares/brightenings in active regions and the quiet Sun (O2.4)</td>
<td>Daniel Nobrega-Siverio: An updated vision of solar surges (O2.9)</td>
<td>Xiaoyan Xie: Numerical experiments of various types of disturbance to the low and middle corona caused by the solar eruption (O3.11)</td>
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<tr>
<td>10:00 – 10:15</td>
<td>Jie Hong: Ellerman bombs: Observations and Simulations (O2.5)</td>
<td>Shao-Xia Chen: Damping of Slow Surface Sausage Modes in Photospheric Wavesguides (O3.9)</td>
<td>Isabell Plantschitsch: Influence of Initial Parameters on Numerical Simulations of Coronal Waves and their Interaction with Coronal Holes (O3.4)</td>
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<tr>
<td>10:30 – 11:00</td>
<td>coffee – break</td>
<td>Matthew Allcock: Diagnosing the Alfven speed in asymmetric fibrils using solar magneto-seismology (O3.2)</td>
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<td>11:00 – 11:15</td>
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<td>16:00 – 16:15</td>
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<tr>
<td>12:30 – 17:00</td>
<td>coffee – break</td>
<td>16:15 – 16:30</td>
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<tr>
<td>17:00 – 18:30</td>
<td>Posters from topics 1-3</td>
<td>16:30 – 17:00</td>
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Wednesday, May 8, 2019

### Session 7  chairperson: Jean-Claude Vial

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<tr>
<th>Time</th>
<th>Speaker</th>
<th>Title</th>
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<tbody>
<tr>
<td>9:00 – 9:30</td>
<td>Jun Zhang</td>
<td>Observational studies on 3D magnetic reconnections in solar eruptions (IT3.2)</td>
</tr>
<tr>
<td>9:30 – 9:45</td>
<td>Rui Liu</td>
<td>Double-Decker Filament Configuration Revealed by Mass Motions (O3.5)</td>
</tr>
<tr>
<td>9:45 – 10:00</td>
<td>Jörg Büchner</td>
<td>Kinetic Physics and electron acceleration by magnetic reconnection in the solar corona (O3.7)</td>
</tr>
<tr>
<td>10:00 – 10:15</td>
<td>Xiaowei Zhou</td>
<td>Coherent emission driven by energetic ring-beam electrons in the solar corona (O3.6)</td>
</tr>
<tr>
<td>10:15 – 10:30</td>
<td>Hugh Hudson</td>
<td>Coronal implosions and their consequences (O3.8)</td>
</tr>
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10:30 – 11:00 coffee – break

### Session 8  chairperson: Bojan Vršnak

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<tr>
<th>Time</th>
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<th>Title</th>
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<tbody>
<tr>
<td>11:00 – 11:30</td>
<td>Xin Cheng</td>
<td>Origin and early evolution of coronal mass ejections (IT4.1)</td>
</tr>
<tr>
<td>11:30 – 11:45</td>
<td>Yihua Yan</td>
<td>Solar Eruptive Events with MUSER Observations (O4.1)</td>
</tr>
<tr>
<td>11:45 – 12:00</td>
<td>Rocksoon Kim</td>
<td>CME-CME interaction near the Earth (O4.13)</td>
</tr>
<tr>
<td>12:00 – 12:15</td>
<td>Bernhard Kliem</td>
<td>Flux rope formation by a confined solar flare preceding a coronal mass ejection (O4.16)</td>
</tr>
<tr>
<td>12:15 – 12:30</td>
<td>Jasmina Magdalenić</td>
<td>Two homologous halo CMEs of a flower-like morphology (O4.8)</td>
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12:30 – 15:00 lunch – break

### Session 9  chairperson: Xin Cheng

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<tr>
<td>15:00 – 15:30</td>
<td>Alessandro Bemporad</td>
<td>Manifestations and Triggering of Coronal Mass Ejections as observed in the EUV-UV emissions (IT4.2)</td>
</tr>
<tr>
<td>15:30 – 15:45</td>
<td>Yang Guo</td>
<td>Magnetic Flux Rope Eruption Simulated by a Data-Driven Magneto-hydrodynamic Model (O4.3)</td>
</tr>
<tr>
<td>15:45 – 16:00</td>
<td>Pietro Zucca</td>
<td>Interferometric observation of three consecutive type II radio bursts observed with LOFAR (O4.4)</td>
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16:00 – 16:30 coffee – break

### Poster session 3

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<tr>
<td>17:00 – 18:30</td>
<td>Posters from topics 4-5</td>
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18:00 – 20:00 Excursion to the "Spanjola" castle

Thursday, May 9, 2019

### Session 10  chairperson: Astrid Veronig

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<tr>
<td>9:00 – 9:15</td>
<td>Ying Li</td>
<td>Spectroscopic Diagnostics of Chromospheric Evaporation Using IRIS and Hinode/EIS (O4.7)</td>
</tr>
<tr>
<td>9:15 – 9:30</td>
<td>Xiaoli Yan</td>
<td>The Eruption of a Small-scale Emerging Flux Rope as the Driver of an M-class Flare and of a Coronal Mass Ejection (O4.9)</td>
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<tr>
<td>Time</td>
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<tr>
<td>9:30 – 9:45</td>
<td>Brigitte Schmieder</td>
<td>Generalisation of the Magnetic Field Configuration of typical and atypical Confined Flares (O4.10)</td>
</tr>
<tr>
<td>9:45 – 10:00</td>
<td>Xudong Sun</td>
<td>Formation of a Kilogauss Magnetic Flux Rope Prior to an X9-Class Flare (O4.11)</td>
</tr>
<tr>
<td>10:00 – 10:15</td>
<td>Chen Xing</td>
<td>Quantifying the Toroidal Flux of a Pre-existing Flux Rope in Coronal Mass Ejections (O4.12)</td>
</tr>
<tr>
<td>10:15 – 10:30</td>
<td>Chaowei Jiang</td>
<td>Data-Driven MHD Simulations of Solar Eruptions (O4.5)</td>
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<td>10:30 – 11:00</td>
<td>Coffee – break</td>
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**Session 11 chairperson: Yuming Wang**

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<tr>
<td>11:00 – 11:30</td>
<td>Lindsay Fletcher</td>
<td>Multi-wavelength Observations of Solar Flares (IT4.3)</td>
</tr>
<tr>
<td>11:30 – 11:45</td>
<td>Krzysztof Barcynski</td>
<td>Solar flare simulation and observations. A spatiotemporal analysis of the magnetic field, electric current density and Lorentz force (O4.2)</td>
</tr>
<tr>
<td>11:45 – 12:00</td>
<td>Janusz Sylwester</td>
<td>High-resolution X-ray spectra around S XV and Si XIII triplets as observed by Diogeness flat crystal spectrometer (O4.6)</td>
</tr>
<tr>
<td>12:00 – 12:15</td>
<td>Yingna Su</td>
<td>Initiation and Evolution of the X9.3 Solar Flare on 2017 Sep 6 (O4.15)</td>
</tr>
<tr>
<td>12:15 – 12:30</td>
<td>Ting Li</td>
<td>Two Categories of Confined Flares (O4.17)</td>
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<td>12:30 – 15:00</td>
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**Session 12 chairperson: Manuela Temmer**

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<tr>
<td>15:00 – 15:15</td>
<td>Erica Lastufka</td>
<td>Multiwavelength Stereoscopic Observation of the May 1, 2013 Solar Flare and CME (O4.18)</td>
</tr>
<tr>
<td>15:15 – 15:45</td>
<td>Astrid Veronig</td>
<td>Space Weather chains connecting the Sun to Earth (IT5.1)</td>
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<tr>
<td>15:45 – 16:15</td>
<td>Yuming Wang</td>
<td>CME Propagation and Space Weather (IT5.2)</td>
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<tr>
<td>16:15 – 16:30</td>
<td>Jasa Calogovic</td>
<td>Predicting CME arrival time and speed with DBEM (O5.1)</td>
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<td>16:30 – 17:00</td>
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**Poster session 4**

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<tr>
<td>17:00 – 18:30</td>
<td>Posters from topics 4-5</td>
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<th>Time</th>
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<tr>
<td>20:00</td>
<td>Conference dinner</td>
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**Friday, May 10, 2019**

**Session 13 chairperson: Loukas Vlahos**

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<tr>
<th>Time</th>
<th>Speaker</th>
<th>Topic</th>
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<tbody>
<tr>
<td>9:00 – 9:30</td>
<td>Milan Maksimovic</td>
<td>Particles and plasma waves from the Sun to the Earth: progress and challenges (IT5.3)</td>
</tr>
<tr>
<td>9:30 – 9:45</td>
<td>Stefaan Poedts</td>
<td>EUHFORIA in the ESA Virtual Space Weather Modelling Centre (O5.2)</td>
</tr>
<tr>
<td>9:45 – 10:00</td>
<td>Xiaolei Li</td>
<td>Reconstructing 3D Solar Wind Structures in the Inner Heliosphere from STEREO Dual Views (O5.3)</td>
</tr>
<tr>
<td>10:00 – 10:15</td>
<td>Mateja Dumbovic</td>
<td>Unusual plasma and particle signatures at Mars and STEREO-A related to inhibited expansion caused by CME-CME interaction (O5.4)</td>
</tr>
<tr>
<td>10:15 – 10:30</td>
<td>Li Feng</td>
<td>3D evolution of a coronal shock and its link to the longitudinal distribution of SEP properties (O5.5)</td>
</tr>
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<td></td>
<td>10:30 – 11:00</td>
<td>Coffee – break</td>
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<tr>
<td>11:00 – 12:30</td>
<td>Final discussion &amp; closing words</td>
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LIST OF POSTERS:

1. Solar Interior, Dynamo and the Solar Cycle

P1.1 Ivana Poljančić Beljan et al.: RELATIONSHIP BETWEEN STEEPNES OF THE SOLAR DIFFERENTIAL ROTATION AND ACTIVITY
P1.2 Alemayehu Cherkos et al.: EFFECT OF VISCOSITY ON PROPAGATION OF MHD WAVES IN ASTROPHYSICAL PLASMA
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GROUND- AND SPACE-BASED SOLAR INSTRUMENTS IN EUROPE

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There is a rich set of solar instruments available to European scientists, with further exciting instruments/telescopes/space missions being developed. Many of the ground-based resources are located in Europe, e.g. the telescopes on the Canary Islands, but others are outside Europe, e.g. ALMA in Chile. On the ground, new instruments breathe new life into even older telescopes, keeping them at the cutting edge. In space, besides the European missions currently producing, often heavily used data or under development (e.g. SOHO, Solar Orbiter, Proba 2 and 3), there are also exciting new possibilities on the horizon, although not necessarily under the ESA umbrella (e.g. Solar-C_EUVST, Lagrange). Finally, balloon-borne telescopes remain a very interesting alternative to space for some fields within solar physics.

GROUND- AND SPACE-BASED SOLAR INSTRUMENTS IN CHINA

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After briefly introducing the current solar facilities in China, we focus mainly on the future solar facilities, like Advanced Space-based Solar Observatory (ASO-S), Advanced Ground-based Solar Observatory (ASO-G), and so on. The progress in the near future are prospected.

1. Solar Interior, Dynamo and the Solar Cycle

PREDICTION OF SOLAR CYCLE 25: PROGRESS AND CHALLENGES

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It is well known that the current solar cycle 24 is a weak cycle and some people predict that a grand minimum might appear during decades in the future, which means that a little ice age would be possible. With increasing spotless days on the solar disk, the current cycle will have a complete descending phase soon, and how about the upcoming solar cycle 25 becomes a hot point in the world. As similar situations in history, many predictions have been proposed for the new cycle. A review on these predictions would be helpful for understanding progress and challenges in solar cycle research. Since August of 2018, we have been collecting papers concerning the new cycle prediction and comparing methods and results presented in these papers. It seems that magnetic field evolution models for solar surface and interior currently work well for solar cycle prediction. A temporal summary, however, will be present during CESPM 2019, and meanwhile a prediction we prefer will be announced.
STATISTICAL ANALYSIS OF FILAMENT FEATURES DURING SOLAR CYCLES 20-24 BY COMPUTER AUTOMATED DETECTION METHOD

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We adopt our filament automated detection method to process the full disk \(^{\text{H}}\alpha\) data mainly obtained by Big Bear Solar Observatory and Kanzelhöhe Observatory from 1973 to 2018, spanning nearly five solar cycles. The butterfly diagrams of the filaments, showing the information of the filament area, spine length, tilt angle, and the barb number, are obtained. The variations of these features with the calendar year and the latitude band are analyzed. The drift velocities of the filaments in different latitude bands are calculated and studied. We investigate the north-south asymmetries of the filament numbers in total and in each subclass classified according to the filament features. The chirality of filaments, featured by the quantitative measure of chirality as a percentage of left-bearing (right-bearing) barbs associated with a given filament, are also studied. We find that the larger the filaments (with relatively more barbs) are, the higher the percentage is in accordance with the hemispheric helicity rule.

HOW 'ROGUE' ACTIVE REGION EMERGENCES AFFECT THE VARIATION OF THE SOLAR CYCLE?

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The building up process of the polar magnetic field is still debated, however, the peak value of that is the most promising solar cycle predictor. According to earlier results, the tilt angles of active regions (AR) emerging close to or across the equator have a crucial role in this question. Besides this, it is pointed out that the flux of an individual AR can be commensurable to the polar cap flux. In the case of strong, cross-equatorial emergences, the contribution to the solar dipole moment is huge. In order to investigate in detail the effect of such peculiar AR emergences on the amplitudes of following cycles, test regions were inserted into sunspot cycles simulated by a coupled 2×2D Babcock-Leighton kinematic solar dynamo model (Lemerle et al., 2015, ApJ 801; Lemerle & Charbonneau, 2017, ApJ 834). Several series of simulation runs were done while we changed the emergence epoch; the latitude of the emergence; the flux and the tilt angle of the AR and the angular separation between the leading and trailing polarities (Nagy et al. 2017, SoPh 292). It was found that ARs emerging close to the equator during the rising phase of a cycle affects the amplitude of the ongoing cycle itself. The peak value of the following cycle is affected the most when the AR appears near cycle maximum. If the flux, tilt angle or the separation was changed, the amplitude of the next cycle changed accordingly. By changing the emergence latitude we found that an AR emerging >20° far from the equator still can have significant effect. Interestingly, the duration of the ongoing cycle is affected as well, despite the constant meridional circulation speed used within the dynamo model used for the analysis.
AUTOMATED EUV WAVE CATALOGUE FOR SOLAR CYCLE 23 AND 24: EUV GLOBAL WAVE ROTATION SENSE Follows Hale Magnetic Cycle

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EUV global waves are among the best and earliest signatures of geoeffective Coronal Mass Ejections. In this work, we present the automatically constructed EUV global coronal waves (EIT waves) catalogue, a result of the application of the Novel EIT wave Machine Observing (NEMO) tool on the EUV solar images archives covering the intervals: 1997 March-2010 February (provided by EIT/SOHO telescope), January 2008 - December 2010 (provided by EUVI/SECCHI/STEREO) and January 2011 - December 2018 (provided by SWAP/PROBA2). Thus, we have studied the EUV waves characteristics through the evolution of the 23th and 24th solar cycle. The NEMO statistics show that small-scale EUV waves (mini-CMEs), firstly detected with SECCHI data, unambiguously contribute to solar wind formation in the outer corona. The possibility that the size and the intensity of eruptive dimming follow a power-law distribution could indicate that mini-CMEs observed in EUV solar corona are not different from the larger well defined EUV global waves. The amplitude-velocity ratio has been found to be also invariant for the statistically significant number of the propagating EUV waves fronts. It is demonstrated that the sense of EUV waves fronts rotation (clockwise or counter-clockwise) changes when initiated in different hemispheres (North or South). This sense of wave front rotation changes during solar maximum period, depending on the direction of the main magnetic sunspot of the active region (where event has been initiated) and follows Hale magnetic cycle. The consistent pattern of EUV waves rotation may contribute to the understanding of the future direction of the CME propagation.

MAGNETIC HELICITY BUTTERFLY DIAGRAM OF SOLAR CYCLES: BREAKING THE SYMMETRY AND BRAKING THE ACTIVITY

Shangbin Yang, Hongqi Zhang

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Sunspots and magnetic butterfly diagrams reflect the period activity of solar cycles, which also take a restriction to the solar dynamo models. The duration of solar cycles requires the asymmetrical structures of fluid flow and magnetic field. However, the fluid flow and magnetic field at the surface are weakly asymmetrical and the detail deep information of fluid flow in the convective zone is still unclear. The complexity of magnetic filed could be represented by the topological value magnetic helicity which measuring how the magnetic field lines are winding up each other. It is approximately conserved in large magnetic Reynolds number, which traces the asymmetrical fluid (magnetic) information in the convective zone. In this study we use the measurement of 128, 289 magnetograms of SDO/HMI and SOHO/MDI in the 23rd and 24th solar cycle to investigate the evolution of magnetic helicity butterfly diagram. Here we show that the clear and similar symmetrical patterns of
the helicity butterfly diagram with solar cycles, which is very different with the sunspots and magnetic butterfly diagrams. It is relative continuous (discrete) in the northern (southern) hemisphere with complex mixture sign. In the southern hemisphere, there are similar helicity patterns with opposite magnetic helicity sign in the two cycles near the solar maximum. The total accumulated magnetic helicity of the two cycles is even near zero in the southern hemisphere. However, it is continuously negative and changes slowly in the 24th solar cycle in the northern hemisphere. Our research reveals the intermittence pattern of magnetic helicity restricted by the magnetic helicity conservation law with solar cycles and reflects the asymmetrical property of fluid flows in the deep of solar convective zone. Those flows may module the solar cycles and take a great challenge to the current solar dynamo theory.

**RELATIONSHIP BETWEEN STEEPNES OF THE SOLAR DIFFERENTIAL ROTATION AND ACTIVITY**

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Theoretical predictions, based on the analytical solutions of the angular momentum transport equation within the convection zone, predict that the net transport of angular momentum towards the equator is less efficient during high solar activity. In times of low solar activity the behaviour is opposite, i.e. the angular momentum is transported more efficiently towards the equator. In other words, during the minimum of magnetic activity, increased equatorial rotation leads to a larger rotation parameter A, while more pronounced differential rotation leads to a larger absolute value of parameter B. The first conclusion mentioned above, concerning parameter A, is in accordance with published experimental results, whereas the behaviour of parameter B does not coincide with the theoretical predictions. To gain more insight into these discrepancies between observations and theoretical predictions, we present preliminary results of the relationship between the solar activity and differential rotation parameter B, determined from the sunspot group position data (1964 - 2016) from the Kanzelhöhe Observatory for Solar and Environmental Research.

**EFFECT OF VISCOSITY ON PROPAGATION OF MHD WAVES IN ASTROPHYSICAL PLASMA**

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We determine the general dispersion relation for the propagation of magnetohydrodynamic (MHD) waves in an astrophysical plasma by considering the effect of viscosity with an anisotropic pressure tensor. Basic MHD equations have been derived and linearized by the method of perturbation to develop the general form of the dispersion relation equation. Our result indicates that an astrophysical plasma with an anisotropic pressure tensor is stable in the presence of viscosity and a strong magnetic field at considerable wavelength.
TEMPORAL VARIATION OF THE SOLAR MAGNETIC FIELD AND ITS SOLAR CYCLE DEPENDENCE

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Background-subtracted Solar Activity Maps (BaSAMs) are a quantitative tool to assess and visualize the temporal variation of, for example, the photospheric magnetic field. The method utilizes data of the Helioseismic and Magnetic Imager (HMI) onboard the Solar Dynamics Observatory (SDO). The availability of high-cadence synoptic full-disk data with a moderate spatial resolution of about one second of arc is a prerequisite for this method. Instead of exploring the rms-contrast of spatial data, we explore the temporal variation of the magnetic field for each pixel on the solar disk. The typical sampling interval is two hours and a "deep" magnetogram represents the background above which the variations are observed. The implementation of BaSAM thus resembles common rms-measurements but in the time domain. The disk-integrated variation of the magnetic field additionally yields an index of long-term solar activity changes for the entire Sun. Decomposition of the index for any given latitude band reveals the latitudinal dependence of solar activity. We will introduce the BaSAM method and present initial results for this new index of solar activity.

MONITORING SOLAR ACTIVITY VARIATIONS USING HIGH-RESOLUTION SUN-AS-A-STAR SPECTROSCOPIC OBSERVATIONS WITH PEPSI

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The Potsdam Echelle Polarimetric and Spectroscopic Instrument (PEPSI) is a state-of-the-art, thermally stabilized, fiber-fed, high-resolution spectrograph for the Large Binocular Telescope (LBT) at Mt. Graham, Arizona. Typically the LBT with its large light-gathering power feeds starlight to PEPSI. However, the spectrograph can also be fed with sunlight from the Solar Disk-Integrated (SDI) telescope. Synoptic solar observations with PEPSI/SDI produce daily spectra with high signal-to-noise ratio, providing access to unprecedented, quasi-continuous, long-term, disk-integrated spectra of the Sun with high spectral and temporal resolution. The observed spectra contain a multitude of photospheric and chromospheric spectral lines in the wavelength range of 380–910 nm. We develop tools to monitor and study solar activity on different time-scales ranging from daily changes, over periods related to solar rotation, to annual and decadal trends. Strong chromospheric absorption lines, like the Ca II K & H lines, are powerful diagnostic tools for solar activity studies, since they trace the variations of the solar magnetic field. Currently, we are developing a data pipeline for extraction, calibration, and analysis of the PEPSI/SDI data. Derivation of activity indices from these and other chromospheric spectral lines allows us to trace and evaluate the chromospheric magnetic field and its variability. Obtained time series will be compared to solar cycle models and activity tracers such as International Sunspot Number (SSN) and radio F10.7cm radio flux. The well established relation between solar calcium indices and UV flux variations motivates us to compare our results with total solar (spectral) irradiance data.
Thus, enabling us to study solar activity trends manifested in the solar atmosphere and its contribution to Space Weather and its impact on Earth and the near-Earth environment. We present results for the Ca II K & H lines, including details of the wavelength and flux calibration. First results from the Ca II K line activity index are discussed in the context of synoptic full-disk images and magnetograms.

ON THE PREDICTION OF THE SOLAR CYCLE

Zhanle Du, Huaning Wang

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Predicting the peak amplitude of an upcoming solar activity cycle is more difficult before the onset of the new cycle than after that time, as less information can be used. To predict the amplitude, one tends to search for a high correlation coefficient between the amplitude and another known parameter. However, we found that a high correlation coefficient does not necessarily bring out a successful result. The high correlation coefficient only means that the two parameters are well correlated at the current stage, and can not reflect the time variation characteristics in the relationship. Therefore, to obtain a reasonable prediction result, one needs also to study the variation in the correlation. Besides, a better prediction result depends more on the recent data than the very early data since the latter could destroy the rule govern the relation at the recent stage. Now, at the descending phase of solar cycle 24, employing the above knowledge, we try to perform a prediction on the next solar cycle (25).

A CONTROLLER FOR FABRE-PEROT INTERFEROMETER AT YUNNAN OBSERVATORY

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A Fabre-Perot Interferometer Controller has been developed at Yunnan Observatory, China. It is proposed to use on our New Vacuum Solar Telescope. This system is still a pure analog component. Its parallelism maintain accuracy is 1.8 nm, keep time about 4 hours, linearity is better than 2 %, dynamic range is about 100 db, and noise density is about $4.62 \times 10^{-5}$ V / Hz, or equivalent capacitance spacing changing 0.67 PM/Hz. A set of digital controllers has also been developed, but its performance is not yet ready for use.

CORONAL INTENSITY EVOLUTION FROM LONG-TERM GREEN LINE DATA

Yu Liu, Xuefei Zhang

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A coronagraph and a filter instrument attached to the Norikura Green Line Imaging System: NOGIS, which observe the intensity and Doppler shift of the coronal green line (Fe XIV 530.3 nm), had been used at the Norikura Solar Observatory (NAO) until 2009. After the closure of Norikura Solar Observatory, the coronagraph and the NOGIS instrument was
relocated to the Lijiang Station of the Yunnan Observatories of CAS in October 2013 and the observation of the solar corona has been resumed. The name should then be changed to YOGIS (Yunnan Observatory Green-line Imaging System). The YOGIS instrument can observe not only coronal plasma motions but also velocity fields. Such observations are important in researches on coronal heating, flares, coronal mass ejections and space weather. In this talk we will introduce the YOGIS instrument and discuss the continuity of coronal green-line data between Norikura and Lijiang observations, as well as the long-term evolution analysis of the coronal green line observations.

DIGITIZATION OF FULL-DISK IMAGES AT THE SOLAR OBSERVATORY EINSTEIN TOWER

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\textsuperscript{3}Astronomical Institute of the Slovak Academy of Sciences, Tatranská Lomnica, Slovak Republic

We present solar full-disk observations, which were recorded at the Einstein Tower during the years from 1943 to 1990 (solar cycles 18-22). High-school students from Potsdam and Berlin digitized more than 3000 full-disk images during two- to three-week internships at AIP. The digital images cover a 15 cm \times 15 cm region on photographic plates, which were scanned at a resolution of 7086 \times 7086 pixels. The raw data are monochromatic 8-bit images in the Tagged Image File Format (TIFF). We calibrated these images and saved them with improved photometry as 16-bit images with 2048 \times 2048 pixels in the Flexible Image Transport System (FITS) format, which contains extensive headers describing the full-disk images and the observations. The various calibration steps include, for example, accurate measurements of the solar radius, determination of the limb-darkening function, and establishing an accurate coordinate system (correction of the solar P-angle and the coelostat azimuth). The contrast-enhanced and limb-darkening corrected images will become publicly available to students and researchers. The data will be described and published within a dedicated data release of the Archives of Photographic PLates for Astronomical USE (APPLAUSE, https://www.plate-archive.org/applause/) project.

OPTIMIZATION OF SURFACE FLUX TRANSPORT MODELS FOR THE SOLAR POLAR MAGNETIC FIELD

M. Talafha and K. Petrovay

Department of Astronomy, Eötvös Loránd University, Budapest, Hungary

The importance of solar polar magnetic fields for the dynamo and for solar cycle forecasting has become increasingly clear in recent years. Polar fields are observed to be built up from active region trailing polarities by meridional flow advection and turbulent diffusion. The surface flux transport (SFT) models describing this process involve a number of free parameters and optional choices such as turbulent diffusivity, meridional flow amplitude or choice of meridional flow profile. In the past these choices were usually optimized to best reproduce the overall time-latitude pattern (butterfly diagram) of the magnetic field distribution. In this approach, mid-latitude features (plumes) are given great weight, while the smaller polar
areas, observed less well due to perspective problems, have little influence. As a result, models optimized in this way often show significant disagreements with observations of the polar field, esp. regarding the timing of polar field reversals and maxima or latitudinal extent of the polar field concentration. Here we take the alternative approach of constraining SFT model parameters and assumptions by reducing the allowed parameter space to the domain where the phase of polar field variations and the latitudinal extent of the polar magnetic cap agree with observational constraints. Results are presented for various assumed meridional flow profiles and for different measures of the polar field (e.g. WSO mean longitudinal field in the polar aperture or dipole moment). These optimizations can further be used in the study of polar field variations in SFT models involving data assimilation.

GLOBAL DIPOLE MOMENT STUDY USING OPTIMIZED SURFACE FLUX TRANSPORT MODEL

M. Talafha and K. Petrovay

Department of Astronomy, Eötvös Loránd University, Budapest, Hungary

The importance of solar polar magnetic fields for the dynamo and for solar cycle forecasting has become increasingly clear in recent years. Polar fields are observed to be built up from active region trailing polarities by meridional flow advection and turbulent diffusion. The surface flux transport (SFT) models describing this process involve a number of free parameters and optional choices such as turbulent diffusivity, meridional flow amplitude or choice of meridional flow profile. In the past these choices were usually optimized to best reproduce the overall time-latitude pattern (butterfly diagram) of the magnetic field distribution. In this approach, mid-latitude features (plumes) are given great weight, while the smaller polar areas, observed less well due to perspective problems, have little influence. As a result, models optimized in this way often show significant disagreements with observations of the polar field, esp. regarding the timing of polar field reversals and maxima or latitudinal extent of the polar field concentration.

We took the alternative approach of constraining SFT model parameters and assumptions by reducing the allowed parameter space to the domain where the phase of polar field variations and the latitudinal extent of the polar magnetic cap agree with observational constraints. One important application of the result is considering the case when initially there is only a simple bipolar region, placed in some latitude, and run the SFT model with optimized parameters for some time until a dipolar field is formed, one can get the relation between the initial and final field, which can be introduced to the global dipole moment as a further factor as a function of latitude.

PHYSICAL CHARACTERISTICS OF CYCLE 23 SUNSPOTS

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Sunspot behaviour are governed by the magnetic dynamo at action deep within the convection zone of the Sun. Therefore, understanding their physical characteristics and how they evolve in time during a solar cycle can help improve solar models. This work analyses the physical
characteristics of sunspots during the solar activity cycle 23, detected using computer vision techniques. Images in visible light and magnetograms of the MDI instrument (Michelson Doppler Imager) on board the space telescope SOHO (Solar and Heliospheric Observatory) were used to detect sunspots and to extract their characteristics. Thus the area, intensity (or temperature), magnitude of magnetic fields of sunspots were determined. Based on the sunspot data, the behaviour of these characteristics and relationships between them were verified. A total of 32,317 sunspots were analysed, with longitude between -40 and +40 deg, throughout the entire solar cycle 23, from May 1996 through April 2008. Nonlinear correlations were found regarding area and extreme magnetic field, as well as temperature and area, and finally regarding temperature and magnetic field. Moreover these correlations presented small variations over time during solar cycle 23, such that larger, cooler sunspots with stronger magnetic fields occurred more frequently during periods of maximum activity. A second component could be distinguished in the data, comprising less than 10% of the spots, with cooler and more intense magnetic fields, most likely related to spots without penumbra.

**OBLIQUE ROTATOR**

Xing Wei¹, Jeremy Goodman²

¹Shanghai Jiao Tong University, Shanghai, China  
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To understand the uniform rotation of stellar radiative zone we propose the idea of oblique rotator, i.e. a magnetic field misaligned to rotational axis. In the kinematic regime the winding-up process facilitates the energy dissipation, while in the dynamic regime the competition between rotation and magnetic field occurs such that rotation can become uniform when field is sufficiently strong (i.e. Lenert number is above unity). In addition, the non-axisymmetric version of Ferraro’s isorotation law is realised.

**EVOLUTIONARY CHARACTERISTICS OF THE INTERPLANETARY MAGNETIC FIELD INTENSITY**

Nanbin Xiang¹, Zhining Qu²

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²Department of Physics, School of Science, Sichuan University of Science and Engineering, Zigong, China

We use several mathematical methods, such as Continuous Wavelet Transform (CWT), Wavelet coherence (WTC) and Partial Wavelet Coherence (PWC), to investigate the distribution and oscillation periods of daily interplanetary magnetic field (IMF) intensity as well as the connection between IMF fluctuations and solar activity indices (Magnetic Plage Strength Index and Mount Wilson Sunspot Index). The daily IMF intensity is generally following the log-normal distribution approximately, which is directly related to distribution of active region flux. The short-term periods of IMF are about 13.7, 27.6, 37.1 and 75.3 days, which are driven by the quasi-periodicity of magnetic surges on the solar surface. The mid-term periods of 1.07 and 1.82 yr should be derived from the stochastic interaction of local fields and meridional flows, since coronal holes reflect the transport of magnetic flux on the solar surface and variations in the meridional flow are seen in the heliosphere. The 10.9-year period is the Schwabe solar cycle and it should be first mentioned. The solar cycle variation of IMF should not be related to solar weak magnetic activity but dominated by
solar strong magnetic field activity seen on the disk, because the time-varying component of interplanetary magnetic flux has foot points rooted in regions near the sources of CMEs which are related to active regions, while the constant component in IMF should initially and mainly come from the solar weak magnetic field activity. Finally, the slow variation of the IMF indicates that it may have a period of longer than 50 yr.

2. Heating and Coupling of the Solar Atmosphere layers

FORMATION, DYNAMICS, AND MAGNETIC CONFIGURATIONS OF SOLAR FILAMENTS

Peng-Fei Chen

School of Astronomy & Space Science, Nanjing University, China

Solar filaments are cold dense materials suspended in the hot tenuous corona. They are intimately associated with solar flares and coronal mass ejections, and are believed to be a key phenomenon in understanding the energy storage and release in the solar corona. Important questions include: How are they formed? How the filament barbs are formed? What is the nature of counterstreamings? How can the streamings and oscillations tell us the information of the otherwise unmeasurable coronal magnetic field? What is the magnetic configuration for each filament? How can we derive their helicity based on imaging observations only? In this review talk, I try to answer some of these questions based on the research in the past several years, for example, about 89% of the filaments in the current solar cycle are supported by flux ropes whilst about 11% are supported by sheared arcades, and about 91.6% of the solar filaments possess negative helicity in the northern hemisphere and positive helicity in the southern hemisphere.

SIMULATIONS OF PARTIALLY IONISED CHROMOSPHERE: PROGRESS AND CHALLENGES

Elena Khomenko, Manuel Collados, Nikola Vitas, Pedro Gonzalez-Morales

Instituto de Astrofisica de Canarias, c/ Via Lactea s/n, La Laguna, Tenerife, Spain

In this contribution we are interested to study the influence of partial ionization of solar plasma into the energy balance of the solar chromosphere. We will discuss our realistic 3D radiative-MHD simulations of magneto-convection that include effects from partial ionization in the single-fluid approach (ambipolar diffusion) as well as other non-ideal effects such as the Biermann battery effect and the Hall effect. It will be shown that ambipolar diffusion causes measurable effects on the amplitudes of waves excited by convection in the simulations, on the absorption of Poynting flux and heating and on the formation of chromospheric structures. Thanks to the simulations with battery-excited dynamo fields we can provide a low bond on the chromospheric temperature increase due to the ambipolar effect. The Hall effect acts into the direction of significantly increasing the Poynting flux to the upper chromospheric layers, in a rough agreement from what is expected from idealistic wave simulations.
VORTEXES IN THE LOWER SOLAR ATMOSPHERE - AUTOMATED SWIRL DETECTION ALGORITHM (ASDA)

Robertus Erdelyi, Jiajia Liu, Chris J. Nelson

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Interest in the nature of swirling motions across the solar atmosphere has recently increased considerably, as a plethora of these rather recondite features have recently been observed. Preliminary studies suggest that these swirls may play a key role in channeling energy from the photosphere into the lower solar atmosphere, up to the low corona. Motivated by the imminent commissioning of the world’s largest aperture solar telescope, DKIST, with its unprecedented resolution of the lower solar atmosphere, here, we will present our findings on swirl propagation obtained by our newly-developed Automated Swirl Detection Algorithm (ASDA). ASDA is found to be very proficient at detecting swirls in a wide variety of synthetic data with various levels of noise. Applying ASDA to photospheric Hinode Solar Optical Telescope (SOT) observations with a spatial resolution of \( \sim 40 \) km, we found a total number of \( 1.62 \times 10^5 \) swirls in the photosphere, with an average radius and rotating speed of \( \sim 290 \) km and \(< 1.0 \) km/s, respectively. Comparisons between swirls detected in numerical MHD simulations carried out by Bifrost and both in ground-based and space-borne observations have also been performed. We found that there is no clockwise and counter-clockwise rotating swirls show similar properties. About 70% of swirls are located in intergranular lanes. Moreover, applying ASDA to simultaneous photospheric and chromospheric observations provides us new and appealing evidence that ubiquitous Alfvén pulses are excited by prevalent intensity swirls in the solar photosphere. Correlation analysis between swirls detected at different heights in the solar atmosphere supported by realistic numerical simulation show that, these prevalent Alfvén pulses propagate upwards through the solar atmosphere and reach the chromospheric layers. They are, therefore, found to be able to potentially carry the energy needed to sustain the temperatures of quiet regions in the upper chromosphere.

SMALL X-RAY FLARES/BRIGHTENINGS IN ACTIVE REGIONS AND THE QUIET SUN

Iain Hannah et al.

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Observing X-rays (above a few keV) from the Sun provides a direct insight into energy release (heating and/or particle acceleration) in the solar atmosphere. Targeting the faintest X-ray emission allows the study of the smallest solar flares, and their contribution to heating the corona. Directly focusing X-rays optics can detect such weak X-rays from the Sun but at the moment no dedicated solar telescope exists to do so. Instead we use the astrophysics telescope NuSTAR and have observed the Sun over times since the start of solar pointing in Sep 2014 through to our latest observations in 2019. See http://ianan.github.io/nsovr/ for a quicklook overview of NuSTAR’s solar observations. NuSTAR has observed faint microflares from active regions as well as several fainter brightenings in the quiet Sun. The NuSTAR X-ray images of these tiny flares are related to sources seen in lower energies, such as softer X-rays with Hinode/XRT and EUV with SDO/AIA. Crucially, NuSTAR’s imaging spectroscopy allows us to obtain and fit the X-ray spectrum from these small events determining the thermal and non-thermal properties, finding emission up to 10MK, as well as other events with thermal energy down to \( 10^6 \) erg. We will present some of the latest solar observations with NuSTAR as we go through the current solar minimum.
ELLERMAN BOMBS: OBSERVATIONS AND SIMULATIONS

Jie Hong\textsuperscript{1,2}, M. D. Ding\textsuperscript{1,2}, Cheng Fang\textsuperscript{1,2}

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Ellerman bombs (EBs) are short-lived, small-scale solar activities that occur in or near active regions. In this talk, we will show recent observations and simulations of EBs. The GST/FISS and IRIS observations show clear evidence of heating in the lower atmosphere, indicated by the wing enhancement in H\textalpha, Ca II 8542 Å, and Mg II triplet lines and also by brightenings in images of the 1700 Å and 2832 Å ultraviolet continuum channels. Considering these particular features, we propose a two-cloud model to fit the observed line profiles and find a temperature increase of 600-2300 K in EBs relative to the quiet Sun. Radiative hydrodynamic simulations of EBs using both non-thermal and thermal models can generate line profiles that are similar to observations. However, in non-thermal models we find dimming in the H\textalpha line wings and continuum when the heating begins, while for the thermal models dimming occurs only in the H\textalpha line core, and with a longer lifetime. This difference in line profiles can be used to determine whether an EB is dominated by non-thermal heating or thermal heating. We will also talk about the relation of EBs and UV bursts.

HEATING DRIVEN BY THE RELEASE OF MAGNETIC TWIST IN THE SOLAR CORONA

Chris Nelson\textsuperscript{1,2}, Jiajia Liu\textsuperscript{2}, Ben Snow\textsuperscript{2}, Robertus Erdélyi\textsuperscript{2}, Mihalis Mathioudakis\textsuperscript{1}

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\end{itemize}

It is widely hypothesised that magnetic free energy stored in twisted magnetic field lines can drive significant heating in the solar corona; however, to date very few observational examples of this process exist. In this talk, we discuss recent observations sampled by the Solar Dynamics Observatory (SDO) linking the reduction of magnetic twist in an isolated magnetic flux rope (no flares occur in the local active region throughout its lifetime) with transient (~1 hour) heating to temperatures in excess of 10 MK. The reduction in twist in the system is inferred through use of a non-linear force-free magnetic field extrapolation, with the heating and subsequent cooling identified through analysis of the coronal Atmospheric Imaging Assembly (AIA) channels. Overall, our results provide evidence that the release of magnetic twist stored in the solar corona can drive heating to flaring temperatures even in quiet active regions.
HOT AND COOL STRUCTURES IN ACTIVE REGION CORES RUNNING IN PARALLEL

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Combining observations of plasma in active region cores at 1 MK and 0.1 MK we find that the loops seen at these very different temperatures are nicely aligned and run in parallel with a small spatial offset. This gives new insight into the magnetic structuring and in particular into the presence of fieldline braiding to energise these loops. For our observations we used data from the second Hi-C rocket experiment from 2018 that provided the highest resolution data ever taken of plasma at 1 MK and combined this with data from IRIS, roughly matching in spatial resolution. We compare these observations to a 3D MHD model of an active region that shows shows similar features. From this we can conclude that the cool loops are originating from the tip of the chromosphere that is found just below low-lying hot coronal loops that emerged into the upper atmosphere. The angle of the line-of-sight is critical as the hot and cool structures appear to be co-spatial or if they have a (small) spatial offset. This also shed some new light on the long-standing question of a multi-thermal versus single-temperature structure of coronal loops. The Hi-C and IRIS observations together with the 3D MHD modelling show how these cool and hot active region loops form and how they are heated through flux-tube-tectonics, a variant of fieldline braiding.

FASOT, AN INSTRUMENT TO REVEAL THE MAGNETIC COUPLING BETWEEN SOLAR PHOTOSPHERE AND CHROMOSPHERE

Zhongquan Qu, FASOT group
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The magnetic coupling among solar atmospheric layers is crucial for magnetic energy transportation and triggering the activities and variations. Therefore, an instrument is needed for tracking such a coupling. Fiber Arrayed Solar Optical Telescope (FASOT) is created for recovering simultaneously the vector magnetic fields, line-of-sight velocities and thermodynamic conditions of photospheric and chromospheric layers and thus revealing the magnetic coupling among these layers. This talk presents the preliminary observational results obtained by FASOT of the first generation, as well as the progresses made in shaping FASOT of the second generation.
BI-DIRECTIONAL PLASMA JET OBSERVED IN AN ACTIVE REGION

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A complex active region with an inversion line composed of two branches nearly East West oriented, and overlaid by two filaments undergoes the emergence of multiple magnetic bipoles. The evolution of the region is followed in SDO/AIA and SDO/HMI movies. The north filament erupts due to the emergence of an anemone of small bipoles but does not produce a coronal mass ejection. The plasma stays in a large expanded structure as it is observed in AIA 131 Å. As the emerging flux continues to expand, we see the reconnection of the emerging flux with the overlying arcades forming an elbow magnetic field line and then becoming straight as the material is ejected. IRIS Si IV and C II spectra indicate bidirectional flows of the order of 200 km/s at the reconnection point which is also slowly moving up. In the first phase the material is ejected along different parallel more or less paths which could be the legs of long loops overlying the active region or twisted /untwisted structure. The velocity of the plasma jet is about 50-60 km/s. At the top of the jet we see small enhancements of brightening suggesting some shock with the environment. The jets finally blow up the material of the filament before coming back during the second phase. In the Hα Dopplergrams from the MSDP spectrograph we see more redshift than blueshift indicating the return of the jet and filament plasma.

AN UPDATED VISION OF SOLAR SURGES

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A bewildering variety of eruptive and ejective phenomena continually take place in the solar atmosphere on a wide range of space and time scales. Even though observationally known for many decades now, among those dynamic phenomena there is one whose understanding has progressed very slowly: the surges. In this talk, we address the surge phenomenon under a threefold perspective. From the theoretical point of view, we show that surges are composed by different populations with distinct evolutionary patterns that are directly related to heating/cooling processes. Concerning observations, although surges are traditionally related to chromospheric lines, we have found that they can exhibit enhanced UV emission in transition region (TR) lines of Si IV with brighter and broader spectral profiles than
the average TR. Through forward modeling, we show that surges are strongly affected by nonequilibrium ionization effects, noticeably increasing the number of emitters of the main lines of Si IV and O IV, and that the departure from statistical equilibrium is due to the short characteristic times of the optically-thin losses and heat conduction during the surge evolution.

NEW RESULTS FROM THE DEM DIAGNOSTIC OF SOLAR CORONAL STRUCTURES

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DEM diagnostic is widely used in studies of coronal structures. It separates plasma at different temperatures within a single pixel or a given region, whose emission are integrated along the line of sight (LOS). Using the improved Sparse method (Cheung et al. 2015, Su et al. 2018), we studied the property and evolution of thermal plasma in a number of coronal phenomena, such as flares, reconnection downflows, cusps, current sheet, coronal holes, and quiet corona. In this talk, we will show the new results obtained from these ongoing works that could help us better understand plasma heating in flares, acceleration of particles, evolution of current sheet, and the plasma components in quiet corona.

PENUMBRA BRIGHTENING EVENTS AND JETS ACTIVITIES ON THE LIGHT BRIDGE OBSERVED BY GST

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In the talk, I would like to show the result from multi-wavelength observations of sub-arcsecond small-scale activities in the solar atmosphere. Penumbra brightening events, whose width is as small as 101 km, occurs two times in 20 minutes and each lasts for about 3 min. The line profiles of Hα lines are reversed during the penumbra brightening events, which is similar to the spectral profiles during solar flares. Regarding the jets activities on the light bridge, two mini jets appear upon the bright fronts of the fan shape jets visible in the AIA 171 Å and 193 Å channels, with a time interval as short as 1 minute. Two kinds of small scale convective motions are identified in the photospheric images, along with the Hα line wing enhancements. The finding of three lobes Stokes V profiles and their inversion with NICOLE code indicates that there is magnetic field lines with opposite polarities in the light bridge. From the Hα -0.8 Å images, we found ribbon like brightenings propagating along the LBs, possibly indicating slipping reconnection.
STATISTICAL ANALYSIS OF THE UV COMPACT BURSTS

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Compact bursts are frequently observed by IRIS in both NUV and FUV channels. They appear as small and intense short lifetime brightenings visible in solar active regions. Some of them can be closely connected with well-known Ellerman bombs and IRIS bombs. In this novel work we present statistical analysis of compact bursts observed in active regions with emerging flux areas, sunspots and plages. Our analysis is based on the IRIS observations in Mg II \textit{h} and \textit{k} lines in NUV band as well as in Si IV and C II transition region lines in FUV band. We used only dense and large rasters for searching of compact bursts with the size of the order of 1". We found more than 2100 compact bursts in 170 such rasters. Only brightenings with the intensity contrast greater than 2 in Mg II \textit{h} line wings at +1.0 and -3.5Å, and greater than 10 in the Mg II \textit{k} line centre were chosen for the analysis. Using Mg II \textit{h} and \textit{k} line profiles for all brightening we run statistical analysis of some parameters of the line profiles: peak separation, peak ratio, line centre intensity, contrast in characteristic profiles points, line profile asymmetries and FWHM. In addition we analysed also intensity of Mg II UV triplet and some parameters of Si IV and C II lines. This analysis allows us to categorise bursts in the way as it was done in Grubecka et al. (2015). We also searched for correlations between the emission of Mg II lines and hotter Si IV line in order to find which of events are linked with IRIS bombs (Peter et al. 2014). Finally, we analysed and defined the observing parameters of those UV bursts, which can be associated with Ellerman bombs.

FLAME-LIKE ELLERMAN BOMBS AND THEIR CONNECTION TO UV BURSTS

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Ellereman bombs (EBs) are compact transient brightenings in the H\textsc{a} wing images without obvious signals in the H\textsc{a} core images. They are generally believed to result from magnetic reconnection in the lower solar atmosphere. EBs present flame-like structures when they are observed near the solar limb. Recent observations from the Interface Region Imaging Spectrograph (IRIS) reveal another type of small-scale reconnection events in the lower atmosphere called UV bursts, and UV bursts can be heated up to more than $10^4$ K. The relationship between EBs and UV bursts is still under debate. We investigate the spatial and temporal relationship between flame-like EBs and UV bursts using joint near-limb observations between the Big Bear Solar Observatory (BBSO) and IRIS. Some EBs are connected to UV bursts, and the UV bursts have a tendency to appear at the upper parts of the flame-like EBs. The intensity variations of EBs and the corresponding UV bursts match well, though the percentages of intensity changes are different. This indicates that UV bursts and EBs may be formed at different heights during the same reconnection processes.
STRUCTURE AND DYNAMICS OF ISOLATED FEATURES IN THE SOLAR CHROMOSPHERE OBSERVED WITH ALMA: A FIRST LOOK

Juan Camilo Guevara Gomez, Shahin Jafarzadeh, Mikolaj Szydlarski, Sven Wedemeyer

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A preliminary study of isolated solar features observed with the Atacama Large Millimeter/submillimeter Array (ALMA) is presented here. Two time series of images, observed in April 2017, were analysed. The datasets were recorded in bands 3 and 6 at 2.6-3.6 mm and 1.1-1.4 mm, respectively. Tracing of both bright and dark small-scale structures in time series of images yielded information about their lifetimes, velocities, and area variations with time at the two passbands. The ALMA images have also been co-aligned with those observed with the Solar Dynamic Observatory (SDO) at various channels, that provides context by means of the large-scale structure and by providing simultaneous observations at various layers of the solar atmosphere. These facilitate a complementary analysis of the detected features.

HEATING EFFECTS FROM DRIVEN KINK AND ALFVÉN WAVES IN CORONAL LOOPS

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Recent numerical studies revealed that transverse motions of coronal loops can induce the Kelvin-Helmholtz Instability (KHI). This process could be important in coronal heating because it leads to dissipation of energy at small spatial-scale plasma interactions. Meanwhile, small amplitude decayless oscillations in coronal loops have been discovered recently in observations of SDO/AIA. We model such oscillations in coronal loops and study wave heating effects, considering a kink and Alfvén driver separately and a mixed driver at the bottom of flux tubes. Both the transverse and Alfvén oscillations can lead to the KHI. Meanwhile, the Alfvén oscillations established in loops will experience phase mixing. Both processes will generate small spatial-scale structures, which can help the dissipation of wave energy. Indeed, we observe the increase of internal energy and temperature in loop regions. The heating is more pronounced for the simulation containing the mixed kink and Alfvén driver. This means that the mixed wave modes can lead to a more efficient energy dissipation in the turbulent state of the plasma and that the KHI eddies act as an agent to dissipate energy in other wave modes. Furthermore, we also obtained forward modelling results using the FoMo code. We obtained forward models which are very similar to the observations of decayless oscillations. Due to the limited resolution of instruments, neither Alfvén modes nor the fine structures are observable. Therefore, this numerical study shows that Alfvén modes probably can co-exist with kink modes, leading to enhanced heating.
USING OBSERVATIONS OF NON-IDEAL VELOCITIES TO TEST THE HYPOTHESIS THAT RECONNECTION HEATS THE ACTIVE REGION CORONA

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Many coronal heating mechanisms have invoked magnetic reconnection in some role. Testing such a mechanism requires a method of measuring magnetic reconnection coupled with a prediction of the heat delivered by reconnection at the observed rate. We propose a heating model based on the discrepancy between the footpoint motion and the local plasma motion, so-called non-ideal motion. A novel method is proposed to measure this velocity discrepancy by combining a time sequence of 3D magnetic field with maps of photospheric velocity. This heating rate is used to predict density and temperature at points along an equilibrium loop and in turn is used to synthesize emission in EUV bands. We perform this analysis using a sequence of HMI vector magnetograms of a particular AR and compare synthesized images to observations of the same AR by SDO. We also compare differential emission measure inferred from those observations to that of the modeled corona.

A SECONDARY FAN-SPINE MAGNETIC STRUCTURE IN ACTIVE REGION 11897

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Fan-spine is a special topology in solar atmosphere and is closely related to magnetic null point, as well as circular-ribbon flares, which can provide important information for understanding the intrinsic 3D nature of solar flares. However, the fine structure within the fan has rarely been investigated. In present paper, we investigate a secondary fan-spine (SFS) structure within the fan of a larger fan-spine topology. On 2013 November 18, this large fan-spine structure was traced out owing to the partial eruption of a filament, which caused a circular-ribbon flare in NOAA Active Region 11897. The extrapolated 3D magnetic fields and squashing factor Q maps depict distinctly this fanspine topology, its surrounding quasi-separatrix layer (QSL) halo, and a smaller quasi-circular ribbon with high Q located in the center, which implies the existence of fine structure within the fan. The imaging observations, extrapolated 3D fields, and Q maps on November 17 show that there indeed exists an SFS surrounded by a QSL, which is enveloped by another QSL halo corresponding to the overlying larger dome-shaped fan. Moreover, the material flows caused by the null-point reconnection are also detected along this SFS. After checking the evolution of the underneath magnetic fields, we suggest that the continuous emergence of magnetic flux within the central parasitic region encompassed by the opposite-polarity fields results in the formation of the SFS under the large fan.
OSCILLATION AMPLITUDES AND ENERGY FLUXES OF SIMULATED DECAYLESS CORONAL KINK OSCILLATIONS FOR DRIVERS OF DIFFERENT STRENGTH

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Recent observations with the Atmospheric Imaging Assembly (AIA) instrument on the SDO spacecraft have revealed the existence of decayless coronal kink oscillations. These transverse oscillations are not connected to any external phenomena like flares or coronal mass ejections, and show significantly lower amplitudes than impulsive decaying oscillations. Numerical studies have managed to reproduce such decayless oscillations in the form of footpoint driven standing waves in coronal loops, and to treat them as a possible mechanism for wave heating of the solar corona. Our aim is to investigate the correlation between the observed amplitudes of the oscillations and the energy flux from different drivers. We perform 3D MHD simulations in single, straight, density-enhanced coronal flux tubes for different drivers. We also construct time distance maps of the emissivity for the 171 and 193 AIA channels, by forward modeling our data with the use of the FoMo code. The development of the KHI leads to mixing of plasma between the flux tube and the hot corona. Once the KHI is fully developed, the amplitudes of the decayless oscillations from the synthetic images show a very weak correlation with the driver strength. Different values are acquired from the synthetic images of each channel and from the density structure, while minor differences are observed for different tracking methods. Finally, the observed energy fluxes in different spectral lines are calculated and compared with the energy flux from the different drivers and the radiative losses in the solar corona.

DETECTED UMBRAL FLASH OSCILLATIONS IN NOAA AR12384

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We investigate umbral oscillations in NOAA AR 12384 AR utilizing H-α off band data acquired on 14 July 2015 with the Visible Imaging Spectrometer (VIS) operating at the Goode Solar Telescope (GST) in Big Bear Solar Observatory. To analyze intensity fluctuation at each individual pixel we used the wavelet analysis method and found the following: i) the darkest core of the sunspot umbrae showed the shortest oscillations (about two minutes), while the outer part of the umbrae showed much longer oscillation (about four minutes); ii) the oscillation period decreases gradually from darker to relatively less darker regions. We thus conclude that oscillations inside sunspot umbrae are strongly related to magnetic field strength.
SMALL-SCALE ACTIVITIES AND DYNAMICS IN AN EQUATORIAL CORONAL HOLE

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Solar physics research gains its fascination by the dynamical processes happening all over the Sun and its atmosphere on nearly all temporal and spatial scales. Among the lesser researched features within the solar atmosphere are coronal holes. They only started to attract a higher scientific interest in the recent years due to being the source region of the solar wind - a steady stream of particles leaving the Sun and interacting with larger and more energetic eruptions so-called CMEs. In this contribution we wish to focus on an observed coronal hole close to the Equator in which we studied small-scale highly active phenomena. Due to the coronal environment, and thus highly reduced background EUV and X-ray radiation levels, coronal holes can be used to study the smallest and least energetic phenomena within the higher solar atmosphere. The data were obtained during a joint campaign (see Poster Utz et al.) in 2017 and the features we wish to shed light upon are two microflare events within the coronal hole. One of them seems to develop a jetlike outflow phenomena while the other one behaves more like a classical micro-flare event. Detailed inspections of EIS spectra, the evolution of the magnetic flux in the region, as well as AIA data analysis will be presented to show the additional level of insights which can be gained by detailed studies of high-energetic small-scale phenomena within coronal holes. This study proves that coronal holes are quite remarkable dynamic, even though they should have a rather simple magnetic field topology.

A NOVEL APPROACH IN CONSTRUCTING MAGNETIC FLUX TUBE ATMOSPHERES

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The solar atmosphere is structured by magnetic fields, often resembling in the lower atmosphere vertical flux tubes opening with height. While these flux tubes are observed with photospheric cross-section magnetic field strengths going well beyond the kG range, in most modelling approaches field strengths of only a few hundred Gauss are used. This has to do with the problems arising in constructing strong vertically opening flux tubes while keeping magneto-static conditions for the whole atmosphere. Reaching higher field strengths while keeping magneto-static conditions in models is of utmost importance as simulations of wave transport but also the formation of spectral lines is dependent on the stratification of the atmosphere and the flux tube parameters. We will introduce here a novel new approach,
namely the introduction of static velocity fields to keep the stratified densities and energies within the flux tubes positive. Moreover, we will outline our approach and show first results and the application to the formation height of Hinode/SOT BFI filters within small-scale strong photospheric magnetic flux tubes.

**SPECTROMETER/TELESCOPE FOR IMAGING X-RAYS (STIX)**

Matej Kuhar, Säm Krucker and the STIX team

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Spectrometer/Telescope for Imaging X-rays (STIX) is a hard X-ray imager that will be launched as one of the ten instruments on-board ESA’s Solar Orbiter mission in February 2020. In this poster, we give an overview of its capabilities and the most interesting scientific topics. A special emphasis is given to its imaging system and the indirect imaging methods based on the use of Moire patterns. In that respect, STIX uses 30 pairs of almost identical/parallel fine tungsten grids with pitches ranging from 40 um to 1 mm, giving highest angular resolution of 7". Due to its much lower background rates when compared to RHESSI at lower X-ray energies around 10 keV, it will be much more sensitive in observing microflaring activity, opening a different parameter space at flare X-ray energies.

**HEATING OF THE PARTIALLY–IONIZED SOLAR CHROMOSPHERE BY 2–FLUID ACOUSTIC WAVES**

Blazej Kuźma, Kris Murawski, Darek Wójcik

*Maria Curie-Skłodowska University, Maria Curie-Skłodowska Square 5, Lublin, Poland*

We investigate the plasma heating resulted from 2–fluid acoustic waves propagating in the gravitationally stratified solar chromosphere. By means of high–resolution 1D simulations we study the behavior of driven high–frequency linear and non–linear waves that originate in the photosphere. We consider ions + electrons and neutrals as separate fluids which interact between their self via collision forces. Due to ion–neutral collisions high–frequency acoustic waves exhibit capability to deposit significant amount of energy in the solar chromosphere.
As part of a joint effort between three observatories, two in Europe and one in Asia, we present the first images of a coordinated campaign following active region NOAA 12709 on 2018 May 13. The active region was close to disk center and enclosed some pores seen in the photosphere and filamentary structures in the chromosphere. We observed the AR at the GREGOR solar telescope on Tenerife (Spain) with spectropolarimetry using the GREGOR Infrared Spectrograph (GRIS) in the He I 10830 Å spectral range. GREGOR also provided context images with the High-Resolution Fast Imager (HiFI) with two filter channels at Ca II 3968 Å and blue continuum at 4505 Å. The Lomnicky Peak Observatory (Slovakia) recorded the AR with the new Solar Chromospheric Detector (SCD) in spectroscopic mode at Hα 6562 Å. The Fuxian Solar Observatory (China) observed the AR with the New Vacuum Solar Telescope (NVST), using the Multi-Channel High Resolution Imaging System at two different channels, Hα 6562 Å and TiO-band 7058 Å. Overview images of the active region from all three telescopes will be shown and the potential of such observations are discussed.

HAZEL INVERSIONS OF GREGOR GRIS DATA FOR THE INVESTIGATION OF A STRONGLY EVOLVING PORE

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Highly spatially and spectropolarimetrically resolved data become more and more widely available due to the larger and better performing telescopes. These data are perfectly suitable for the investigation of the evolution of solar magnetic fields. However, to tell something about magnetic fields one must treat the spectropolarimetric data with some inversion tool first, which retrieves the magnetic field and sometimes other atmospheric parameters from the Stokes parameters. In this contribution we use the sophisticated Hazel code currently maintained by Andres sensio Ramos (IAC) on data obtained by the Gregor telescope’s Gris instrument. After fundamental data reduction we applied the code to an evolving pore in the
solar atmosphere. As our data covers a photospheric Silicon spectral line (Si I $\sim$ 10827) as well as chromospheric Helium spectral line (He I $\sim$ 10830) we are able to retrieve atmospheric and magnetic field parameters co-temporal from the photosphere and chromosphere. We outline here our ongoing work and first results on the evolution of the pore. Other data at hand comprise VTT observations as well as HiFi G-band and GFPI line scans.

**AN ANALYSIS OF LARGE-SCALE SOLAR STRUCTURES OBSERVED WITH ALMA**

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The radiation of the solar chromosphere can be observed in the millimeter and submillimeter wavelength range. The new ALMA radio telescope can map the solar chromosphere with high spatial, temporal, and spectral resolution at wavelengths between 0.3 mm and 8.6 mm. Formation height of the continuum radiation increases with increasing observing wavelength which enables very accurate measurements of solar chromosphere’s temperature as a function of height. The study has an observational and a modeling part. In the observational part, data reduction is performed on ALMA CSV data made publicly available. Models of various observed solar structures were developed and compared with actual ALMA observations. Radiation models are based on various VAL and FAL atmosphere models with thermal bremsstrahlung as the dominant mechanism responsible for the emission at ALMA wavelengths. Fast-scan single dish maps are used to analyze the Sun’s millimetre radiation and to identify regions of interest. The visibility of various large-scale solar features (active regions, coronal holes, prominences, and inversion magnetic lines) is checked in solar ALMA images and compared with other measurements (optical and EUV images). Preliminary results indicate that active regions appear bright, inversion magnetic lines dark, while coronal holes and prominences on disc have negligible contrast against the quiet Sun background. These results are interpreted and compared with modeling efforts.

**MAGNETIC BRIGHT POINTS: FROM SMALL-SCALE DYNAMICS OVER WAVES TO LONG-TIME EFFECTS**

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Magnetic Bright Points (MBPs) constitute an important ingredient in the zoo of solar magnetic features. They are identifiable in the solar photosphere as bright intergranular spots already in the continuum but with a much higher contrast level in special wavelength bands like the by molecular absorption lines dominated G-band. MBPs represent the photospheric cross-section of kG strong magnetic field concentrations and thus outlining strong vertical
magnetic flux tubes. The dynamics they undergo not only influence the nearby magneto-
convection but can create MHD waves of all kinds travelling into the higher solar atmosphere
leading to an energy deposition and thus heating of the upper atmosphere. Besides of these
dynamical effects and processes it is of interest to study their long time evolution as it can
tell us about cycle dependent magneto-convection changes as well as their relationship to
the global and/or local dynamo. Besides, as they are brighter than their surrounding, a
variability of them in number as well as intensity might be a crucial component of the total
solar irradiance variation (TSI). In the current talk we would like to give an overview of
these interesting topics and their relationships to MBPs.

A PROMISING MULTI OBSERVATORY CAMPAIGN IN 2017

Dominik Utz\textsuperscript{1,2}, Peter Gömöry\textsuperscript{3}, Carsten Denker\textsuperscript{4}, Horst Balthasar\textsuperscript{4}, Jose Ivan Campos Rozo\textsuperscript{1,5}, Judith Palacios\textsuperscript{6}, Kilian Krikova\textsuperscript{1}, Sergio Gonzalez Manrique\textsuperscript{3}, Christoph Kuckein\textsuperscript{4}, Meetu Verma\textsuperscript{4}, Julius Koza\textsuperscript{3}

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\end{itemize}

In 2017 our team had the chance to use the Gregor telescope with its 3 instruments (HiFi, GFPI, and GRIS) together with VTT and the Hinode as well as IRIS spacecraft in an extended roughly 2 weeks long campaign. We obtained interesting data of a coronal hole and its inside dynamics from the spacecrafts (see Krikova et al.) as well as of a highly active magnetic region following a sunspot. Within this region we covered an evolving magnetic pore (see Campos Rozo et al.). In this contribution we want to outline the principle features of the campaign, involved instruments, targets and obtained data.

GRANULATION-EXCITED WAVES IN TWO-FLUID SOLAR ATMOSPHERE

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\end{itemize}

A realistic model of the solar atmosphere that accounts for partially-ionized and weakly magnetized plasma is developed and used to study the propagation conditions for granulation-excited magnetoacoustic-gravity waves. The model allows calculating numerically variations of the cutoff period in the solar atmosphere, and reproducing the recent observational results reported by Wiśniewska et al. (2016) and Kayshap et al. (2018). Differences and similarities between the behaviour of ions and neutrals in the model are identified and explained, and their effects on the wave propagation are discussed. The obtained results are used to present a novel explanation of the origin of solar chromospheric oscillations.
UV BURSTS IN EMERGING ACTIVE REGIONS AND SUNSPOT LIGHT BRIDGES

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IRIS observations have revealed numerous intense, compact and transient brightenings at typical transition region temperatures (around 100,000 K). These so-called UV bursts are characterized by chromospheric absorption lines superimposed on the greatly broadened transition region line profiles, and are believed to result from magnetic reconnection in the lower chromosphere or even the photosphere. Since their discovery, the UV bursts have received a lot of attention as they reveal significantly new insight into the physical process of magnetic reconnection in the partially ionized lower solar atmosphere. In this talk, I will discuss about the connection of UV bursts to the well-known Ellerman bombs, their occurrence frequency at different stages of active region evolution, the associated magnetic field structures, and the accompanied electron acceleration.

THE DYNAMICS OF AR 12700 IN ITS EARLY EMERGING PHASE: TETHER-CUTTING RECONNECTION

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The emergence of active regions (ARs) leads to various dynamic activities, whose details have been rarely reported. Using high-resolution and long-lasting H\textalpha{} observations from the New Vacuum Solar Telescope, we report the dynamics of NOAA AR 12700 in its emerging phase on 26 February 2018 in detail. In this AR, constant tether-cutting reconnections between emerging fibrils and preexisting ones were detected. Driven by the flux emergence, small-scale fibrils observed in H\textalpha{} wavelength continuously emerged at the center of the AR and reconnected with the ambient preexisting fibrils, forming new longer fibrils. We investigate three scenarios of such tether-cutting reconnection in two hours. Specially, the third scenario of reconnection resulted in the formation of longer fibrils that show pronounced rotation motion. To derive the evolution of the magnetic structure during the reconnections, we perform nonlinear force-free field (NLFFF) extrapolations. The extrapolated three-dimensional magnetic fields clearly depict a set of almost potential emerging loops, two preexisting flux ropes at 03:00 UT before the second reconnection scenario, and a set of newly formed loops with less twist at 03:48 UT after the third reconnection scenario. All of these extrapolated structures are consistent with the fibrils detected in H\textalpha{} wavelength. Based on the aforementioned observations and extrapolation results, we propose that the constant tether-cutting reconnections resulted in that the magnetic twist was redistributed from preexisting flux ropes towards the newly-formed system with longer magnetic structure and weaker twist.
NEW LOOK AT THE RADIO FINE STRUCTURES WITH LOFAR AND BEAM-PLASMA INTERACTIONS IN THE SOLAR CORONA

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Solar radio bursts are a signature of accelerated electrons undergoing beam-plasma interactions with the plasma environment they travel through. Fine structures in the frequency evolution of this radio emission are believed to be related to fine structures in the electron density of the background plasma. By understanding the physics behind solar radio fine structures, we can use it as an important diagnostic tool for studying the turbulent nature of the solar corona and solar wind plasma. Whilst there is a long history of radio fine structure analysis, LOw Frequency ARray (LOFAR) has recently supplied us with radio imaging that has detailed fine spectral and temporal resolution, not available before. I will present some recent observational studies of frequency fine structures together with new theoretical studies on beam-plasma interactions that deal with fine structures. I will discuss how these studies are helping to constrain the turbulent nature of the solar corona, the kinetic evolution of the accelerated electron beams propagating out from the Sun, and posing new theoretical challenges that need to be overcome to unlock the full diagnostic potential of fine structures in solar radio emission.

OBSERVATIONAL STUDIES ON 3D MAGNETIC RECONNECTIONS IN SOLAR ERUPTIONS

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Magnetic reconnection (MR) is a basic physics process in which the opposite polarity magnetic fields approach, disconnect, and reconnect. Classical 2D MR model can not completely explain the intrinsic 3D nature and the complex evolution of eruptive flares, so several kinds of 3D MR models have been proposed. One kind of 3D model is slipping MR. MR can take place at sites where the magnetic connectivity is continuous but with a strong gradient, i.e., quasi-separatrix layers (QSLs). Other two kinds of 3D models are tether-cutting (TC) and magnetic breakout MRs. We display observational studies on different kinds of 3D MRs in solar eruptions.
DIAGNOSING THE ALFVÉN SPEED IN ASYMMETRIC FIBRILS USING SOLAR MAGNETO-SEISMOLOGY

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We present the first application of a magneto-seismology technique using asymmetric waveguides. By applying the recently developed Amplitude Ratio Method to chromospheric fibrils, we are able to diagnose the local Alfvén speed, which has previously been nearly impossible to determine given the observational difficulty to directly measure the magnetic field. The solar magneto-seismology (SMS) diagnostics is carried out by finding the boundaries of the dark fibrils using Gaussian fitting, then taking the ratio of the measured maximum amplitudes of each boundary oscillation. This amplitude ratio provides a proxy of the internal magnetic field strength of the waveguide and is exploited using a numerical inversion scheme. Five fibrils are analysed as a proof of concept. Their internal Alfvén speeds are estimated and agree well with previous studies, demonstrating the powerful diagnostic applicability of the SMS to asymmetric MHD waveguides.

DAMPING OF SLOW SURFACE SAUSAGE MODES IN PHOTOSPHERIC WAVEGUIDES

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There has been considerable interest in sausage modes in photospheric waveguides such as pores and sunspots, and slow surface sausage modes (SSSMs) have been suggested to damp sufficiently rapidly to account for chromospheric heating. Working in the framework of linear resistive magnetohydrodynamics, we examine how efficient electric resistivity and resonant absorption in the cusp continuum can be for damping SSSMs in a photospheric waveguide with equilibrium parameters compatible with recent measurements of a photospheric pore. For SSSMs with the measured wavelength, we find that the damping rate due to the cusp resonance is substantially less strong than theoretically expected with the thin-boundary approximation. The damping-time-to-period ratio $\tau/P$ we derive for standing modes, equivalent to the damping-length-to-wavelength ratio for propagating modes given the extremely weak dispersion, can reach only $\sim 180$. However, the accepted values for electric resistivity $\eta$ correspond to a regime where both the cusp resonance and resistivity play a role. The values for $\tau/P$ attained at the largest allowed $\eta$ may reach $\sim 30$. We conclude that electric resistivity can be considerably more efficient than the cusp resonance for damping SSSMs in the pore in question, and needs to be incorporated into future studies on the damping of SSSMs in photospheric waveguides in general.
OBSERVATIONS OF TURBULENT MAGNETIC RECONNECTION WITHIN A SOLAR CURRENT SHEET

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Magnetic reconnection is a fundamental physical process in various astrophysical, space, and laboratory environments. Many pieces of evidence for magnetic reconnection have been uncovered. However, its specific processes that could be fragmented and turbulent have been short of direct observational evidence. Here, we present observations of a super-hot current sheet during the SOL2017-09-10T X8.2-class solar flare that display the fragmented and turbulent nature of magnetic reconnection. As bilateral plasmas converge toward the current sheet, significant plasma heating and nonthermal motions are detected therein. Two oppositely directed outflow jets are intermittently expelled out of the fragmenting current sheet, whose intensity shows a power-law distribution in the spatial frequency domain. The intensity and velocity of the sunward outflow jets also display a power-law distribution in the temporal frequency domain. The length-to-width ratio of current sheet is estimated to be larger than the theoretical threshold and thus ensures its occurrence. The observations therefore suggest that fragmented and turbulent magnetic reconnection occurs in the long stretching current sheet.

CME-DRIVEN TYPE II SOLAR RADIO BURST WITH LOFAR AND RADIO-WAVE SCATTERING

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Shocks driven by coronal mass ejections can accelerate electrons which through the plasma emission mechanism can produce radio signatures known as Type II solar radio bursts. A characteristic of some Type II bursts is the splitting of a harmonic band into further lanes, a phenomenon known as band splitting. We present a detailed imaging and spectroscopic observation of a split-band Type II burst recorded with the LOw-Frequency ARray (LOFAR). We show, for the first time, simultaneous locations of the higher- and lower-frequency sub-band sources and find that the sources of the two sub-bands experience a separation. The effect of radio-wave scattering – the dominant process affecting radio waves – is taken into account. We find that the scattering shifts the sources farther from their true location, with the lower-frequency source displaced farther than the higher-frequency source so that the true sub-band sources of Type II bursts could be virtually co-spatial. This provides supporting evidence for band splitting models that require the emission sources of a split-band Type II to originate from nearly the same spatial location, like the model attributing the split-band emission from the upstream and downstream regions of a shock front.
MIXED PROPERTIES OF MHD WAVES IN NON-UNIFORM PLASMAS

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This talk shows that MHD waves in a non-uniform plasma have properties that clearly differ from those known for a uniform plasma of infinite extent. For the latter situation the MHD waves can be divided in two separate classes: Alfvén waves and magneto-acoustic waves. The Alfvén waves are the only waves that propagate parallel vorticity, but they are incompressible and have no parallel component of displacement (parallel refers to parallel to the magnetic field). The magneto-sonic waves have the opposite properties: they are compressible and do have a parallel component of displacement, but do not propagate parallel vorticity. In short for a uniform plasma of infinite extent there are no mixed properties. Going from a uniform plasma of infinite extent to a non-uniform plasma introduces new physics. Expressions are derived for compression and vorticity for MHD waves in a non-uniform plasma. It is shown that pure slow and fast magneto-sonic waves and pure Alfvén waves, hardly ever exist for a non-uniform plasma. It is pointed out that in a non-uniform plasma the general rule is that MHD waves propagate both parallel vorticity as in classic Alfvén waves and compression as in classic magneto-sonic waves. The strength of the mixing of the wave properties depend on position. MHD waves have different appearances in different parts of the plasma because of the inhomogeneity of the plasma. This phenomenon that the properties of an MHD wave change as the wave propagates through a non-uniform environment is most clearly at work in resonant absorption. Resonant slow/Alfvén waves occur when the MHD waves have frequencies in the slow/Alfvén continuum of the spectrum. At the resonant surface the MHD wave turns into a local resonant slow/Alfvén wave with corresponding typical dominant behaviour in parallel/ perpendicular component in displacement/ vorticity and compression. It has been shown in numerical simulations that the strong shear in the perpendicular component of displacement with large values of the parallel component of vorticity causes violent KH-instabilities in resonant Alfvén waves that accelerate the damping of the MHD waves and facilitate heating of plasma. It is anticipated that the strong shear in the parallel component of displacement with large values of the perpendicular component of vorticity causes violent KH-instabilities in resonant slow waves.

CORONAL IMPLOSIONS AND THEIR CONSEQUENCES

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The storage of magnetic "free energy" in the corona has the consequence that releases of this energy, on short time scales, will reduce the field volume. The law of conservation of energy does not specify how these implosions actually work mechanically. The consequences include flares, CMEs and coronal shock waves, oscillations in the corona and sunquakes beneath the photosphere. This picture has good observational support, which I review, trying to explain why implosions do not invariably appear. The sunquake phenomenon poses a further related but non-intuitive question: how does sufficient coronal energy and momentum get into the sub-photospheric regions? I suggest that this results from a focusing effect involving the global coronal structure and the very intense and highly sheared magnetic fields found in photospheric channels (Zirin & Wang, 1993).
It is often envisaged that dense filament material lies in the dips of magnetic field lines belonging to either a sheared arcade or a magnetic flux rope. But it is also debated which configuration correctly depicts filaments magnetic structure, due to our incapacity to measure the coronal magnetic field. In this paper, we address this issue by employing mass motions in an active-region filament to diagnose its magnetic structure. The disturbance in the filament was driven by a surge initiated at the filament’s eastern end in the NOAA active region 12685, which was observed by the 1-m New Vacuum Solar Telescope (NVST) in the H-\(\alpha\) line center and line wing (±0.4 Å). Filament material predominately exhibits two kinds of motions, namely, rotation about the spine and longitudinal oscillation along the spine. The former is evidenced by antisymmetric Doppler shifts about the spine; the latter features a dynamic barb with mass extending away from the H-\(\alpha\) spine until the transversal edge of the EUV filament channel. The longitudinal oscillation in the eastern section of the filament is distinct from that in the west, implying that the underlying field lines have different lengths and curvature radii. The composite motions of filament material suggest a double-decker host structure with mixed signs of helicity, comprising a flux rope atop a sheared-arcade system.

KINETIC PHYSICS AND ELECTRON ACCELERATION BY MAGNETIC RECONNECTION IN THE SOLAR CORONA

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There is still a controversy going on which role magnetic reconnection plays in solar flares and CME eruptions. Since the coronal plasma is collisionless, coronal reconnection is a kinetic process closely related with turbulence. Kinetic reconnection causes electron acceleration, which in turn can generate electromagnetic waves escaping the corona. We discuss recent numerical simulation results of reconnection in the solar corona and its possible remote radio-diagnostics. These results are part of an ongoing Sino-German collaboration.
INFLUENCE OF INITIAL PARAMETERS ON NUMERICAL SIMULATIONS OF CORONAL WAVES AND THEIR INTERACTION WITH CORONAL HOLES

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The interaction of coronal waves (CWs) with coronal holes (CHs) leads to various effects which depend, among other parameters, on the density inside the CH, the initial amplitude of the CW as well as the magnetic field structure and the shape of the CH. The resulting effects of this interaction can be divided into a group of, first, wave-like features, such as reflected and transmitted waves and, second, stationary features at the CH boundaries. By performing 2.5D magnetohydrodynamic simulations we will quantify the influence of the initial parameters on specific simulation results, such as the phase speed of the reflected wave and the lifetime of stationary features. Moreover, the numerical results will be compared to recent observations of CW-CH-interaction.

MUL TIPLE EUV WAVE REFLECTION FROM A CORONAL HOLE

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EUV waves are large-scale propagating disturbances in the solar corona initiated by coronal mass ejections. We investigate the multiple EUV wave reflections at a coronal hole boundary, as observed by SDO/AIA on 1 April 2017. The EUV wave originates from Active Region (AR) 12645 close to the disk center and propagates toward the south polar coronal hole with an average velocity of 430 km/s. The interaction of the EUV wave with the coronal hole, which represents a region of high Alfvén speed, is observed as a splitting into two wave components: one continues propagation inside the coronal hole with an increased velocity of 850 km/s (transmitted wave), while the other one moves back toward the AR, also with an increased velocity of 600 km/s (reflected wave). The reflected EUV wave is subsequently reflected again from the AR and propagates toward the coronal hole with an average velocity of 350 km/s, where it is reflected for the second time at the coronal hole boundary and propagates again toward the AR with a velocity of 300 km/s. These events are observed over an interval of 40 minutes. The high cadence SDO imagery allows us to study in detail the kinematics of the direct and multiple times reflected EUV wave. In addition, its multi-wavelength EUV imagery allows us to derive the plasma properties of the corona and the EUV wave pulse via Differential Emission Measure analysis. These results are used to compare the observed characteristics of the wave interaction with the coronal hole simulations.
NUMERICAL EXPERIMENTS OF VARIOUS TYPES OF DISTURBANCE TO THE LOW AND MIDDLE CORONA CAUSED BY THE SOLAR ERUPTION

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Based on the solar catastrophe model, we explore the disturbance caused by the solar eruption, especially some types of large-scale disturbance via numerical experiments. In addition to the phenomena that have been showed by previous numerical experiments, a new structure known as the plasma 'pile-up' was also seen. As the disrupting magnetic structure moves outwards, a fast-mode shock was invoked in front of it. The fast-mode shock expands sideward when propagating forward, and evolves to a crescent shape; eventually the two ends of the crescent touch the bottom boundary and cause various types of disturbance to the near region. As expected, the echo is a common feature that can be identified easily among these types of disturbance. Associating with it is a plasma 'pile-up' region, which is produced by the plasma accumulation behind the echo. This is a brand new phenomenon that has not been reported previously. Two features of the 'pile-up' region drew our attention: its height from the bottom boundary is similar to that of some EUV waves, and its velocity is about 1/3 the velocity of the fast-mode shock touch down site on the bottom boundary, which is believed to be the location of the Moreton wave front. This suggests that the 'pile-up' may be a source of the EUV wave as well. According to our numerical results, we also obtain 'observed' SDO/AIA images in different wave bands. The results show that the characteristics of the EUV waves 'observed' in different bands are indeed different, which is consistent with the true observational results regarding the EUV waves.

COHERENT EMISSION DRIVEN BY ENERGETIC RING-BEAM ELECTRONS IN THE SOLAR CORONA

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We investigate the emission properties driven by an unstable ring-beam electron distribution in a uniform magnetic field, e.g., saturations and anisotropic emissions of different wave modes as well as polarization of these emissions. With the ring-beam distribution, free energies for emission exists in both parallel ($u_{||} \cdot df/du_{||} > 0$) and perpendicular ($df/du_{\perp} > 0$) directions to the ambient magnetic field, where $f$ indicates the electron distribution function. These free energies can trigger beam instability and electron cyclotron maser (ECM) instability to enhance the emission in plasmas with respect to the normal isotropic Maxwellian plasmas. Due to the beam and ECM instabilities are kinetic processes, 2.5D particle in cell (PIC) simulations are used for this study. Contributions of these two instabilities on different wave mode emissions are studied in details. For the emission characteristics at different locations along the trajectory of the ring-beam electrons in the solar corona, emission properties dependence on the number density ratio between the ring-beam and total electrons $n_{rb}/n_t$ as well as the frequency ratio between the electron cyclotron frequency $\omega_{ce}$ and the electron plasma frequency $\omega_{pe}$ are discussed.
ENERGY RELEASE AND PLASMA ENERGIZATION IN MAGNETIC RECONNECTION OUTFLOW REGIONS DURING THE PRE-IMPULSIVE PHASE OF A SOLAR FLARE

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One of the intriguing aspects of solar flares is how efficiently they energize electrons. The energization is believed to happen as a result of magnetic reconnection in the corona. One of the most direct observational signatures of energized electrons is found at X-ray wavelengths. However, due to the relatively low coronal density and low dynamic range of current instruments, the emission of these electrons from the acceleration site itself is difficult to observe. Here we present observations of electron energization in magnetic reconnection outflows during the pre-impulsive phase of a solar flare during which two X-ray sources, one above the presumed reconnection region and one below, were observed. Imaging spectroscopy X-ray observations from RHESSI are combined with EUV images from SDO/AIA and forward-fitted simultaneously to determine the mean electron distribution function as a function of time over an energy range from 0.1 keV up to several tens of keV. The measured electron distribution spectrum is consistent with a kappa-distribution with $\kappa = 3.5 - 5.5$. The spectral evolution suggests that electrons are accelerated to progressively higher energies in the source above the reconnection region, while in the source below, the spectral evolution suggests density increase due to evaporation and heating. The main mechanisms by which energy is transported away from the source regions are conduction and free-streaming electrons. The latter dominates by more than one order of magnitude, suggesting efficient acceleration even during this early phase of the flare.

PARAMETRIC STUDY OF TORUS INSTABILITY THRESHOLD

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Utilizing the analytical model of Titov & Demomulin (1999) to set a toroidal current channel in force-free equilibrium, partially submerged under the solar photosphere to model a solar prominence, we studied the threshold of torus instability for a range of different geometries and external toroidal field strengths. Four parameters of the equilibrium have been varied: minor radius and footpoint distance of the current channel, strength of the external toroidal field, and sunspot distance. The sunspot distance determines the height profile of the external poloidal field’s decay index, thus, determines the torus-unstable height range. We found that the critical decay index at the torus instability threshold increases (corresponding to a more stable situation) when the strength of the external toroidal field or the radius of the current channel increase. For given apex height, the threshold does not depend significantly on the footpoint distance of the current channel.
KAPPA-DISTRIBUTIONS AND O III - O VI SPECTRA - EFFECTS AND DIAGNOSTIC PROPOSAL FOR SPICE

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We analysed effects of kappa-distributions on the O III - O VI line intensities observable by the SPICE instrument onboard Solar Orbiter to provide possible non-Maxwellian diagnostics. Synthetic spectra for the kappa-distributions with different kappa, electron density, and temperatures were calculated using the KAPP A package corresponding to the CHIANTI 8.0 software and database. Our calculations showed that the Oxygen line ratios observable by SPICE are generally not sensitive to the electron density and presence of the radiative field. Several combinations of lines give a possibility to diagnose the kappa-distributions.

SMALL-SCALE VARIATIONS OF THE MAGNETIC FLUX SPATIAL DISTRIBUTION IN THE QUIET SUN

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We analyzed spectro-polarimetric observations obtained onboard the Hinode satellite with SOT/SP in the FeI lines at 630 nm at a maximum and a minimum of the solar cycle. We derived the magnetic flux maps on \(10'' \times 10''\) internetwork regions at various heliocentric angles. The magnetic maps and granulation images were corrected for defocus and for the effect of the Point Spread Function by means of a Richardson-Lucy algorithm. In 2013 (solar maximum) the Fourier power spectrum of the magnetic flux distribution shows two broad maxima at 2'' and 0.8'' respectively, in 2007 the maximum at 2'' disappears. The power maximum at 0.8'' may be due to a small-scale dynamo operating at the solar surface.

THE BIRTH OF A CORONAL MASS EJECTION

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The Sun’s atmosphere is frequently disrupted by coronal mass ejections (CMEs), coupled with flares and energetic particles. In the standard picture, the coupling is explained by magnetic reconnection at a vertical current sheet connecting the flare loops and the CME, with the latter embedding a helical magnetic structure known as flux rope. As it jumps upward due to instabilities or loss of equilibrium, the flux rope stretches the overlying coronal loops so that oppositely directed field is brought together underneath, creating the current sheet. However, both the origin of flux ropes and their nascent paths toward eruption remain elusive. Here we present an observation of how a stellar-sized CME bubble evolves continuously from plasmoids, mini flux ropes that are barely resolved, within half an hour. The eruption initiates when plasmoids springing from a vertical current sheet merge into a leading plasmoid occupying the upper tip of the current sheet. Rising at increasing speed to stretch the overlying loops, this leading plasmoid then expands impulsively into the CME bubble, in tandem with hard X-ray bursts. This observation illuminates for the first time
a complete CME evolutionary path that has the capacity to accommodate a wide variety of plasma phenomena by bridging the gap between micro-scale dynamics and macro-scale activities.

**SHEAR MAGNETOHYDRODYNAMICS INSTABILITY IN THE SOLAR WIND PLASMA**

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We investigated a shear instability of the Kelvin–Helmholtz (KH) type in a plasma with temperature anisotropy under the MHD approximation. To solve the problem, a system of 16–moment MHD transport equations are used. We consider supersonic flows of two semi–infinite anisotropic and homogeneous plasma layers with different physical parameters and velocities. For the general case, i.e. when the interface between these two flows is a transition layer with a finite thickness, we derived a general linear differential equation framework for determining the eigenmodes in the system. Furthermore, we considered thoroughly the limiting case of a zero thickness transition zone (contact discontinuity). The analysis enabled applying appropriate boundary conditions to derive the dispersion equation for interface waves. The obtained equation is analyzed in detail for the case when heat fluxes are absent along the discontinuity in the background state.

**CAN RADIO TRIANGULATION HELP IN UNDERSTANDING COMPLEX SHOCK WAVE SIGNATURES?**

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Eruptive events such as Coronal mass ejections (CMEs) and flares can accelerate particles and generate shock waves which in turn are a threat to our technologies at Earth and in space. Tracking of shock waves and predicting shock arrival at the Earth has therefore been an important goal for space weather. Space based radio observations provide the unique opportunity to track shock waves in the inner heliosphere. We present study of the CMEflare event on September 27/28, 2012. The GOES C3.1 flare that originated from NOAA AR 1577 was associated with a full–halo CME (first seen in the SOHO/LASCO C2 field of view at 23:47 UT) and white light shock wave observed by all three spacecraft STEREO A, STEREO B, and SOHO. The associated radio event shows a group of type III bursts and two somewhat unusual type II bursts with significantly different starting frequencies. To understand the origin of the two shock waves we performed multi-wavelength study, and radio triangulation in which we used goniopolarimetric measurements from STEREO/WAVES.
and WIND/WAVES instruments. We also did data–driven modelling of the CME propagation using EUHFORIA cone model (EUropean Heliospheric FORcasting Information Asset) and validate the results by comparison with in–situ data. Results of this study indicate that, although temporal association between the shocks and the CME is good, the low frequency type II burst occurs significantly higher in the solar corona than the associated CME and has therefore unclear origin. In order to understand origin of the low frequency type II burst we studied preceding event at 10:20 UT (STEREO A/C OR2) on September 27, 2012. The radio triangulation study shows that the type II source positions are in the southern solar hemisphere and thus may be associated to the type II emissions in the radio event succeeding it. We therefore demonstrate the importance of radio triangulation studies in understanding relationship between the CMEs and possibly associated shock wave.

DETERMINATION OF THE TOTAL ACCELERATED ELECTRON RATE AND POWER USING SOLAR FLARE HARD X-RAY SPECTRA

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Solar flare hard X-ray spectroscopy serves as a key diagnostic of the accelerated electron spectrum. However, the standard approach using the collisional cold thick-target model poorly constrains the lower-energy part of the accelerated electron spectrum, and hence the overall energetics of the accelerated electrons are typically constrained only to within one or two orders of magnitude. Here we develop and apply a physically self-consistent warm-target approach which involves the use of both hard X-ray spectroscopy and imaging data. The approach allows an accurate determination of the electron distribution low-energy cutoff, and hence the electron acceleration rate and the contribution of accelerated electrons to the total energy released, by constraining the coronal plasma parameters. Using a solar flare observed in X-rays by the RHESSI spacecraft, we demonstrate that using the standard cold-target methodology, the low-energy cutoff (and hence the energy content in electrons) is essentially undetermined. However, the warm-target methodology can determine the low-energy electron cutoff with 7 % uncertainty at the 3-sigma level and hence permits an accurate quantitative study of the importance of accelerated electrons in solar flare energetics.

FORMATION AND MATERIAL SUPPLY OF AN ACTIVE REGION FILAMENT DRIVEN BY A SERIES OF JETS

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We present a formation process of a filament in active region NOAA 12574 during the period from 2016 August 11 to 12. Combining the observations of the Global Oscillation Network Group Hα, the Hida spectrum, and the Solar Dynamics Observatory/AIA 304 Å, the formation process of the filament is studied. It is found that cool material is ejected by a series of jets originating from the western footpoint of the filament. Simultaneously, the magnetic flux emerged from the photosphere in the vicinity of the western footpoint of the filament. These observations suggest that cool material in the low atmosphere can be directly injected into the upper atmosphere and the jets are triggered by the magnetic reconnection.
between pre-existing magnetic fields and new emerging magnetic fields. A detailed study of a jet at 18:02 UT on August 11 with GST/BBSO TiO observations revealed that some dark threads appeared in the vicinity of the western footpoint after the jet and the projection velocity of plasma along the filament axis was about 162.6 km/s. Using these observations of the Domeless Solar Telescope/Hida, we find that the injected plasma by a jet at 00:42 UT on August 12 was rotating. Therefore, we conclude that the jets not only supplied the material for the filament, but also injected the helicity into the filament simultaneously. Comparing the quantity of mass injection by the jets with the mass of the filament, we conclude that the estimated mass loading by the jets is sufficient to account for the mass in the filament.

THERMAL INSTABILITY AND PROMINENCE FINE STRUCTURE

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Thermal instabilities give rise to condensations in the solar corona, and are the most probable scenario for coronal rain and prominence formation. We revisit the original theoretical treatment done by Field (1965) in homogeneous plasmas with heat-loss effects, combined with state-of-the-art numerical simulations to verify growth rate predictions and address the long term nonlinear regime. We especially investigate interaction between multiple magneto-hydrodynamic (MHD) wavemodes and how they in turn trigger thermal mode development. The numerical MHD simulations retrieve analytically predicted growth rates for all modes, of thermal and slow or fast MHD type. In typical coronal conditions, the latter are damped due to radiative losses, but their interaction can cause slowly changing equilibrium conditions which ultimately trigger thermal mode development. To retrieve the exact growth rates from linear theory, also in the far nonlinear interaction regime, it is imperative to use the correct eigenfunction variations of the linear modes, especially in their entropy wavefunction. Our wave-wave interaction setups are relevant for coronal loop sections which are known to host slow wave modes, and hence provide a new route to explain the sudden onset of coronal condensation. Synthetic H-$\alpha$ views on the simulations for selected 3D simulations show clear trends in developing filamentary substructure, and can provide statistical quantifications of how aligned the filament threads are with the local magnetic field.

RADIO EVIDENCE ON ELECTRON ACCELERATION DURING CONFINED SOLAR FLARES: ACTIVE REGION 12192 (OCTOBER 2014)

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We study the radio emission of a series of confined solar flares in October 2014. Using sensitive observations with the MUSER Radioheliograph in China and the Nançay Radioheliograph in France, as well as complementary spectrographic observations, we show that confined flares as strong as X-class did not have significant radio counterparts from the
corona, at frequencies in the 100 MHz - 1 GHz range, whereas they produced conspicuous emission at higher frequencies. Neither did they produce any signature of electrons escaping to the interplanetary medium. This is consistent with energy release and particle acceleration in a strongly confined volume in the low solar atmosphere. However, the active region did show quasi-continuous acceleration of electrons to suprathermal energies throughout most of its disk passage, as witnessed by noise storms observed between 450 and about 200 MHz. We discuss the electron acceleration signatures with respect to the source location in the magnetic field configuration of this active region.

THE INFLUENCE OF A REALISTIC RESPONSE FUNCTION OF THE SOLAR ELECTRON AND PROTON TELESCOPE ON THE VELOCITY DISPERSION ANALYSIS

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Timing of solar energetic particles (SEPs) with respect to flare emission (e.g., hard X-ray production, type III radio bursts) and signatures of CME driven shocks (e.g., type II radio bursts) is generally a tool for identification of the particles acceleration source. Of special interest are near-relativistic electrons that are measured by the Solar Electron and Proton Telescope (SEPT) aboard the STEREO spacecraft, because it was found that the injection of near-relativistic electrons is delayed by up to 30 minutes compared to radio and X-ray emissions. Due to strong scattering as well as photon production, electrons with higher energies contribute to the flux measured in electron channels at lower energies. Here, we will present the correction method as well as the influence for a set of SEP events.

ANALYZING THE KINEMATICS OF EUV WAVES BY COMBINING SIMULATIONS AND MULTI-INSTRUMENT OBSERVATIONS

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EUV ("EIT") waves are wavelike disturbances of enhanced EUV emission that propagate away from an eruptive active region across the solar disk. We present a framework, where we treat the EUV waves as fast-mode MHD waves, study their kinematics and their connection with type II bursts. We propagate numerically a fast mode MHD wave based on the model of Uchida (Uchida 1968, 1970, 1973) and the formalism of Wang 2000 (ray tracing). To accomplish that we use a 3D MHD-based coronal model (from Predictive Science Inc.) that provides density, temperature and Alfvén speed in the undisturbed coronal medium. Next, taking advantage of the high cadence and multi-wavelength observations of SDO/AIA images, we compare the propagation of the computed wavefront with the observed wave. Finally, we use the frequency drift of the type II radio bursts to track the propagating shock wave. We compare the kinematics of the simulated wavefront, identifying the most probable wave vectors that match the best the kinematics deduced from the radio emission. We focus our attention on two eruptive events on 03/04/2017 and 12/09/2017, where EUV waves are observed respectively above the limb and on the disk. We make use of a collection of high quality and multi instrument observations (PROBA2/SWAP, STEREO/SECCHI,
The contribution presents results of analysis of the tornado-like prominence which shows swirling-like motions in the SDO/AIA imagery at EUV wavelengths, using the Hα 2D spectral imaging acquired with the Coronal Multi-channel Polarimeter for Slovakia (CoMP-S) situated at the Lomnicky Peak Observatory in Slovakia. The aim of the study is to address the question whether this structure is a real tornado (vertical column of plasma violently rotating around central axis) or we just observe illusive signatures of an apparent rotational motion, like oscillation. Our results indicate that: a) the detected Doppler shifts do not show a permanent blue/red-shift pattern along the vertical axis of the structure during the whole 45-min observing interval, b) the present variations of the Doppler shifts (±4 kms⁻¹) are not clearly correlated in general with the Hα integral line emission of the structure, c) the Doppler shift variations do not show any regular oscillatory pattern. We conclude that the Doppler shifts of this particular tornado-like structure cannot be interpreted as real cold plasma rotation around the vertical axis of the structure. However, the SDO/AIA observations show clear illusive vortical motions in this tornado-like structure. We suggest that the 'vortical illusion' (Panasenco et al., 2014) - a combination of the counter-streaming flows in the prominence threads and possible radiative transfer effects - are causing the apparent rotational motion of this tornado-like structure.

We present high-resolution observations of two kinds of dynamic behavior in a quiescent prominence using the New Vacuum Solar Telescope, i.e., Kelvin-Helmholtz instabilities (KHi)s and small-scale oscillations. The KHi{s} were identified as rapidly developed vortex-like structures with counterclockwise/clockwise rotations in the Hα red-wing images at +0.3 Å, which were produced by the strong shear-flow motions on the surface/interface of prominence plumes. Our observational results further suggest that the shear velocities (i.e., supersonic) of the mass flows are fast enough to produce the strong deformation of the boundary and overcome the restraining surface tension force. This flow-driven instability might play a significant role in the process of plasma transfer in solar prominences. The small-scale oscillations perpendicular to the prominence threads are observed in the Hα line-center images. The oscillatory periods changed non-monotonically and showed two changing patterns, in which one first decreased slowly and then started to increase, while the other grew fast at
the beginning and then started to decrease. Both of these thread oscillations with changing periods were observed to be unstable for an entire cycle, and they were local in nature. All our findings indicate that the small-scale thread oscillations could be magnetohydrodynamic waves in the solar corona.

**CORONAL CONDENSATIONS CAUSED BY MAGNETIC RECONNECTION BETWEEN CORONAL LOOPS**

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Employing Solar Dynamics Observatory (SDO)/Atmospheric Imaging Assembly (AIA) multi-wavelength images, we report the coronal condensation during the magnetic reconnection (MR) between a system of open and closed coronal loops, and the quasi-periodic fast magnetoacoustic waves propagating away from the MR region upward across the higher-lying open loops during the MR process. Higher-lying magnetically open structures, observed in AIA 171 Å images above the solar limb, move downward and interact with the lower-lying closed loops, resulting in the formation of magnetic dips in the former. An X-type structure forms at the interface. The interacting loops reconnect and disappear. Two sets of newly reconnected loops then form and recede from the MR region. Disturbances originating from the MR region propagate upward across the magnetic dip region of higher-lying loops with the mean speed and mean speed amplitude of 200 and 30 km/s, respectively. During the MR process, bright emission appears sequentially in the AIA 131 and 304 Å channels repeatedly in the magnetic dips of higher-lying open structures. This indicates the cooling and condensation process of hotter plasma from \(\sim 0.9\) MK down to \(\sim 0.6\) MK, and then to \(\sim 0.05\) MK, also supported by the light curves of the AIA 171, 131, and 304 Å channels. The mean speed of the propagating disturbances decreases from \(\sim 230\) km/s to \(\sim 150\) km/s during the coronal condensation process, and then increases to \(\sim 220\) km/s. This temporal evolution of the mean speed anti-correlates with the light curves of the AIA 131 and 304 Å channels that show the cooling and condensation process of coronal plasma. Furthermore, the propagating disturbances appear quasi-periodically with a peak period of 4 minutes. The part of higher-lying open structures supporting the condensation participate in the successive MR. Without support from underlying loops, the condensation then rains back to the solar surface along the newly reconnected loops. Our results suggest that the MR between coronal loops leads to the condensation of hotter coronal plasma and its downflows. MR thus plays an active role in the mass cycle of coronal plasma because it can initiate the catastrophic cooling and condensation. This underlines that the magnetic and thermal evolution has to be treated together and cannot be separated, even in the case of catastrophic cooling. Our results also suggest that the disturbances represent the quasi-periodic fast propagating magnetoacoustic (QFPM) waves originating from the MR between coronal loops.
FLOW INSTABILITIES IN SOLAR JETS

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Kelvin–Helmholtz instability (KHI) and Raleigh–Taylor instability (RTI) are basic physical process in fluids and magnetized plasmas. Using high-resolution data from the Interface Region Imaging Spectrograph (IRIS), we study the development of the KHI in a blowout jet. Two upward flows pass along the left boundary of the jet successively. Next, KHI develops due to a strong velocity shear (~ 204 km s\textsuperscript{-1}) between these two flows, and subsequently the smooth left boundary exhibits a sawtooth pattern, evidencing the onset of the KHI. Using the Atmospheric Imaging Assembly 304 Å images obtained from the Solar Dynamics Observatory, we observe that many vortex-like structures occur during the upstream and downstream regimes of the jets, i.e., when the jets eject upwards to the corona and fall down from the higher atmosphere. Comparing the observations with the theoretical estimation, we suggest that the vortex-like structures in the upstream regime of the jet are manifestations of the KHI, and the vortex-like structures in the downstream regime may be caused by both the RTI and KHI.

THE NATURE OF ELSASSER VARIABLES IN COMPRESSIBLE MHD

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The Elsasser variables are often used in studies of plasma turbulence, in helping differentiate between MHD waves propagating parallel or anti-parallel to the main magnetic field. While for pure Alfvén waves in an incompressible plasma the method is strictly valid, we show that in the compressible case the Elsasser variables change their nature and cannot be used to strictly separate parallel and anti-parallel propagating waves. This finding has implications for turbulence studies in inhomogeneous and compressible plasmas, such as the solar corona and solar wind.

THE LOW-FREQUENCY SOLAR CORONA IN CIRCULAR POLARIZATION

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We present spectropolarimetric imaging observations of the solar corona at low frequencies (80 - 240 MHz) using the Murchison Widefield Array (MWA). These images are the first of
their kind, and we survey the range of circular polarization (Stokes V) features detected in over 100 observing runs near solar maximum. We report a characteristic ring-like structure observed for many low-latitude coronal holes in which a central polarized component is surrounded by a ring of the opposite sense. The central component does not match the sign expected from thermal Bremsstrahlung emission, and we speculate that propagation effects or an alternative emission mechanism may be responsible. We detect around 800 compact polarized sources across our dataset with polarization fractions ranging from less than 0.5% to nearly 100%. These sources exhibit a strong positive correlation between polarization fraction and total intensity, and we interpret them as a continuum of plasma emission "noise storm" (Type I burst) sources associated with active regions. We show that the large-scale polarimetric structure at our lowest frequencies is reasonably well-correlated to the line-of-sight (LOS) magnetic field component inferred from the global potential field source surface (PFSS) model. The boundaries between opposite circular polarization signs are generally aligned to polarity inversion lines in the model at a height roughly corresponding to that of the radio limb. However, at higher frequencies, there is no straightforward agreement between the LOS magnetic field direction and polarization sign. To produce these data, we also introduce an algorithm to mitigate an instrumental artefact for which the total intensity signal contaminates the polarimetric images due to calibration errors.

PLASMOID-MEDIATED RECONNECTION IN SOLAR UV BURSTS

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UV burst are events seen in the (upper) solar atmosphere with a strong enhancement of the emission in the extreme UV for one to several minutes. These have been known under a range of names, e.g. explosive events, blinkers, or IRIS bombs, and are generally associated with reconnection. We conducted a set of numerical experiments guided by observations to better understand the nature and dynamics of these UV bursts. In the observation we found a small magnetic patch with a magnetic polarity opposite to the surrounding sunspot and pore. In our 2D reconnection experiment covering the atmosphere from the photosphere to the chromosphere we drove the system with a changing magnetic field at the bottom boundary resembling the observations. The resulting X-point above the small opposite polarity then stretches into a current sheet that gets unstable to plasmoids formation resulting in a bi-directional jet and plasmoids. With these models we can recover key observational features such as the strong intensity increase and the substructure of the light curve in time with short bursts. More importantly, these models that include the stratification of plasma from the photosphere to the corona give a natural explanation why the UV burst seem to be restricted in a temperature range around a few 0.1 MK. If the reconnection happens to deep in the atmosphere, the energy from the footpoint driving is not sufficient to get a significant thermal response of the chromosphere, and if the reconnection point would be too high, there is no sort-term storage of magnetic energy that could lead to the burst. With our numerical experiments we can provide a comprehensive understanding of UV bursts, and we can show a path how to unify these with other events such as Ellerman bombs.
THE POLYTROPIC INDEX OF CORONAL FAN LOOPS AND ITS RELATION TO THERMAL CONDUCTION

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The regular observations of slow magnetoacoustic waves in coronal fan loops have allowed us to derive several important parameters including the plasma temperature, magnetic field strength, geometry and sub-resolution structure of coronal loops, and the polytropic index. It has been shown that the polytropic index in a coronal loop is close to the isothermal value 1.0, indicating that the thermal conduction is very efficient. On contrary, recent investigations on a hot flare loop reveal a higher value of polytropic index, closer to the adiabatic value 5/3, suggesting a suppression of thermal conduction. We investigated about 35 coronal fan loops from 30 different active regions and derived polytropic indices from the observed slow wave properties. It is found that the polytropic index, indeed, increases with temperature bringing both the previous results to an agreement. The increase in polytropic index, however, does not directly translate to a suppression in thermal conduction. Using the observed damping characteristics of slow waves, we explore how the polytropic index is related to thermal conduction.

INVESTIGATION OF HEATING AND PLASMA FLOWS IN TWO CORONAL LOOPS

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In this study, we examined evolution of the magnetic at four foot–points of two warm coronal loops well observed in Atmospheric Imaging Assembly (AIA) 171 images. These loops were observed on 5 May 2016 in NOAA AR 12542 (Loop I) and 17 Dec 2015 in NOAA AR 12470 (Loop II). Both loops had their one foot–point rooted in (Loop II) or nearby (Loop I) of a sunspot, while the other one ("remote") was located in an Active Region (AR) plage area. We used Solar Dynamic Observatory (SDO) and Goode Solar Telescope (GST) data to describe the phenomenon and understand its causes. The observed activity was driven by magnetic reconnection between small–scale emerging dipoles and large–scale pre–existing fields, suggesting that the reconnection occurred in the lower chromosphere at the edge of an extended plage region, where the loops were rooted. We suggest that plasma evaporated during reconnection events gradually filled the loops and the density front was observed to propagate at the rate of 90–110 kms⁻¹. This study also indicates that at least some of the bright loops seen in SDO/AIA images rooted in sunspot umbra may be due to magnetic activity taking place at the remote (non–sunspot) foot–point.
ON THE DYNAMIC NATURE OF A QUIESCENT PROMINENCE OBSERVED BY IRIS AND MSDP SPECTROGRAPHS

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Quiescent solar prominences are generally considered to have a stable large-scale structure. However, they consist of multiple small-scale structures that are often significantly dynamic. To understand the nature of prominence plasma dynamics we use the high spatial, temporal and spectral resolution observations obtained by IRIS during a coordinated campaign with the MSDP spectrograph at the Meudon Solar Tower. Detailed analysis of the IRIS observations of Mg II lines, including the analysis of Doppler shift and line width obtained with two different methods (quantile method, Gaussian-fit method) are discussed in the frame of the dynamic nature of the structures. Large-scale coherent blue and redshift features are observed in Mg II lines and Hα exhibiting a slow evolution during 1:40 hour of observations. We explain the presence of several significantly asymmetric peaks in the observed Mg II line profiles by the presence of several prominence fine structures moving with different velocities located along the line of sight. In such a case, the decrease of the intensity of individual components of the observed spectra with the distance from the central wavelength can be explained by the Doppler dimming effect. We show that C II line profiles may be used to confirm the existence of multi-components along the line-of-sight.

NON-LTE MODELLING OF ACTIVE FILAMENTS OBSERVED IN THE Hα LINE USING THE 2D FLUX-TUBE MODEL

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We present results of the modelling of the Hα spectroscopic observations of two active filaments using our 2D non-LTE model. It is assumed in the model that filaments of such type are composed of flux-tubes located in the transition region and/or corona and relatively cool plasma can flow along these flux-tubes with various velocities. The flux-tube system is approximated in the model by a 2D horizontal slab where its finite dimensions form its cross section and the infinite dimension is parallel to the solar surface. The isothermal and isobaric slab is irradiated from the bottom and the sides and the non-LTE radiative transfer in the 2D geometry is solved using the MALI numerical technique. Assuming that flux-tubes are oriented along the magnetic field, orientation of plasma flow in the slab is defined by the azimuth and inclination angles of the magnetic field. Moreover, all unresolved plasma motions in the slab are characterized by the velocity of micro-turbulence as an additional
input parameter of the model. The first filament observed on 29 May 2017 with the IBIS interferometer located at the DST telescope was in state of activation and observations carried out one day before its eruption were modelled. Only spectroscopic observations of this filament were available, thus, only line-of-sight velocities of plasma flows were obtained from the modelling. Despite of this, the results clearly showed that the filament is not activated in the same way in its whole spine - some parts are being heated up while other stays cool but behave very dynamic (large macroscopic velocities and high micro-turbulence). The second filament was a small-scale arc filament located in the active region AR12597 observed on 28 September 2016 with the Echelle spectrograph at the VTT telescope. Simultaneously with the Hα observations the full-Stokes spectropolarimetric data in the infrared He I triplet were also obtained with the GRIS polarimeter located at the GREGOR telescope. These spectropolarimetric data provided us with the possibility of estimation of the magnetic field vector using the HAZEL inversion code. Thus, azimuth and inclination angles of the plasma-flow velocity are fixed in the model and the absolute magnitude of the velocity can be obtained. We further plan to continue the development of our model by introducing temperature and pressure variations and fine structure (a so-called multi-slab).

TOTAL MASS OF PROMINENCES ESTIMATED FROM THEIR OBSERVATIONS IN EUV, X-RAYS AND THE Hα AND CA II 8542 Å LINES

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Several prominences were observed during a coordinated campaign held in October 2012 in the Hα and Ca II 8542 Å lines by the COMP-S instrument at the Lomnický Peak Observatory (AISAS, Slovakia) equipped with the tunable Lyot filter. Complete spectral profiles of both lines in 11 wavelength points were obtained at each position at the prominence area. Full-disk observations in the soft X-rays made by the XRT instrument on-board of the Hinode satellite were also obtained during the campaign. Cotemporal full-disc EUV images recorded by the AIA instrument on-board of the SDO satellite were supplemented. Three prominences with relatively large and well pronounced absorption counterparts in the EUV images were selected. For the selected prominences values of the total mass of their hydrogen and helium plasma were estimated using the method of Schwartz et al. (2015). The method is based on two mechanisms which cause intensity decrease at a prominence - absorption and coronal emissivity deficit in the volume occupied by cool prominence plasma. As the X-ray coronal radiation at 10 Å observed by XRT is not absorbed by the hydrogen and helium plasma, it can be used to disentangle contributions of the two mechanisms to decrease of the EUV coronal radiation. Then, from measure of the radiation decrease at wavelengths below 912 Å due to absorption only at the prominence location, column density of the hydrogen and helium prominence plasma is derived. Values of the ionisation degree of hydrogen necessary for correct calculations of the column mass were obtained from the Hα and Ca II 8542 Å line profiles using simple cloud model together with catalogue of the 1D isobaric and isothermal non-LTE models of Heinzel et al. (1994). Finally, the total mass of a prominence was calculated integrating the column mass over whole prominence area. Values of total masses of the three selected prominences are compared with those estimated for other prominences in Schwartz (2015) where the Hα and Ca II line profiles obtained with a spectrograph were used instead.
SYNTHETIC EMISSIONS OF THE Fe XXI 1354 Å LINE MODULATED BY STANDING FAST SAUSAGE MODES IN FLARE LOOPS

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Inspired by recent IRIS observations, we forward model the response of Fe XXI 1354 Å line to fundamental, standing, linear fast sausage modes (FSMs) in flare loops. Starting with the fluid parameters of an FSM in a straight tube, we synthesize the line profiles by incorporating the non-equilibrium ionization (NEI) effect in the computation of the contribution function. We find that both the intensity and Doppler shift oscillate at the wave period (P). The phase difference between the two differs slightly from the expected values (90°) because of the marginal role of NEI in determining the ionic fraction of Fe XXI. The Doppler width modulations possess an asymmetric in the first and second halves of a wave period, leading to a secondary periodicity at P/2 in addition to the primary one at P. This behaviour results from the competition between the broadening due to bulk flow and that due to temperature variations. The expected signatures, with the exception of the Doppler width, are largely consistent with the IRIS measurements. The forward modeling signatures are useful to identify fundamental FSMs in flare loops from measurements of the Fe XXI 1354 Å line with instruments similar to IRIS, even though a higher cadence is required for the expected behaviour in the Doppler width to be detected.

WAVES AND INSTABILITIES IN AN INCLINED MAGNETIC FIELD

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While surface waves propagating at tangential discontinuities have been studied in great detail, few studies have looked into the nature of waves at contact discontinuities. By introducing magnetic field inclination, the frequency of waves is rendered complex, where the imaginary part describes wave attenuation, due to lateral energy leakage. Thus waves may display attenuation, without the need for damping mechanisms. We also present an investigation into the effect of magnetic field inclination on magnetic Rayleigh-Taylor instabilities at these interfaces.
PARTICLE ACCELERATION AND HEATING IN REGIONS OF MAGNETIC FLUX EMERGENCE

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Emerging magnetic flux into preexisting magnetic fields drives the formation of reconnecting magnetic fields in tens of minutes and can be the source of several dynamic solar phenomena. Numerical simulations suggest that a key element for the explosive phenomena following the formation of the large scale current sheet is its fragmentation and the formation of a strongly turbulent environment. We show that the statistical properties of the spontaneously formed fragmented electric fields are responsible for the efficient heating and acceleration of the charged particles, which form a super-hot component and a power law tail on sub-second time scales. A small fraction of the energized particles escapes the acceleration volume with a super-hot component, with temperature close to 4.5 MK, and a power law high energy tail with index close to 3. We estimate the transport coefficients from the dynamics of the charged particles inside the fragmented and fractal electric fields, and the solution of the appropriate fractional transport equation for a strongly turbulent plasma agrees with our test particle simulations. Our results confirm the observations reported for the high energy particles (Hard X-rays, Type III bursts and Solar Energetic Particles) during standard and blow up jets.

STATISTICAL PROPERTIES OF TURBULENCE NEAR SOLAR WIND MAGNETIC RECONNECTION REGION

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Turbulence can be generated by magnetic reconnection processes, and conversely, reconnection current sheets can also be produced by turbulence. How magnetic energy dissipated in these processes is an interesting topic. Here we investigate the statistical properties of turbulence near solar wind magnetic reconnection region. It is revealed that the region near solar wind magnetic reconnection center shows a multifractal scaling in the dissipation range, while the ambient solar wind turbulence reveals a monofractal dissipation process for most of the time. Further analyses suggest that this multifractal scaling effect introduced by magnetic reconnection would decay fast and mix with the surrounding turbulence as it extends out from the reconnection site. To have a better understanding to these phenomena, we again carry out numerical simulations to try to explain the involved problems.
EVOLUTION OF RELATIVE MAGNETIC HELICITY IN THE DATA-DRIVEN MHD SIMULATIONS

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For a better understanding of the dynamics of the solar corona, it is important to analyse the evolution of the helicity of the magnetic field. Since the helicity cannot be directly determined by observations, we have recently proposed a method to calculate the relative magnetic helicity in a finite volume for a given magnetic field, which however required the flux to be balanced separately on all the sides of the considered volume. We developed a scheme to obtain the vector potential in a volume without the above restriction at the boundary. We studied the dissipation and escape of relative magnetic helicity from an active region. In order to allow finite magnetic fluxes through the boundaries, a Coulomb gauge was constructed that allows for global magnetic flux balance. The property of sinusoidal function was used to obtain the vector potentials at the 12 edges of the considered rectangular volume extending above an active region. We tested and verified our method in a theoretical force-free magnetic field model. We applied our method to the magnetic field above active region NOAA 11429 obtained by a new photospheric-data-driven magnetohydrodynamics (MHD) model code GOEMHD3. We analysed the magnetic helicity evolution in the solar corona using our new method. We find that the normalized magnetic helicity is equal to -0.038 when fast magnetic reconnection is triggered. This value is comparable to the previous value (-0.029) in the MHD simulations when magnetic reconnection happened and the observed normalized magnetic helicity (-0.036) from the eruption of newly emerging active regions. We find that only 8% of the accumulated magnetic helicity is dissipated after it is injected through the bottom boundary. This is in accordance with the Woltjer conjecture. Only 2% of the magnetic helicity injected from the bottom boundary escapes through the corona. This is consistent with the observation of magnetic clouds, which could take magnetic helicity into the interplanetary space. In the case considered here, several halo coronal mass ejections (CMEs) and two X-class solar flares originate from this active region.

SOLAR MAGNETIC FIELDS FROM OBSERVATIONS

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In this talk, we would like to present the study of the vector magnetic fields in solar active regions based on the observations at Huairou Solar Observing Station in National Astronomical Observatories of China. A series of local and full disk vector magnetograms have been successfully observed at Huairou Solar Station for many years. We also compare with the observations from the solar space projects. We also would like to introduce some study on the formation of the non-potential magnetic field, magnetic helicity in the solar active regions and also the statistical analysis with solar cycles with my colleague in recent years, especially on the current helicity and its spectral distribution based on the observations of solar vector magnetograms. These analyses would be more important for understanding the basic information on the generation of magnetic fields and their transfer from the inside of the Sun.
THE INITIAL MORPHOLOGIES OF THE WAVEFRONTS OF EXTREME ULTRAVIOLET WAVES

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The morphologies of the wavefronts of extreme ultraviolet (EUV) waves can shed light on their physical nature and driving mechanism that are still strongly debated. In reality, the wavefronts always deform after interacting with ambient coronal structures during their propagation. Here, we focus on the initial wavefront morphologies of four selected EUV waves that are closely associated with jets or flux rope eruptions, using the high spatio-temporal resolution observations and different perspectives from the Solar Dynamics Observatory and the Solar-Terrestrial Relations Observatory. For the jet-driven waves, the jets originated from one end of the overlying closed loops, and the arc-shaped wavefront formed around the other far end of the expanding loops. The extrapolated field lines of the Potential Field Source Surface model show the close relationships between the jets, the wavefronts, and the overlying closed loops. For the flux-rope-driven waves, the flux ropes (sigmoids) lifted off beneath the overlying loops, and the circular wavefronts had an intimate spatio-temporal relation with the expanding loops. All the results suggest that the configuration of the overlying loops and their locations relative to the erupting cores are very important for the formation and morphology of the wavefronts, and both two jet-driven waves and two flux-rope-driven waves are likely triggered by the sudden expansion of the overlying closed loops. We also propose that the wavefront of EUV wave is possibly integrated by a chain of wave components triggered by a series of separated expanding loops.

MHD WAVES IN ASYMMETRIC WAVEGUIDES: BUILDING THEORY AND PREPARING HIGH-RESOLUTION APPLICATIONS

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The theory of magneto-acoustic waves propagating in a homogeneous magnetic slab is further developed, by enclosing it in an asymmetric magnetic environment. The new, mixed character quasi-sausage and quasi-kink eigenmodes are explored. Finally, analytical and numerical solutions for the dispersion relation are provided for parameter sets representative of observable solar waveguides (such as prominences).
4. Manifestations and Triggering of Solar Flares and Coronal Mass Ejections

MANIFESTATIONS AND TRIGGERING OF CORONAL MASS EJECTIONS AS OBSERVED IN THE EUV-UV EMISSIONS

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The availability of high-cadence and high-resolution images acquired from space in different EUV ranges from different past missions (e.g. Yohkoh, TRACE, SOHO, PROBA-2, Hinode, SDO, IRIS, etc.), in combination with other space- and ground-based data, provided a new view for the triggering and early evolution of Coronal Mass Ejections (CMEs). Many new information have been recently derived for instance on the early formation of CME flux ropes, of CME fronts and CME-driven shocks, and their relationships with other phenomena (e.g. EUV waves, post-CME current sheets, type-II bursts, SEP acceleration, etc...). Moreover, the availability of multi-view point observations allowed for the first time 3D reconstructions of many solar eruptions. Higher up in the extended corona, the early evolution of CMEs has been studied not only in the visible light, but also in the UV emission over more than 15 years (1996-2012) thanks to the UVCS (UV Coronagraph Spectrometer) instrument onboard SOHO. The UVCS captured the transit of hundreds of small- and large-scale solar eruptions (CMEs, jets, prominences). These observations (combined with data acquired by other instruments) allowed to characterize the early evolution of plasma embedded in solar eruptions, and to derive different plasma temperatures, elemental abundances, non-thermal broadenings, etc. in CME plasmas, information that cannot be derived with classical visible light coronagraphs. The next generation of multi-channel coronagraphs (such as Metis onboard Solar Orbiter or LST on-board ASO-S) will observe at the same time and same locations the Visible Light and the UV HI Lyman-α extended corona. These data will really provide a new view not only of solar eruptions, but also of the ambient solar wind in their early acceleration region. Future prospects will be summarized here.

ORIGIN AND EARLY EVOLUTION OF CORONAL MASS EJECTIONS

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Coronal mass ejections (CMEs) and flares are the large-scale and most energetic eruptive phenomena in the solar system and may lead to serious space weather effects. To estimate and even predict the possibility of CMEs/flares, much attention was paid to investigate their origin and early evolution in the past decades. In this review talk, I will begin with various observational manifestations of magnetic flux rope, which is believed to be a fundamental structure resulting in CMEs/flares. Then, I will discuss the initiation and early evolution of magnetic flux rope toward a CME/flare.
MULTI-WAVELENGTH OBSERVATIONS OF SOLAR FLARES

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The conversion of magnetic energy stored in the coronal magnetic field into the kinetic energy of thermal and non-thermal particle energy, mass motion, and radiation, remains a central question in solar flare physics. Progress is made only by piecing together observations from across the entire electromagnetic spectrum. The gamma-ray, hard X-ray, and radio ranges provide rather direct information about flare-accelerated non-thermal particles and their origin. The soft X-ray, EUV, UV, optical, IR and mm ranges tend to give information on the evolving plasma and magnetic conditions as the energy conversion and transport take place, and the heating and dynamics of the flaring atmospheres that result. This (necessarily selective) talk will review some recent observations that help constrain the heating, dynamics and ionisation of the flare atmosphere, the development of turbulence and its link to flare heating and particle acceleration, and the evolving magnetic environment in which this takes place.

SOLAR FLARE SIMULATION AND OBSERVATIONS: A SPATIOTEMPORAL ANALYSIS OF THE MAGNETIC FIELD, ELECTRIC CURRENT DENSITY AND LORENTZ FORCE

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We discuss dependencies of magnetic field, electric current density and Lorentz force in erupting flare. In addition, we focus on different methods of Lorentz force calculation. The high-spatiotemporal resolution of the 3D simulation outputs allows us a detailed study of the morphology, evolution, and dynamics, giving us a new view of processes occur in the solar flares. We compare our results of the 3D simulation with observational studies. We find that the contraction of the inflow of the magnetic fields is determined by the currents and Lorentz forces. Additionally, we show that the surface integral coming from the volume integral of the Maxwell stress tensor, as usually used in observational data analysis as the proxy of the Lorentz force, present a different behaviour than the Lorentz force itself. The Lorentz force characterises more complicated morphology than mentioned integrand. Moreover, based on the analysis of the induction equation in the simulation, we unveil that the increase of the horizontal magnetic filed around active region PILs during eruptions is solely and exclusively result of the flare reconnection-driven contraction of flare loops. Using our simulation and observations of several flares, we found clear decrease of $J_z$ at the footpoints of the flux rope. These findings can be important in flare diagnostic.
MAGNETIC FLUX ROPE ERUPTION SIMULATED BY A DATA-DRIVEN MAGNETOHYDRODYNAMIC MODEL

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The combination of magnetohydrodynamic (MHD) simulation and multi-wavelength observations is an effective way to study mechanisms of magnetic flux rope eruption. We develop a data-driven MHD model using the zero-beta approximation. The initial condition is provided by nonlinear force-free field derived by the magneto-frictional method based on vector magnetic field observed by the Helioseismic and Magnetic Imager (HMI) aboard the Solar Dynamics Observatory (SDO). The bottom boundary uses observed time series of the vector magnetic field and the vector velocity derived by the Differential Affine Velocity Estimator for Vector Magnetograms (DAVE4VM). We apply the data-driven model to active region 11123 observed from 06:00 UT on 2011 November 11 to about 2 hours later. The evolution of the magnetic field topology coincides with the flare ribbons observed in the 304 and 1600 Angstrom wavebands by the Atmospheric Imaging Assembly. The morphology, propagation path, and propagation range of the flux rope are comparable with the observations in 304 Angstrom. We also find that a data-constrained boundary condition, where the bottom boundary is fixed to the initial values, reproduces a similar simulation result. This model can reproduce the evolution of a magnetic flux rope in its dynamic eruptive phase.

DATA-DRIVEN MHD SIMULATIONS OF SOLAR ERUPTIONS

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Although it is well recognized that solar flares/eruptions are driven by magnetic field of the Sun, why and how these phenomena occur are still open questions. Over the past forty years a variety of models have been proposed to explain the initiation mechanism of solar eruptions. Some researchers emphasize the importance of ideal magnetohydrodynamic (MHD) instabilities, in which, a magnetic flux rope emerges from the convection zone and is launched into the corona due to its kink or torus instability. Others stress the primary role of magnetic reconnection, and believe that without magnetic reconnection eruption can never happen even if the magnetic energy is excessively supplied. All these models are, however, idealized or hypothetical simplification of the realistic case that is much more complex and elusive in observation. In this presentation, we will show how the solar eruptions originate and develop in an unprecedentedly realistic way by using full MHD modeling driven directly by magnetic field data from observation without any kind of artificial configuration or constraint. We demonstrate that our model can reproduce the magnetic field and its evolution in an excellent agreement with the state-of-the-art EUV observation following the timeline from a long-duration quasi-static evolution (over days) to the fast eruption (in minutes), which is a typical evolution pattern of solar eruptions from its origin to onset. Our studied events represent a wide range of flares from the minor C-class to major X-class and include both the confined and eruptive ones, either typical two-ribbon flares or atypical ones such
as circular-ribbon and X-shaped flares. We conclude that magnetic flux emergence and the resulted photospheric shearing motions play a primary role in leading to the solar eruptions and their triggers can either be magnetic reconnection or MHD instability, and how the solar eruptions occur, once being triggered, can be predicted by following evolution of the unstable pre-eruptive magnetic configuration.

CME-CME INTERACTION NEAR THE EARTH

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In coronagraph images, it is often observed that two successive CMEs merge into one another and form complex structures. This phenomenon, so called CME cannibalism caused by the differences in ejecting times and propagating velocities, can significantly degrade forecast capability of space weather. This phenomenon can occur anywhere in the interplanetary space as well as near the Sun. Regarding this, we attempt to analyze the cases expecting to merge around 1 AU based on CME arrival times. For this, we select 13 CME-CME pairs detected by ACE, Wind and/or STEREO-A/B. Among them, 5 pairs clearly show magnetic holes between two respective shock structures, which mean before the merging. The other events show only one shock structure. Based on detailed investigation for each pair and statistical analysis for all events, we can get clues for following questions: 1) How does the solar wind structure change when they are merging? 2) Are there any systematic characteristics of merging processes according to the CME properties? 3) Is the merging process associated with the occurrence of energetic storm particles? 4) What causes errors in calculating CME arrival times? Our results and discussions can be helpful to understand energetic phenomena not only close to the Sun but also near the Earth.

FLUX ROPE FORMATION BY A CONFINED SOLAR FLARE PRECEDING A CORONAL MASS EJECTION

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Two categories of onset mechanism for solar eruptions (coronal mass ejections [CMEs], filament or prominence eruptions, and flares) are currently being debated. Ideal MHD mechanisms suggest the instability of a magnetic flux rope, thus, must assume that a flux rope exists at eruption onset. Reconnection mechanisms assume that a (not yet verified) mechanism of self-amplifying magnetic reconnection commences in a sheared magnetic arcade, triggering and driving the eruption and forming a flux rope as a result. Here we analyze an eruption event which strongly indicates that a magnetic flux rope was formed prior to a major CME by a preceding confined flare (i.e. a flare not associated with a CME). We also present evidence that such flux-rope-forming precursor flares often occur prior to CMEs, which lends support to the ideal MHD mechanism for solar eruptions.
MULTIWAVELENGTH STEREOSCOPIC OBSERVATION OF
THE MAY 1, 2013 SOLAR FLARE AND CME

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A M7.1 solar flare accompanied by a (≈ 400 km/s) CME was observed by multiple instruments on May 1, 2013. From Earth’s perspective, the flare was highly occulted (≈ 30°) behind the west limb. X-ray observatories RHESSI and GOES, along with SDO’s AIA and the Nobeyama Radioheliograph observed emissions 110 Mm above the flare site. STEREO’s twin spacecraft observed the event directly (B) or also as occulted (A). The Gamma Ray Spectrometer aboard Mars Odyssey provided an additional direct view of high energy (100-2000 keV) particles emitted in the chromosphere. This diverse suite of instrumentation and the unique observing geometry made this event a rare opportunity to study properties of plasma displaced into the corona by a solar eruption. RHESSI images showed a transient hard X-ray source and a larger, more persistent soft X-ray source that expanded as it moved away from the solar limb. Fitting the spectrum of coronal emission at the flare peak revealed a moderate temperature of 12 MK, with a power-law index of 3.8, which indicated a strong non-thermal contribution to the emission. The full-flare view of GRS measured a spectral index of 2.31 at the flare peak, with photon fluxes ≈ 103 times greater than from the coronal source. Coronal HXR sources are often interpreted as the result of non-thermal particles trapped in hot loops. However, radio observations at 17 and 34 GHz corresponded almost perfectly with AIA 304 Å, implying that the majority of the mass in the eruption was cool (thermal around 10-11 MK). Despite the moderate size of the flare, we found that it shared characteristics with previous observations of very large events. Notably, the ratio of the chromospheric to coronal HXR counts and spectral index difference were similar to those observed in X-class flares. The presence of an extended HXR source far above the flare loops, which were not even visible due to occultation, was also remarkable. This study suggests that such properties might be common to flares regardless of magnitude, and highlights the need for X-ray instrumentation that can provide a statistical sample of stereoscopic observations.

TWO CATEGORIES OF CONFINED FLARES

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We carry out a statistical analysis of 18 confined flares larger than M5.0 class during 2011-2017 based on the flare dynamics and extrapolated coronal magnetic fields, and first classify the confined flares into two types according to their different physical mechanisms. In "Type I" confined flares, multiple slipping magnetic reconnections occur in a complex magnetic configuration along two or more QSLs overlying the flux ropes, and the entire magnetic system involved in the flare still remains stabilized. "Type II" has the magnetic configuration consistent with the standard flare model, but strong strapping fields or strong magnetic connectivity gradients are present over the flaring region in the high atmosphere.
SPECTROSCOPIC DIAGNOSTICS OF CHROMOSPHERIC EVAPORATION USING IRIS AND HINODE/EIS

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Chromospheric evaporation refers to drastic mass motions in flaring loops as a result of rapid energy deposition in the chromosphere. It can be diagnosed by Doppler shift measurements in spectral lines: the evaporated (upward) mass motions generate blueshifts usually in warm and hot lines, and downward mass motions (or chromospheric condensation) produce redshifts in relatively cool lines. Blueshifts/redshifts caused by evaporation/condensation have been observed in the UV and EUV lines from IRIS and EIS. Worthy of mentioning results include dominant blueshifts in the hot Fe XXI line from IRIS (Li et al. 2015), which bridges the gap between EIS observations and theoretical models, both evaporation and condensation signatures in the transition region Si IV line (Li et al. 2019, in preparation), and different shapes of line profiles corresponding to different heating mechanisms (Li et al. 2017, 2019 in preparation), etc. Combining the IRIS and EIS spectroscopic observations can greatly help diagnose the chromospheric evaporation process. I will present the main results of chromospheric evaporation from these two instruments and also discuss some implications on heating mechanisms in solar flares.

TWO HOMOLOGOUS HALO CMES OF A FLOWER-LIKE MORPHOLOGY

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We present first results on the study of two homologous CME flare events. The events were originating on the far side of the Sun as seen from the Earth, and observed by the coronagraphs onboard SOHO, STEREO A, and STEREO B. They originated from the same complex active region numbered as NOAA AR 1574 when it was on the visible side of the solar disc. The particularity of the studied events is their flower-like morphology with three clearly distinguishable petals, as seen by the SOHO/LASCO C2 and SOHO/LASCO C3 coronagraphs. The first halo CME was first seen in the SOHO/LASCO C2 field of view at 10:36 UT (and at 10:25 UT in the STEREO A/COR 1 field of view) on September 28, 2012. The plane-of-the-sky projected CME speed was about 770 km/s. The peak of the associated flare was observed at 10:15 UT (STEREO A, 195 Å images). The second, somewhat weaker flower-shaped halo CME was first observed by the SOHO/LASCO C2 coronagraphs at 00:12 UT on September 29, 2012 (and at 23:55 UT on September 28, in the STEREO A/COR 1 field of view) and had speed of about 750 km/s. The peak of the associated flare was at about 00:05 UT, as observed in the STEREO A, 195 Å images. Both CMEs have associated EIT waves, in particularly well defined for the first event, and also white light shock waves quite clearly observed along the petals. The first event was also associated with intense type III radio bursts and a multiple lane type II burst observed by all three Waves instruments (onboard of WIND and STEREO spacecraft). The second, weaker event was associated with a few type III radio bursts and a weak type II burst observed only by STEREO B. The STEREO B COR 1 observations show pancaking/flattening of the CME front, in particular for the first CME, at unusually low heights. We focus the study on the low coronal signatures of the CMEs trying to understand the reason for the peculiar morphology of the two CMEs.
GENERALISATION OF THE MAGNETIC FIELD CONFIGURATION OF TYPICAL AND ATYPICAL CONFINED FLARES

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A typical flares cannot be naturally explained with standard models. To predict such flares, we need to define their physical characteristics, in particular, their magnetic environment, and identify pairs of reconnected loops. Here, we present in detail a case–study of a confined flare preceded by flux cancellation that leads to the formation of a filament. The slow rise of the non–eruptive filament favours the growth and reconnection of overlying loops. The flare is only of C5.0 class but it is a long duration event. The reason is that it is comprised of three successive stages of reconnection. A non–linear force–free field extrapolation and a magnetic topology analysis allow us to identify the loops involved in the reconnection process and build a reliable scenario for this atypical confined flare. The main result is that a curved magnetic polarity inversion line in active regions is a key ingredient for producing such atypical flares. A comparison with previous extrapolations for typical and atypical confined flares leads us to propose a cartoon for generalizing the concept.

INITIATION AND EVOLUTION OF THE X9.3 SOLAR FLARE ON 2017 SEP 6

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Two X-class flares occurred within three hours in NOAA AR 12673 with a quadripolar configuration on 2017 September 6. The first X2.2 class flare is confined, while the second X9.3 class flare is eruptive with an associated CME. We focus the initiation and evolution process of the later eruptive flare. After the first confined flare, a break-out type reconnection appears and lasts for about 2 hours until the eruptive flare onset. As evidenced by the SDO/AIA observations, the reconnection occurs between two sheared arcades and results in a large-scale hot structure above the X-point and below which lies a small cusp-shape arcade. This reconnection is in general very mild, and peaks two times with significant brightenings, which is corresponding to the two flare precursors. The impulsive phase of the eruptive flare begins with the eruption of the underlying hot channel, which pushes the overlying large-scale hot structure outwards quickly. The eruption happens in three stages, i.e., it starts with the eastward eruption of an overlying cold structure, followed by the eruption of the hot structure towards the south, and the northern hot structure erupted towards the west finally. We aim to understand the initiation and dynamics of the eruptions with detailed observational analysis and magnetic field modeling.
FORMATION OF A KILOGAUSS MAGNETIC FLUX ROPE PRIOR TO AN X9-CLASS FLARE

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A magnetic flux rope (MFR) is a coherent, volumetric current channel with helical field wrapping around its central axis. The twisted field structure can store a large amount of magnetic free energy, and is at the center of many solar eruption models. Here we report on an extended strong-field "bald patch" (BP) magnetic topology in AR 12673 prior to an X9-class flare and a modeled kilogauss, low-lying MFR with a twist over 2 turns. Over one day, we observe co-spatial fast photospheric down flow and converging flow, smooth azimuth rotation, decrease of horizontal field, and increase of the vertical field gradient near the local polarity inversion line. We discuss how flux cancellation may unite these observations and its role in forming the kilogauss MFR.

HIGH-RESOLUTION X-RAY SPECTRA AROUND S XV AND SI XIII TRIPLETS AS OBSERVED BY DIOGENESS FLAT CRYSTAL SPECTROMETER

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We present for the first time fully reduced spectra obtained using Polish flat scanning Bragg spectrometer Diogeness placed aboard CORONAS-F Russian solar observatory. The instrument operated during a period of high solar activity in 2001. In particular the spectra obtained in the vicinity of He-like ions of Si XII and S XV will be demonstrated. Besides the strong triplet lines of resonance, intercombination and forbidden transition, multiple dielectronic satellite lines are observed, some of them identified for the first time in astrophysical spectra. We will discuss their relative and absolute intensities that are dependent on abundances of parent elements and ions. Different patterns of spectra of Si and S ions will be shown and discussed in terms of changing plasma differential emission measure during the large X5.3 class flare on 25 August 2001. Observed changes will provide insight into the overall flare energetics in the soft and harder X-ray ranged (including earlier studied Diogeness Ca XIX spectra) and taking into account auxiliary soft and EUV imaging as observed by Yohkoh.
QUANTIFYING THE TOROIDAL FLUX OF A PRE-EXISTING
FLUX ROPE IN CORONAL MASS EJECTIONS

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Coronal mass ejections (CMEs) are the largest-scale eruptions in the solar system and may
impact on the safety of high-tech activities in outer space. In past decades, much progress on
the origin and evolution of CMEs has been achieved. However, the question of determining
the flux of a pre-existing flux rope in a CME is still unanswered. In this work, based on
a quasi-2D reconnection model, we propose a method to estimate the toroidal flux of a
pre-existing flux rope by measuring the reconnection flux and geometric parameters of flare
ribbons, as well as the toroidal flux of magnetic clouds near the Earth. We then apply the
method to four CME/flare events and find that the ratio of toroidal flux in the pre-existing
flux rope to that of the associated magnetic cloud lies in the range of 0.40–0.88. Thus, for
these events the pre-existing flux rope has a contribution to the CME flux that is usually as
least as large as the flux arising from the flare reconnection process.

THE ERUPTION OF A SMALL-SCALE EMERGING FLUX
ROPE AS THE DRIVER OF AN M-CLASS FLARE AND OF A
CORONAL MASS EJECTION

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Solar flares and coronal mass ejections are the most powerful explosions in the Sun. They
are major sources of potentially destructive space weather conditions. However, the possible
causes of their initiation remain controversial. Using high-resolution data observed by the
New Solar Telescope of Big Bear Solar Observatory, supplemented by Solar Dynamics Ob-
servatory observations, we present unusual observations of a small-scale emerging flux rope
near a large sunspot, whose eruption produced an M-class flare and a coronal mass ejection.
The presence of the small-scale flux rope was indicated by static nonlinear force-free field
extrapolation as well as data-driven magnetohydrodynamics modeling of the dynamic evolu-
tion of the coronal three-dimensional magnetic field. During the emergence of the flux rope,
rotation of satellite sunspots at the footpoints of the flux rope was observed. Meanwhile,
the Lorentz force, magnetic energy, vertical current, and transverse fields were increasing
during this phase. The free energy from the magnetic flux emergence and twisting magnetic
fields is sufficient to power the M-class flare. These observations present, for the first time,
the complete process, from the emergence of the small-scale flux rope, to the production of
solar eruptions.
SOLAR ERUPTIVE EVENTS WITH MUSER OBSERVATIONS

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The solar radio bursts are strongly related to the solar activities including flares and coronal mass ejections (CME), which are primary driving sources for solar-terrestrial disturbances or space weather. 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 studying solar flares and CMEs. Here we introduce some eruptive events observed with MUSER. The future plans to extend MUSER will also be introduced.

INTERFEROMETRIC OBSERVATION OF THREE CONSECUTIVE TYPE II RADIO BURSTS OBSERVED WITH LOFAR

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In this work, we present a series of three consecutive type II radio bursts observed with the interferometric mode of LOFAR. Using core and remote station a spatial resolution of 15 arcseconds was achieved. The detailed propagation of the radio bursts and the study of the related fine structures such as band splitting will be presented. The presentation includes a discussion of the new observing modes and capabilities of LOFAR for solar observations and a detailed comparison of LOFAR imaging with the Nancay Radio heliograph.

MASS MOTION IN A PROMINENCE BUBBLE REVEALING A KINKED FLUX-ROPE CONFIGURATION

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Quiescent filaments are observed to have a lifetime of up to a few days. In view of observed continuous mass draining, driven by the gravitational pull, one or more efficient mechanisms for mass loading to the prominence must be at play. Although the prominence bubbles observed at the chromospheric height (often seen in the form of a cavity) are known to be active locations for the formation of 'plumes' which carry the prominence material upward, their formation mechanism and magnetic field structure is not well known. We investigate the dynamical activities of the material inside a bubble, observed in the Hα line center
and in ±0.4 Å wings by the 1-m NVST telescope, observed just above the spicule height in prominence, which was located at the N-W limb of the Sun on October 20, 2017. The red and blue-wing images exhibited a distinctive trend of mass motions within the cavity. Further investigations by synthesizing the mass flow map, derived using the NAVE procedure, along with the Doppler map, revealed the signature of a circular motion of the material inside the cavity; comprised of the blue-shifted material (towards the observer) to be exhibiting prevalent upward motion, while the red-shifted mass to be exhibiting a downward motion. This led us to infer that the magnetic field structure within the prominence bubble conforms well with a kinked flux-rope morphology. Further, in view of no discernible signature of the brightening inside the cavity in the SDO/AIA EUV images, we further propose that the prominence bubble is the site of emerging flux rope.

A SURVEY OF CHANGES IN MAGNETIC HELICITY FLUX ON THE PHOTOSPHERE DURING RELATIVELY LOW-CLASS FLARES

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Using the 135 s cadence of the photospheric vector data provided by the Helioseismic and Magnetic Imager telescope on-board the Solar Dynamic Observatory, we examined the time evolution of magnetic helicity fluxes across the photosphere during 16 flares with the energy class lower than M5.0. During the flare, in four out of 16 events, we found impulsive changes in the helicity fluxes. This indicates that even the flare with less energy could be associated with anomalous transportation of the magnetic helicity across the photosphere. Accompanying the impulsive helicity fluxes, the pointing fluxes across the photosphere evolved from positive to negative. As such, the transportations of magnetic energy across the photosphere were toward the solar interior during these flares. In each of the four events, the impulsive change in the helicity flux was always mainly contributed by an abrupt change in the horizontal velocity field on a sunspot located near the flaring polarity inversion line. The velocity field on each sunspot shows either an obvious vortex pattern or a shearing pattern relative to the magnetic polarity, which tended to relax the magnetic twist or shear in the corona. During these flares, an abrupt change in the Lorentz force acting on these sunspots was found. The rotational motions and shearing motions of these sunspots always had the same directions with the resultant Lorentz forces. These results support the view that the impulsive helicity transportation during the flare could be driven by the change in the Lorentz force applied on the photosphere.

A FOKKER-PLANCK FRAMEWORK FOR STUDYING THE DIFFUSION OF RADIO BURST WAVES IN THE SOLAR CORONA

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Scattering of electromagnetic waves off density inhomogeneities in the solar corona is an important process in determining both the source size and the time profile of radio bursts observed at 1 AU. Here we model the scattering process using a Fokker-Planck equation and apply this formalism to several regimes of interest. In the first regime the density fluctuations...
are considered quasi-static; in this case diffusion in wavevector space is dominated by angular diffusion on the surface of a constant energy sphere. In the small-angle ("pencil beam") approximation, this diffusion further occurs over a small solid angle in wavevector space, resulting in both angular broadening and propagation delays relative to unscattered photons. The second regime corresponds to a much later time, by which scattering has rendered the photon distribution near isotropic; further scattering now results in a spatial diffusion of the radiation. The third regime involves time-dependent fluctuations which result in Fermi acceleration of photons. Combined, these results provide a comprehensive theoretical framework within which to understand several important features of propagation of radio burst waves in the solar corona: emitted photons are accelerated in a relatively small inner region and then diffuse outwards to larger distances. En route, angular diffusion results both in source sizes which are substantially larger than the intrinsic source, and in observed intensity-versus-time profiles that are asymmetric, with a sharp rise and an exponential decay. Both of these features are consistent with observations of solar radio bursts.

INVESTIGATIONS OF SUPRA-ARCADE FAN AND TERMINATION SHOCK ABOVE THE TOP OF THE FLARE LOOP SYSTEM OF THE 2017 SEPTEMBER 10 EVENT

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On 2017 September 10, a major eruption on the west solar limb produced a class X-8.2 flare and a superfast coronal mass ejection (CME). During the eruptive process, the geometric topology of the disrupting magnetic configuration presented a clear flare-current sheet (CS)-CME structure. Analyzing the images and spectral data from the Solar Dynamics Observatory/Atmospheric Imaging Assembly (SDO/AIA) and the Interface Region Imaging Spectrograph (IRIS), we studied the supra-arcade fan (SAF) region between the bottom of CS and the top of flare loops in the south part of the disrupting configuration. Our results indicated that the SAF contained hot plasma of temperature up to $10^7$ K and electron density of $2.63 \cdot 10^9$ cm$^{-3}$, and the fast variation component (FVC) of the SAF light-curve shown by the IRIS slit-jaw images (SJI) displayed a quasi-periodic oscillating feature with the period of 1.28 min. We utilized the ATHENA code to simulate detailed evolutionary features of the magnetic structure of a typical two-ribbon flare. The numerical experiments duplicate observational features in many respects, including the spatial distribution and evolution in structures of the plasma and magnetic field, the turbulence and the termination shock (TS) in the SAF. Our results suggest that the SAF should be a high temperature structure that possibly contains the TS.
A FAILED FILAMENT ERUPTION ASSOCIATED WITH FILAMENT OSCILLATIONS

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A filament located in NOAA active region 12014 undergoes a failed eruption on July 5th, 2014. This eruption is associated with two small flares (i.e., C1.3 and C2.5) but without any CME. This "filament" actually consists of three segments that differ in height and/or location. The upper and lower filaments follow nearly the same distribution, resembling an apparent double-decker structure. Intermittent injections along the middle one into the system leads to the oscillations of the upper filament for 2 hours before eruption. The upper filament rises up and rotates about 180 degree then falls back towards a pair of sunspots with strong magnetic fields, while the lower one stays and remains the original shape. We study the relation between material injections, flares, filament oscillations, and the failed eruption. The cause of the strange behavior of the clockwise rotation of the failed eruption will also be investigated.

MAGNETIC RECONNECTION AND HARD X-RAY ENERGETICS IN DOZENS OF TWO-RIBBON FLARES

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The mechanisms of electrons acceleration during a flare has not been understood very well. We analyzed tens of flares by using SDO observations to study their reconnection properties combined with HXR emissions. In most of these flares, the X-ray photon spectrum (in 12 - 25 keV energy) is seemed to be harder at the time of peak reconnection rate, which usually occurs before the peak HXR emission. We also discussed the evolution of the HXR spectrum combined with the shear angles of post-reconnection loops.
**SIMULATIONS AND TESTING OF STIX SOFTWARE**

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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. At Graz we are involved in the development of the software for the operation of STIX, and the analysis of its data. The ground analysis software will allow scientists to analyse STIX data, in terms of spectroscopy, imaging and imaging-spectroscopy. The flight software is critical for STIX, due to the limited bandwidth, and we are thus also involved in simulations and testing in support of this. In particular, we are focused on tasks relating to spectroscopy and calibration. This includes modelling of the detector response and measuring the calibration of each detector, using the position of the calibration lines in the low-latency background spectra. In order to fully test our simulations of the instrument, flight software and ground analysis software, end-to-end testing of the spectroscopy data product, using simulated data has been performed. RHESSI data is used as a starting point to provide realistic input into our simulations. This is then processed through the full software chain. The data is then analysed using OSPEX (Object Spectral Executive), an interface which has been used extensively in the analysis of solar HXR data.

**STUDY OF MAGNETIC FIELD VARIATIONS IN HIGH-CADENCE VECTOR MAGNETOGRAMS DURING SOLAR FLARES**

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Solar flares are an explosive manifestation of the complex magnetic structure of active regions in the solar atmosphere. It has been observed that the photospheric magnetic field of these regions changes rapidly, abruptly and significantly during flaring events. Previous studies are based mainly on visual line or low cadence data. In this work we investigate the temporal and spatial evolution of the permanent changes in the magnetic field of solar flares from high-cadence vector data (135 seconds) of the imaging system (dopplergrams and magnetograms) of the SDO/HMI instrument, which are suitable to probe the phenomenon. The highly energetic events under study occurred during the current solar cycle 24, in a range of high and low energy, according to the GOES classification. The analysis also represents a crucial input for the investigation of sunquakes.
A NEW TOOL FOR AUTOMATED CME DETECTION AND TRACKING USING MACHINE LEARNING

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Coronal mass ejections (CMEs) are causes of major geomagnetic storms which can cause severe space weather problems. With the accumulation of the white-light coronagraph images observed by different space missions, e.g., SOHO/LASCO and STEREO/COR, automated detection and tracking of CMEs becomes more and more necessary and crucial for their predictions and statistical studies. We treat the detection of CME events from white-light coronagraph images as a supervised image classification problem and solve it by training a Convolutional Neural Network LeNet with training labels obtained from CME catalogs available online. Next, to identify the CME region within each CME-detected image, we use DDT (Deep Descriptor Transforming) which can evaluate correlations between descriptors from a CNN model to localize the common object in an image set. A following step is to apply graph cuts technique in computer vision to finely tune the CME boundary. We have compared our results of the automated CME identification via the machine learning approach with those via traditional image segmentation techniques. It shows that the new method has the capabilities to identify a larger number of CME events and trace more complete CME structures, etc. A catalogue of the identified CME events with their major parameters is to be provided as well to the community for statistical studies and CME arrival predictions.

MAGNETIC TOPOLOGY SKELETON OF ACTIVE REGION AND FLARE-CME ERUPTION

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We study the magnetic topology skeleton in an active region related to a halo flare-CME event. Based on the high-resolution vector magnetograms obtained by HMI/SDO, we made NLFFF extrapolation with a boundary integrated model. We analyzed the 3D topology skeleton of the active region and the eruption features in the chromospheric and coronal observations, and found that the magnetic topology skeleton plays an important role in the process of the flare-CME eruption. Our results suggested that magnetic topology skeleton could be helpful for analyzing the possible eruption behaviour in solar active regions and therefore could be helpful for the solar activity forecast.
WHITE-LIGHT FLARES OBSERVED BY ONSET

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The Optical and Near-infrared Solar Eruption Tracer (ONSET) was constructed by Nanjing University in cooperation with Yunnan Astronomical Observatory. It consists of four tubes, which allow the quasi-simultaneous observations of the Sun in four wavebands, He I 10830 Å, H\textalpha, and 3600 and 4250 Å continua. A number of white-light flares have been observed since its operation. Some case studies of these white-light flares are presented in this talk. Since the two continuum wavebands 3600 and 4250 Å are within and outside the Balmer continuum, respectively, we are able to figure out whether these white-light emissions possess a Balmer jump or not. We compare the magnitude and spatial distribution of the Balmer jump of white-light flares with that of RHESSI hard X-ray kernels. Some statistical results are also presented in this talk.

THE LYMAN-ALPHA LINE IN RESPONSE TO DIFFERENT FLARE HEATING MODELS

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The Ly\alpha line in the Sun is the strongest in the ultraviolet waveband, and is greatly enhanced during flares. Here we present radiative hydrodynamic simulations of flares under different heating models, and calculate this line assuming non-equilibrium ionization of hydrogen and partial frequency distribution. We find that in non-thermal heating models, the Ly\alpha line can show a red/blue asymmetry corresponding to the chromospheric evaporation/condensation. The asymmetry will change from red to blue if the electron beam flux is large enough to drive impulsive evaporation of chromospheric plasma. In the Ly\alpha lightcurve, there appears a dip when the change of asymmetry takes place. In thermal models, the Ly\alpha intensity peaks quickly and then falls, which has similar features to heating by a soft electron beam. The Ly\alpha profile shows a single red peak in the end of thermal heating, and the whole line is formed in a very small height range.
OBSERVATION OF A REVERSAL OF BREAKOUT RECONNECTION PRECEDING A JET: EVIDENCE OF OSCILLATORY MAGNETIC RECONNECTION

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Recent studies have revealed that solar jets involving minifilament eruptions may be initiated under the well-known magnetic-breakout mechanism. Before or just at the onset of those jets, there should be a current sheet, where breakout magnetic reconnection takes place, between open fields and the outside of the jet-base arcade carrying minifilament in its core. In this paper we present a jet produced by eruption of two minifilaments lying at the jet base. A current sheet is directly detected near the jet base before the onset of the eruption, suggesting the magnetic-breakout mechanism. However, we further find that the current sheet undergoes a transition. The current sheet first shortens to zero in length, but then lengthens towards an orthogonal direction relative to its initial orientation. The change of the current sheet gives rise to a reversal of the breakout reconnection, as the inflow and outflow regions before the transition become the outflow and inflow regions after the transition, respectively. We therefore propose that this observation provides evidence for the so-called oscillatory reconnection which is defined by a series of reconnection reversals but not yet proved to exist in real plasma environment of the solar atmosphere.

ERUPTION OF A MULTI-FLUX-ROPE SYSTEM IN SOLAR ACTIVE REGION 12673 LEADING TO THE TWO LARGEST FLARES IN SOLAR CYCLE 24

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Magnetic flux rope is a set of magnetic field lines winding around a central axis and is closely connected with solar eruptions, such as flares and coronal mass ejections. The classical scenario assumes a single flux rope for each eruption, but it is reasonable to expect multiple flux ropes in a complex active region (AR). Recently, AR 12673 in 2017 September produced the two largest flares in Solar Cycle 24: the X9.3 flare on September 6 and the X8.2 flare on September 10. The evolutions of the AR magnetic fields and the two large flares reveal that significant flux emergence and successive interactions between the different emerging dipoles resulted in the formations of multiple flux ropes and twisted loop bundles, which successively erupted like a chain reaction within several minutes before the peaks of the two flares. We propose that the eruptions of a multi-flux-rope system rapidly released enormous magnetic energy and resulted in the two largest flares in Solar Cycle 24.
Solar flares originate from the release of the energy stored in the magnetic field of solar active regions, hence the magnetic field evolution is the key point for solar flare forecasting. However, the pre-flare conditions of magnetic field evolution in active regions are still not very clear. In the current work, long short-term memory network, which is one of deep learning methods, is applied to learn the evolutional patterns from time series of magnetic field parameters in active regions, and finally set up a real time and automatic solar flare forecasting model. This model provides the rolling solar flare forecast every 96 minutes. The step in the rolling forecasting results can be used to estimate the flare onset time. In short, the occurrence and onset time of solar flares are given by one rolling forecasting model for the first time. A data set is created from active regions observed by SDO/HMI from 2010 to 2016 and corresponding soft X-ray solar flares observed by GOES. The data from 2010 to 2014 is used as training set, and the remaining data is used as testing set. The testing results of the forecasting model indicate that (1) 20 hours are suitable evolutional time for magnetic field parameters in the proposed forecasting model; (2) the proposed forecasting model has a good performance for flare occurrence, the hit rate of 81% and false alarm rate of 90%; (3) the error of flare onset time is within 24 hours for the 80% flares.

Investigating the Formation and Eruption of a Mini-Sigmoid in Coronal Hole

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In this paper, we study the formation and eruption of a mini-sigmoid within a cross-equatorial coronal hole that was observed by SDO from 2017 January 28 to 31. The HMI line-of-sight magnetograms reveal that the source region of the sigmoid first appeared as a dipole, which subsequently experienced a rapid emergence followed by a long-term decay. Correspondingly, the coronal structure initially appeared as a group of arc-like loops, which then gradually transformed into continuously sigmoidal loops, mainly owing to the flux cancellation near the polarity inversion line. We also analyze the thermal property of the sigmoid and find that the temperature of the J-shaped and sigmoidal loops is about $2 \times 10^6$ K, greater than that of the background coronal hole. Using the flux rope insertion method, we further reconstruct the nonlinear force-free fields of the sigmoid at three time instants. The modeling well reproduces the transformation of the near-potential field into a sigmoidal field. Through inspecting the distribution of the electric current $J$ and squashing factor $Q$, it is also found that the sheared and sigmoidal loops are mainly concentrated at around the hyperbolic flux tube, where $J$ and $Q$ are high. It implies that the reconnection
most likely takes place there to form the sigmoidal field and heat the plasma. Moreover, our results also suggest that the mini-sigmoid, at least the one in our study, could have the same formation process as the large-scale one.

**MAGNETOHYDRODYNAMIC SIMULATION OF THE X9.3 FLARE ON 2017 SEPTEMBER 6: EVOLVING MAGNETIC TOPOLOGY**

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Three-dimensional magnetic topology is crucial to understanding the explosive release of magnetic energy in the corona during solar flares. Much attention has been given to the pre-flare magnetic topology to identify candidate sites of magnetic reconnection, yet it is unclear how the magnetic reconnection and its attendant topological changes shape the eruption structure and how the topology evolves during the eruption. Here we employed a realistic, data-constrained magnetohydrodynamic simulation to study the evolving magnetic topology for an X9.3 eruptive flare that occurred on 2017 September 6. The simulation successfully reproduces the eruptive features and processes in unprecedented detail. The numerical results reveal that the pre-flare corona contains multiple twisted flux systems with different connections, and during the eruption these twisted fluxes form a coherent flux rope through tether-cutting-like magnetic reconnection below the rope. Topological analysis shows that the rising flux rope is wrapped by a quasi-separatrix layer, which intersects itself below the rope, forming a topological structure known as a hyperbolic flux tube, where a current sheet develops, triggering the reconnection. By mapping footpoints of the newly reconnected field lines, we are able to reproduce both the spatial location and, for the first time, the temporal separation of the observed flare ribbons, as well as the dynamic boundary of the flux rope’s feet. Furthermore, the temporal profile of the total reconnection flux is comparable to the soft X-ray light curve. Such a sophisticated characterization of the evolving magnetic topology provides important insight into the eventual understanding and forecasting of solar eruptions.

**THE DEVELOPMENT OF LOWER-ATMOSPHERE TURBULENCE EARLY IN A SOLAR FLARE**

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Waves and turbulence play a key role in the transfer of energy in magnetized plasmas. We present the first observational study of the onset and evolution of solar flare turbulence in the lower solar atmosphere on an unprecedented time scale of 1.7 s using the Interface Region Imaging Spectrograph (IRIS). We observe the line Si IV (1402.77 Å), formed at a transition region temperature of 80000 K, at the eastern flare footpoint, over a region of <0.3 arcseconds (sit-and-stare) during the flare duration. At 1.7 s time resolution, non-thermal spectral line broadening, indicating turbulent velocity fluctuations, precedes the flare onset at this temperature and is coincident with net blue-shifts. The broadening decreases as the flare brightens and then oscillates with a period of approximately 10 s. These observations
are consistent with turbulence in the lower solar atmosphere at the flare onset, heating that region as it dissipates. This challenges the current view of energy release and transport in the standard solar flare model, suggesting that turbulence partly heats the lower atmosphere.

ANALYSIS OF THE FLARING PLASMA CHARACTERISTICS BASED ON THE FIRST- AND THIRD-ORDER X-RAY RESIK SPECTRA

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Observations from the Polish spectrometer RESIK operating aboard Russian Coronas-F satellite (2001 - 2003) constitute a unique database of solar spectra and give a possibility of completing X-ray plasma diagnostics in the temperature range 3 - 30 MK. Usually RESIK observed the spectra in the first order of reflection (3.3 Å - 6.05 Å). However by forcing appropriate voltage on the detectors, spectra in higher orders of reflection were sometimes observed. For the Si 111 mon-crystal cuts used in RESIK, the second order of reflection is prohibited, while the allowed third order of reflection includes the He-like Fe line complex (at 1.85 Å) and Ni line complex (1.55 Å). We present the results of preliminary analysis of flaring plasma spectra, available in both the first and the third orders of reflection.

SMM BENT CRYSTAL SPECTROMETER ARCHIVE, CATALOGUE AND EVENTS

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The Bent Crystal Spectrometer (BCS) aboard Solar Maximum Mission satellite (1980-1989) was a unique instrument, which observed the X-ray solar spectra with yet unprecedented resolution, both temporal and spectral. New calculations of the instrument effective area in its eight spectral channels allow to interpret the recorded spectra correctly. Thanks to this, all archival observations can be interpreted, (some of them re-interpreted) in order to determine flaring plasma velocities, turbulence, temperatures, emission measures and the chemical composition (Ca & Fe). The catalogue which has been built based on BCS SMM data will be introduced and a number of representative observations will be shown and discussed.
PRE-FLARE DYNAMICS OF THE FLARING ACTIVE REGIONS IN THE LOWER SOLAR ATMOSPHERE

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We present our method where we focus on the pre-flare evolution of the 3D magnetic field skeleton of flaring ARs. The 3D magnetic structure is based on PF/NLFFF extrapolations and PENCIL MHD code simulations to encompassing a vertical range from the photosphere through the chromosphere and transition region into the low corona. The basis of our proxy measure of activity prediction is the so-called weighted horizontal gradient of magnetic field (\(WG_M\)) defined between opposite polarities in the entire delta-type sunspot. The temporal variation of the distance of the barycenter of the opposite polarities is also found to possess potentially important diagnostic information about the flare onset time estimation as function of height. We found that at a certain height in the lower solar atmosphere the onset time may be estimated much earlier than at the photosphere or at any other heights. Therefore, we present a tool and recipe that may potentially identify the optimum height for flare prognostic in the solar atmosphere allowing to improve our flare prediction capability and capacity.

ON THE RELATIVE IMPORTANCE OF CORONAL AND CHROMOSPHERIC EMISSION DURING FLARES

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Solar flares radiate energy at all wavelengths, but are best observed at "hot" (coronal) wavelengths where the contrast is larger. Consequently, the flare classification relies on soft X-ray observations made by the GOES 0.1nm – 0.8nm passbands. There are however evidence that most of the flare energy is radiated by the colder layers of the Sun, in particular in the chromosphere, and at longer wavelengths. We have investigated if the contribution of "chromospheric emissions" changes with the size of the flares as measured in Soft X-rays. We used high-cadence TSI measurements and chromospheric extreme-ultraviolet (EUV) observations by SDO/EVE and found evidences for a larger contribution of the chromospheric radiation when considering smaller soft X-ray flares. In other words, the ratio of chromospheric to coronal emission appears to increase when going from X-class flares to smaller flares. These results have impact on the energy transport during flares (e.g. on the importance of thermal conduction) and possibly on the contribution of small flares to solar irradiance variations.

STUDY OF FINE STRUCTURES IN SOLAR RADIO EMISSION

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Solar radio emission an be broadly categorized as: i) continuum emission and ii) transiente-mission. The former is composed of a non-variable stationary component considered to deduce to the free-free emission from the inherent electron distribution in the corona and a "slowly-varying" component due to the extreme density condensations above "Active Regions". At
times the radio emission from the Sun can be impulsive in nature and are often referred as "radio bursts". The solar radio bursts are often identified and classified based on their spectro-temporal characteristics seen in the frequency-time plane. These transient phenomena are observed to occur over a broad range of frequencies from a few kHz up to a few GHz, and show very high brightness temperatures in the range 1012-1014K. The impulsive radiation is often associated with the solar transients, viz. Flares, Coronal Mass Ejections (CMEs), etc. which are the consequences of large scale magnetic energy releases that take place on the Sun. With the advent of digital technology and improved radio instrumentation techniques the next generation of very sensitive radio telescopes offer the capability of spectroscopic imaging observations covering many octaves of the radio frequency band with very high spectral and temporal resolution. This has paved way for in-depth studies of weak and fragmented emission features in the solar radio radiation particularly during the solar minimum period. Detailed observational studies of such phenomenon give us a better understanding of coronal physics. High sensitivity radio telescopes (viz. LWA1, LOFAR, uGMRT, MWA, MUSER) with wide instantaneous bandwidth at high spectro-temporal and angular resolutions are ideal for such observational studies, particularly during periods of low solar activity. Here I will describe some of our recent high "resolution" observations of fragmented radio emission from the Sun and their usefulness in understanding the solar corona.

**LOFAR INTERFEROMETRIC OBSERVATION OF A GROUP OF SPATIALLY AND TEMPORALLY RESOLVED TYPE III SOLAR RADIO BURSTS**

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Using the interferometric and beam formed capabilities of LOFAR, we analyzed the propagation of a group of Type III radio bursts observed on 30 March 2018, in the height range from ≈1.5 Rsun to ≈4 Rsun in the solar corona, which corresponds to the harmonic plasma frequency emission from 80 to 20 MHz. Taking advantage of the interferometric high spectral and temporal resolution of LOFAR (160 ms / 196 kHz), we were able to distinguish five different paths of propagation for the electron beams in the type III group. In addition, with the simultaneous LOFAR beam formed full Stokes observations, (frequency and time resolution of 10 ms and 12 kHz, respectively), we estimated the coronal magnetic field along these five electron beam paths. This was done by calculating the degree of circular polarisation using the IQUV spectra of the harmonic plasma emission from the type III bursts. The data analysis method and obtained results will be discussed here.

**SOLAR Hα IMAGING SPECTROMETER - A COMPLEMENTARY SPACE MISSION TO ASO-S**

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We present an introduction to the space mission - Solar Hα Imaging Spectrometer (SHIS). It is a payload onboard a new developed satellite platform, and will be launched at the end of
2020, SHIS will be the first full-disk Hα space telescope that provides imaging and spectroscopic data. The scientific objective of the SHIS is to study the dynamics and mechanisms of solar activities on the lower atmosphere. SHIS will be a good complementary space mission to the ASO-S.

**DOPPLER SHIFT OSCILLATIONS OBSERVED IN Fe XXI**

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Quasi-periodic oscillations are usually detected as spatial displacements of coronal loops in imaging observations or as periodic shifts of line properties (i.e., Doppler velocity, line width and intensity) in spectroscopic observations. They are often applied for remote diagnostics of magnetic fields and plasma properties on the Sun. Based on the imaging and spectroscopic measurements of available space missions, we investigated the properties of Doppler shift oscillations at flaring loops. Both the damping and non-damping oscillations were reported here, they were detected in two solar flares, which erupted on 2014 September 06 and 27, respectively. Using the magnetohydrodynamic seismology diagnostics, the magnetic field strengths of the flaring loops were estimated to be about 100 G.

**THE LYMAN-ALPHA SOLAR TELESCOPE (LST) FOR THE ASO-S MISSION: PROGRESS AND UPDATES**

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The Lyman-alpha Solar Telescope (LST) is one of the three payloads of the Advanced Space-based Solar Observatory (ASO-S) and as scheduled it will be in phase C when the CESPM 2019 opens. The LST consist of a Solar Disk Imager (SDI), a Solar Coronal Imager (SCI), a White-light Solar Telescope (WST) and a Guide Telescope (GT). With all the instruments, LST is to observe solar flares, coronal mass ejections (CMEs) and other phenomena from disk center up to 2.5 solar radii in both the Lyman-alpha line and white-light wavebands with high tempo-spatial resolution. Due to its strong intensity and large temperature coverage of the Lyman-alpha line, LST can access both low- and high-temperature features on the Sun, such as filaments (prominences), jets, loops, coronal holes, CMEs, flares, etc. In this talk, I will review solar observations with the Lyman-alpha line done by various satellites and sounding rockets, introduce the up-to-date progress of LST and outline the possible LST contributions to study of the Sun.
SOLAR JET-LIKE FEATURES ROOTED IN FLARE RIBBONS

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Employing the high spatio-temporal Interface Region Imaging Spectrograph $1330$ Å observations, we investigated the jet-like features that occurred during the X8.2 class flare in NOAA active region (AR) 12673 on 2017 September 10. These jet-like features were rooted in the flare ribbons. We examined 15 features, and the mean values of the lifetimes, projected widths, lengths and velocities of these features were 87 s, 890 km, 2.7 Mm and $70$ km s\textsuperscript{-1}, respectively. We also observed many jet-like features which happened during the X1.0 class flare on 2014 October 25. We studied the spectra at the base of a jet-like feature during its development. The Fe XXI 1354.08 Å line in the corona displays blueshift, while the Si IV 1402.77 Å line in the transition region exhibits redshift, which indicates the chromospheric evaporation. This is the first time that the jet-like features are reported to be rooted in the flare ribbons, and we suggest that these jet-like features were driven by the mechanism of chromospheric evaporation.

PROPAGATION OF A SOLAR MOVING TYPE IV RADIO BURST USING LOFAR

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Type IV radio burst is the long-lasting broadband continuum emission in metric wavelength. In this study, we present a moving type IV radio burst observed by LOFAR. We performed a detailed comparison of NRH and LOFAR imaging. Using the full Stokes parameters from the LOFAR dynamic spectra, we have also calculated the degree of circular polarization during the propagation of the moving type IV. Finally, we combined LOFAR interferometric data with SDO-AIA and LASCO-C2 to track the evolution of this type IV and relate it with the CME.
RAPID BUILDUP OF A MAGNETIC FLUX ROPE DURING A
CONFINED X2.2 CLASS FLARE IN NOAA AR 12673

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Magnetic flux ropes (MFRs) are believed to be the core structure in solar eruptions, nevertheless, their formation remains intensely debated. Here we report a rapid buildup process of an MFR-system during a confined X2.2 class flare occurred on 2017 September 6 in NOAA AR 12673, three hours after which the structure erupted to a major coronal mass ejection (CME) accompanied by an X9.3 class flare. For the X2.2 flare, we do not find EUV dimmings, separation of its flare ribbons, or clear CME signatures, suggesting a confined flare. For the X9.3 flare, large-scale dimmings, separation of its flare ribbons, and a CME show it to be eruptive. By performing a time sequence of nonlinear force-free fields (NLFFFs) extrapolations we find that: until the eruptive flare, an MFR-system was located in the AR. During the confined flare, the axial flux and the lower bound of the magnetic helicity for the MFR-system were dramatically enhanced by about 86% and 260%, respectively, although the mean twist number was almost unchanged. During the eruptive flare, the three parameters were all significantly reduced. The results evidence the buildup and release of the MFR-system during the confined and the eruptive flare, respectively. The former may be achieved by flare reconnection. We also calculate the pre-flare distributions of the decay index above the main polarity inversion line (PIL) and find no significant difference. It indicates that the buildup of the magnetic flux and helicity of the MFR-system may play a role in facilitating its final eruption.

ENA CODING APERTURE IMAGER FOR
STEM MISSION AT L5

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The ENA coding aperture imager is designed for Solar Terrestrial Environment Monitor mission (STEM) at L5 which collect the energy-neutral atoms generated by solar coronal mass ejection (CME) in 5-300 keV energy range. We can extend the energy spectrum of a single particle event to 10 MeV. The original detection data of each ENA event generated by interplanetary CME, including the energy and position information of CME ions at the time of charge exchange carried by ENA, \( P(t, x, y, E) \), were recorded with a two-dimensional detector. The ENA energy spectrum image, \( P(x, y, E) \), was obtained by integrating the modulation data. The image reconstruction algorithm is applied to reconstruct the target image, that is, the ENA telemetry image generated by CME driven shock particle acceleration. The total field of view is \( 20^\circ \times 20^\circ \), and the center of the field of view is \( 10.27^\circ \) away from the sun along the heliospheric line. The spatial resolution is \( 1^\circ \times 1^\circ \). This study was supported by the National Natural Science Foundation of China (Grant Nos. 41574152).
INVESTIGATION OF A LOWERING HXR FOOTPOINT SOURCE HEIGHTS DURING IMPULSIVE PHASE OF SOLAR FLARES

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The thick target model, is well developed. It gives an opportunity to diagnose the physical conditions within flaring structure. The thick target model predicts that in flare footpoints we should observe lowering HXR sources altitude with increasing energy. The footpoint HXR sources are the effect of direct interaction of non-thermal electron beams with plasma in footpoints. Therefore we can estimate the plasma density distribution along the non-thermal electron beam directly from observations of altitude-energy relation obtained for HXR footpoint sources. However, the relation is not density dependent only. Its shape is also determined by the power-law distribution of HXR flux. Additionally, during impulsive phase, the plasma density and degree of ionization within footpoints may change dramatically due to heating and chromospheric evaporation. For this reason the interpretation of observed HXR footpoint sources altitudes is not straightforward and needs detailed numerical modelling of the electron precipitation process. We will present the results of numerical modelling of several well observed solar flares. We use HXR observations obtained by RHESSI. The numerical model was calculated using the modified hydrodynamic 1D Solar Flux Tube Model (see Mariska et al.1982,1989; Falewicz et al.2011, 2014 for details) with applied Fokker-Planck formalism for non-thermal beam precipitation. The obtained results significantly improve our understanding of non-thermal electron beam precipitation and allow to refine the energy balance in solar flare footpoints during the impulsive phase.

THE CATALOGUE OF FAILED ERUPTIONS REGISTERED BY THE SDO/AIA

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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. 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. We developed automated algorithm which can recognize moving structures in AIA images. We searched whole 8 years of AIA database, and we found more than 15 000 dynamic events. Among them almost 1500 were failed eruptions which we collected into the catalogue. The catalogue is available on-line, and contains basic information about eruption kinematics, properties of accompanying flare, decay index of magnetic field in the active region etc. The catalogue and preliminary statistical analysis of found failed eruptions will be presented.
EUV AND X-RAY EMISSION OF TURBULENT FLARE LOOPS

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Turbulence has been observed in flare loops and is believed to be crucial in the acceleration of particles and in the emission of X-ray photons in flares, but how the turbulence is produced is still an open question. A scenario proposed by Fang et al. (2016) suggests that fast evaporation flows from flare loop footpoints can produce turbulence in the looptop via the Kelvin-Helmholtz instability (KHI). We revisit and improve on this scenario and study how the KHI turbulence influences the Extreme Ultra-Violet (EUV) and X-ray emission from flare loops. A 2.5D numerical simulation is performed in which we incorporate the penetration of high energy electrons as a spatio-temporal dependent trigger for chromospheric evaporation flows and looptop turbulence due to KHI. EUV, soft X-ray (SXR) and hard X-ray (HXR) emission are synthesized based on the evolving plasma parameters and given energetic electron spectra. We find that KHI turbulence leads to clear brightness fluctuations in the EUV, SXR and HXR emission. The spectral profile of the Fe XXI 1354 line is also synthesized and found to be broadened due to the turbulent motion of plasma. We find that the turbulence in the apex can lead to short period standing slow magnetoacoustic waves via the modification of the magnetic field configuration. This job will be submitted to ApJL.

DATA-CONSTRAINED MHD SIMULATIONS OF ACTIVE REGION ERUPTIONS

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We present data-constrained MHD simulations of the CME eruptions of the February 2009 sigmoid. The initial conditions for the simulations have been produced with the flux rope insertion method, which creates highly observationally-constrained non-linear force-free models of the pre-flare states of the sigmoid for different times. The best-fit models in these cases, as has been shown before, are actually not force-free, but slightly unstable, which leads to eruptions in the MHD simulations of the different CMEs. We analyse the dynamics, the evolution of twist, and strong-to-weak shear transition in the (post-)flare loops. We perform topology analysis and identify the site of reconnection, the ribbon locations and motions, and dimmings size and evolution. We compare the properties of the different eruptions as the region evolves. All this is compared and validated by STEREO-B EUVI observations, for which, luckily the region is at disk center.
ON SOLAR JETS: DRIVING MECHANISM AND FINE STRUCTURES

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Soar jets are omnipresent in the solar atmosphere. However, physical interpretations about their formation mechanism and fine structures are still open questions. By using the recent high resolution multi-wavelength observations taken by ground and space solar telescopes, we find that the eruptions of mini-filaments confined by the jet-base magnetic field are significant for explain many observing features in solar jets. In this talk, we will show that no matter the so-called standard jets or two-sided-loop jets are all originated from the eruption of mini-filaments, and the cool plasma flow in the jet spire is also form by the mini-filament eruption. In addition, solar jets can also launch large-scale coronal mass ejection. The physical mechanism and the relationship between solar jets and coronal mass ejections will also be introduced in this talk.

THE REVERSAL OF A SOLAR PROMINENCE ROTATION ABOUT ITS ASCENDING DIRECTION DURING A FAILED ERUPTION

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The magnetic orientation of solar coronal mass ejections (CMEs) near the Earth’s magnetosphere is one major parameter that influences the geoeffectiveness of CMEs. The orientation often varies during the eruption and propagation from the Sun to the Earth due to the deflection and/or rotation of CMEs. It is common to observe the counterclockwise (CCW) or clockwise (CW) rotation (viewed from above) of solar prominences in the corona, which can be used to predict the space weather effect of associated CMEs. In this Letter, we report an intriguing failed prominence eruption that occurred on 2010 December 10, exhibiting the CCW and CW rotations sequentially in the corona. The eruption is recorded by both the Atmospheric Imaging Assembly on board the Solar Dynamics Observatory and the Extreme Ultraviolet Imager on board the Solar Terrestrial Relations Observatory. This stereoscopic combination allows us to reconstruct the three-dimensional structure and identify the rotation reversal without ambiguity. The prominence first rotates CCW about its ascending direction by $\sim 135^\circ$ in $\sim 26$ minutes and then reverses to the CW rotation by $\sim 45^\circ$ in $\sim 15$ minutes; i.e., the average CCW and CW rotation speeds are $\sim 5.2$ and $\sim 3.0$ deg minute$^{-1}$, respectively. The possible mechanisms leading to the rotation and reversal are discussed.
The kinematics of the prominence is also analyzed, which indicates that an upward force acts on the prominence during the entire process.

THE THREE-PART STRUCTURE OF A FILAMENT-UNRELATED SOLAR CORONAL MASS EJECTION

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Coronal mass ejections (CMEs) often exhibit the typical three-part structure in the corona when observed with white-light coronagraphs, i.e., the bright leading front, dark cavity, and bright core, corresponding to a high-low-high density sequence. As CMEs result from eruptions of magnetic flux ropes (MFRs), which can possess either lower (e.g., coronal-cavity MFRs) or higher (e.g., hot-channel MFRs) density compared to their surroundings in the corona, the traditional opinion regards the three-part structure as the manifestations of coronal plasma pileup (high density), coronal-cavity MFR (low density), and filament (high density) contained in the trailing part of MFR, respectively. In this paper, we demonstrate that filament-unrelated CMEs can also exhibit the classical three-part structure. The observations were made from different perspectives through an event that occurred on 2011 October 4. The CME cavity corresponds to the low-density zone between the leading front and the high-density core, and it is obvious in the low corona and gradually becomes fuzzy when propagating outward. The bright core corresponds to a high density structure that is suggested to be an erupting MFR. The MFR is recorded from both edge-on and face-on perspectives, exhibiting different morphologies that are due to projection effects. We stress that the zone (MFR) with lower (higher) density in comparison to the surroundings can appear as the dark cavity (bright core) when observed through white-light coronagraphs, which is not necessarily the coronal-cavity MFR (erupted filament).

SOFT X-RAY POLARIMETRY USING BRAGG CRYSTALS

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We present novel concept of the soft X-ray spectrometer-polarimeter, which can provide unique opportunity to complement the efforts to reliably measure the X-ray polarization and contribute towards understanding the physics of solar flares. The standard flare model states that electrons are being accelerated at or near of the magnetic reconnection site in
specific regions of the corona and then propagate along newly reconnected magnetic field lines toward the atmospheric denser layers. Here, they are decelerated by the increasingly growing "opposition" of the atmosphere and lose their energy mainly through the bremsstrahlung process. The processes of bremsstrahlung emission of supposedly polarized X-ray flux can be monitored by measurements of soft X-ray emission lines by the proposed instrument.

SHOCK MAGNETIC STRUCTURE FOR A TYPE II RADIO BURST

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Coronal shocks are magnetohydrodynamic shocks that can happen ubiquitously and closely to human beings, type II radio bursts are the radio signature of the coronal shocks. What magnetic conditions are needed for the generation of type II radio bursts is still puzzling us. Here, we study a type II radio burst, whose corresponding coronal shock is observed by the Solar Dynamics Observatory and the Solar Terrestrial Relations Observatory in extreme-ultraviolet bands at three different positions. Based on the extreme-ultraviolet observations, we reconstruct the 3 dimension shock surface. Combined with the Nanay Radio Heliograph observations and the coronal magnetic field extrapolation model, the shock magnetic condition for the source region of the type II radio burst is given: the type II radio burst is generated by a quasi-parallel shock. We also use Rankine-Hugoniot relations to describe the coronal shock at the source region of the burst.

CHARACTERISTICS OF QUEIESCENT CORONA AT THE MINIMUM OF ACTIVITY IN 2009 AS OBTAINED BASED ON SPHINX X-RAY SPECTRA

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We present observations of X-ray fluence and spectra of the Sun in the range 1.2 - 5 keV obtained with the PIN detector, a part of SphinX spectrophotometer aboard CORONAS-Photon Russian solar observatory. For the study, we selected 141 time intervals, when the X-ray rates were below 200 cts/s, approximately 10 times below the detection threshold of GOES X-ray monitors. These spectra were fitted in the traditional one-temperature approximation as well as using multi-thermal approach, where the plasma in the temperature range 1.5-10 MK was allowed. Using complimentary X- and EUV- images, we extended
the multi-temperature analysis of (non-flaring, non-active region) corona down to \( T \sim 0.5 \) MK. We will present and discuss the basic physical characteristics of solar quiescent corona, stressing importance of the higher temperature \( (T > 5 \text{ MK}) \) plasma component with very small amount of emission measure. Based on SphinX and other X-ray data the characteristic average coronal plasma density and the other important plasma characteristics have been determined. In particular the minimum energy input rates necessary to sustain coronal X-ray emission will be provided.

**HIGH MILLIMETER POLARIZATION OF SOLAR FLARE DUE TO MAGNETIC FIELD ASYMMETRY**

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Polarization measurements from solar flares at millimeter-waves are used to investigate the magnetic field configuration, energy distribution of accelerated particles, and the origin of polarized solar radio emission. Two similar solar flares observed by the radio polarimeters (POEMAS) at 45 and 90 GHz were analyzed. However, the flare on November 5th, 2013, presented high degree of polarization of 20-40%, whereas the other flare on February 17th, 2013, showed only 10-15% polarization degree. Additional spectral data at microwaves from 1 - 15 GHz from the Radio Solar Telescope Network (RSTN) and at high frequencies (212 GHz) by the Solar Sub-millimeter Telescope (SST) were also used, when available. Also, the footpoints of the flaring magnetic field were obtained from RHESSI hard X-ray images. For each flare, we identified sources at 45 and 90 GHz with maximum intensity of same polarities in the dipole loop. The flux density and polarization radio spectra were fit using a model that simulates gyro-synchrotron emission in inhomogeneous 3D magnetic fields loops. We used two types of magnetic field morphology, a symmetric and an asymmetric one. The simulations were able to reproduce the degree of polarization and radio spectrum observed for each event. The results indicated that high circular polarization at 45 and 90 GHz is best explained by emission from an electron population with a hard energy distribution located on an asymmetric loop, whereas low polarization is associated with symmetric loops.

**HIGH-RESOLUTION SPECTROSCOPY OF A SURGE IN AN EMERGING FLUX REGION**

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The regular pattern of quiet Sun magnetic fields is disturbed by newly emerging magnetic flux, and all atmospheric layers are affected by its appearance. Hence, simultaneous observations in various spectral lines are needed to understand the interaction of rising flux tubes with the surrounding plasma during and after emergence. We observed a newly emerged region on 11 September 2018 using Vacuum Tower Telescope (VTT) at the Observatorio del Teide, Tenerife, Spain. High-spectral resolution spectroscopic observations using the
Echelle spectrograph in three spectral lines Hα (656.3 nm, chromosphere), Cr I (578.1 nm, photosphere), and Hβ (486.1 nm, chromosphere) were obtained in the early growth phase of active region NOAA 12722. High resolution context images were obtained with a high-cadence CMOS camera system simultaneously recording broad- and narrow-band Hα images. The Solar Dynamic Observatory (SDO) provides additional continuum images, LOS magnetograms, and EUV images, which link the different solar atmospheric layers. The region started as bipolar region but the continuous flux emergence in the region resulted in many mixed polarity features between leading and trailing pores. The region evolved fast and completely disappeared by 13 September 2018. In the beginning it contained an arch filament system. However, the leading part included an absorption feature that surged. Strong up and downflows occurred in close proximity to this feature. We will present various physical parameters such as line-of-sight (LOS) velocities and line core intensity obtained in three spectral lines characterizing both the surge and the overall active region.

OPEN QUESTIONS REGARDING THE ENERGY PARTITION IN SOLAR FLARES

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The knowledge of the energetics of thermal and nonthermal particle populations is essential for our understanding of energy release and transport processes as well as particle acceleration mechanisms. Several recent studies have tried to quantitatively characterize the thermal-nonthermal energy partition, with various conclusions. I will review these studies and point out several key aspects that require closer scrutiny before we can come to firm conclusions. This will include the issues of the multithermality of the flare plasma, the role of conductive losses, bolometric energies, cold versus warm thick-target model, and the temporal evolution of the energy partition.

MULTI-WAVELENGTH DIAGNOSTICS OF THE FAILED ERUPTION OF A HELICAL KINK-UNSTABLE PROMINENCE

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Multi-wavelength diagnostics of the prominence eruption provides an opportunity to unravel the sequence of processes leading to its instability and eventual triggering. In this paper, we investigated prominence eruption of October 14, 2012 recorded in Hα, EUV, and X-ray wavelengths. This event was observed as a filament eruption accompanied with a flare by STEREO B. The prominence show the evidence of twist converting to writhe in the EUV observations, and particularly, a kinked structure in the AIA 131 Å and 94 Å images as it evolved. The twist of the prominence was estimated to be at least 3τ (1.5 turns) which reached up to the threshold of the kink instability. This indicates the predominant cause of the prominence eruption to be the accumulated magnetic twist which progressively drove the magnetic configuration to be kink-unstable. The largest rising speed was estimated to be 228 km/s which subsequently displayed a sudden rapid acceleration (2715 m/s²) associated with the flare. Moreover, a cusp shaped structure, observed in AIA 131 Å and 94 Å images along with the co-spatial high-energy X-ray emission, as recorded from RHESSI revealed the representative location of magnetic reconnection. Followed to this, the erupted material
undergone deceleration with the maximum value 391 m/s², which is even larger than the free-fall speed on the Sun or the local solar gravity acceleration. Such intriguing prominence evolution suggests that the prominence was pulled back by an inward magnetic tension force which resulted in a failed eruption.

MINI-FILAMENT ERUPTIONS TRIGGERING CONFINED SOLAR FLARES OBSERVED BY ONSET AND SDO

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Using the observations from the Optical and Near-infrared Solar Eruption Tracer (ONSET) and the Solar Dynamics Observatory (SDO), we study an M5.7 flare in AR 11476 on 2012 May 10 and a micro-flare in the quiet Sun on 2017 March 23. Before the onset of each flare, there is a reverse S-shaped filament above the polarity inversion line, then the filaments become unstable and begin to rise. The rising filaments gain the upper hand over the tension force of the dome-like overlying loops and thus successfully erupt outward. The footpoints of the reconnecting overlying loops successively brighten and are observed as two flare ribbons, while the newly formed low-lying loops appear as post-flare loops. These eruptions are similar to the classical model of successful filament eruptions associated with coronal mass ejections (CMEs). However, the erupting filaments in this study move along large-scale lines and eventually reach the remote solar surface; i.e., no filament material is ejected into the interplanetary space. Thus, both the flares are confined. These results reveal that some successful filament eruptions can trigger confined flares. Our observations also imply that this kind of filament eruption may be ubiquitous on the Sun, from active regions (ARs) with large flares to the quiet Sun with micro-flares.

FIRST DETERMINATION OF 2D SPEED DISTRIBUTION WITHIN THE BODIES OF CORONAL MASS EJECTIONS

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The determination of the speed of Coronal Mass Ejections (CMEs) is usually done by tracking brighter features (such as the CME front and core) in visible light coronagraphic images and by deriving unidimensional profiles of the CME speed as a function of altitude or time. Nevertheless, CMEs are usually characterized by the presence of significant density inhomogeneities propagating outward with different radial and tangential speeds, resulting in a complex evolution eventually resulting in the Interplanetary CME. In this work, we demonstrate for the first time how coronagraphic images can be analyzed to derive 2D maps of the almost instantaneous plasma speed distribution within the body of CMEs. This is done both with the analysis of synthetic data, and real observations. Results from this work will allow to characterize the distribution of kinetic energy inside CMEs and the distribution of the Doppler dimming factor. In the future, CMEs can be observed by two channels (VL and
UV Ly-alpha) coronagraphs, such as Metis on-board ESA Solar Orbiter mission (launch in 2020) as well as Lyman-alpha Solar Telescope (LST) on-board Chinese Advanced Space-based Solar Observatory (ASO-S) mission (launch in 2022). These future observations and our results could help to estimate the CME plasma temperature, while taking into account Doppler dimming effect.

MODELING MG II H, K AND TRIPLET LINES AT FLARE RIBBONS

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Observations from the Interface Region Imaging Spectrograph (IRIS) often reveal significantly broadened and non-reversed profiles of the Mg II h, k and triplet lines at flare ribbons. To understand the formation of these optically thick Mg II lines, we perform 1-D plane parallel radiative hydrodynamics modelling with the RADYN code, and then recalculate the Mg II line profiles from RADYN atmosphere snapshots using the 1-D radiative transfer code RH. We find that the current RH code significantly underestimates the Mg II h & k Stark widths. By implementing semi-classical perturbation approximation results of quadratic Stark broadening from the STARK-B database in the RH code, the widths are found to be one order of magnitude larger than those calculated from the current RH code. However, the improved Stark widths are still too small, and another factor of 30 has to be multiplied to reproduce the significantly broadened lines and adjacent continuum seen in observations. We suggest that 3-D effect and non-thermal electrons may account for this factor of 30. Without modifying the RADYN atmosphere, we have also reproduced non-reversed Mg II h & k profiles, which appear when the electron beam energy flux is decreasing. The non-reversed profiles are found to be formed at an electron density of $\sim 8 \times 10^{14}$ cm$^{-3}$ and a temperature of $\sim 1.4 \times 10^4$ K, where the source function slightly deviates from the Planck function. Our investigation suggests that the quadratic Stark broadening plays an important role in the formation of the broad Mg II lines at flare ribbons, and that the non-reversed Mg II lines can be reproduced in a self-consistent atmosphere.

A TWO-STEP MAGNETIC RECONNECTION IN A CONFINED X-CLASS FLARE IN SOLAR ACTIVE REGION 12673

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Solar flares are often associated with coronal eruptions, but there are confined ones without eruption, even for some X-class flares. How such large flares occurred and why they are confined are still not well understood. Here we studied a confined X2.2 flare in NOAA 12673
on 2017 September 6. It exhibits two episodes of flare brightening with rather complex, atypical ribbons. Based on topology analysis of extrapolated coronal magnetic field, we revealed that there is a two-step magnetic reconnection process during the flare. Prior to the flare, there is a magnetic flux rope (MFR) with one leg rooted in a rotating sunspot. Neighboring to the leg is a magnetic null-point structure. The sunspot drives the MFR to expand, pushing magnetic flux to the null point, and reconnection is first triggered there. The disturbance from the null-point reconnection triggers the second reconnection, i.e., a tether-cutting reconnection below the rope. However, these two reconnections failed to produce an eruption, because the rope is firmly held by its strapping flux. Furthermore, we compared this flare with an eruptive X9.3 flare in the same region with 2 hours later, which has a similar MFR configuration. The key difference between them is that, for the confined flare, the MFR is fully below the threshold of torus instability, while for the eruptive one, the MFR reaches entirely above the threshold. This study provides a good evidence supporting that reconnection alone may not be able to trigger eruption, rather, MHD instability plays a more important role.

5. Solar-Terrestrial Relations, Solar Wind, Space Weather and Space Climate

PARTICLES AND PLASMA WAVES FROM THE SUN TO THE EARTH: PROGRESS AND CHALLENGES

Maksimović Milan
LESIA, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, Univ. Paris Diderot, Sorbonne Paris Cité, 5 place Jules Janssen, 92195 Meudon, France

The Solar Wind is a particularly interesting laboratory for studying space plasmas particles and waves interactions. In this presentation I will review both theory and most recent observations of these interactions in a wide range of energies from the thermal plasma up to suprathermal particles generated during Solar Flares and injected in the Heliosphere.

SPACE WEATHER CHAINS CONNECTING THE SUN TO EARTH

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Space weather is driven by the variability of the solar magnetic field. Major space weather events are due to sudden reconfigurations of the coronal field that lead to energy releases and eruptions forming flares and coronal mass ejections. These solar events result in a variety of manifestations that affect the Earth’s space environment, its magnetosphere and uppermost atmosphere. There are basically three ways how the Sun affects the Earth’s space environment: the electromagnetic radiation, the plasma flow (solar wind) and the high-energy charged particles. In this review, we will discuss the solar sources of major space weather events, the relevant transport and coupling processes in the interplanetary space and their interaction with the Earth’s magnetosphere and upper atmosphere.
Coronal mass ejections (CMEs) are the largest erupted structure from the Sun, and have potential strong impacts on the geospace. After its launch, CME's space weather effects depend on various factors, as it has to propagate through 1 AU interplanetary medium before it can make any effect except the SEPs. These factors include the geometric properties, kinematic properties and magnetic properties of the CME. By reviewing the progresses achieved in the past years, I would like to show what we have known, what still unknown or unclear and what the next is that we should aim to.

**PREDICTING CME ARRIVAL TIME AND SPEED WITH DBEM**

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The Drag-based Model (DBM) 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 and depends on certain initial parameters such as CME launch speed, background solar wind speed and empirically derived drag parameter. DBM uses a CME cone geometry that includes CME’s angular half-width and longitude of CME source region as additional input parameters. The main advantage of DBM is a very short computational time (<1 ms) which allowed to develop the Drag-Based Ensemble Model (DBEM) that considers the variability of model input parameters by making an ensemble of n different input parameters to calculate 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. Recently, a fully operational DBEM web application was integrated as one of the ESA Space Situational Awareness portal services providing an important tool for space weather forecast. Using a simple web interface, the user can enter all input parameters and their uncertainties in order to get the CME arrival time and speed distributions at the target (e.g. Earth) based on several thousand DBM calculations within just few seconds. Recent developments of DBEM will be shown together with validation tests where DBEM is compared with observations and more complex numerical models (e.g. ENLIL).
UNUSUAL PLASMA AND PARTICLE SIGNATURES AT MARS AND STEREO-A RELATED TO INHIBITED EXPANSION CAUSED BY CME-CME INTERACTION

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On July 25 2017 a multi-step Forbush decrease (FD) with the total amplitude of more than 15% was observed by MSL/RAD at Mars and this is one of the biggest FDs ever detected on Mars. We find that these particle signatures are related to very pronounced plasma and magnetic field signatures detected in situ by STEREO-A on July 24 2017, with a higher than average total magnetic field strength reaching more than 60 nT. In the observed time period STEREO-A was longitudinally close to Mars and both were located at the back side of Sun as viewed from Earth. Using multi-spacecraft and multi-instrument (both in situ and remote-sensing) observations, as well as modelling, we find that the solar sources of these in situ signatures are 2 CMEs which erupted on July 23 2017 from the same source region on the back side of the Sun as viewed from Earth and interacted in the interplanetary space, inhibiting the expansion of one of the CMEs. We present a detailed investigation on this complex interaction event on its way from Sun to Mars. 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.

3D EVOLUTION OF A CORONAL SHOCK AND ITS LINK TO THE LONGITUDINAL DISTRIBUTION OF SEP PROPERTIES

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We follow the 3D evolution of a coronal shock from its birth in the AIA field of view (FOV) to its propagation in interplanetary space till Mars. The shock structure is identified using the center-median filtering method which is applied to EUV observations including SDO/AIA and Proba2/SWAP. Then 3D shock morphology is reconstructed with the updated and validated mask-fitting method from the triple-view observations at Earth, STEREO A and B in the FOV from EUV through coronagraph to heliospheric images. The mask-fitting method allows us to obtain a better shape of the 3D shock and calculate the anisotropy of shock evolution. The shock signals were later recorded in in-situ data by Messenger (0.39 AU), Venus Express (0.72 AU), WIND/ACE (1AU), STEREO B (1.03AU), Mars Science Laboratory (1.20AU), and Mars Express(1.52AU). These spacecraft were located at different distances and different longitudes relative to the Sun. Therefore, the corresponding in-situ data can provide further constraint on the shock dynamics along different directions on one hand, on the other hand reveal longitudinal distributions of SEPs in a wide angle of about 120 degrees. We also run MHD simulations based on the derived 3D shock morphology and
dynamics. The magnetic field connectivity to aforementioned spacecraft and the obtained shock characteristics (e.g., shock geometry, speed, Alfvén Mach number, etc.) at cobpoint can help with the understanding of the SEP properties (e.g., energy spectra) measured at different longitudes.

**RECONSTRUCTING 3D SOLAR WIND STRUCTURES IN THE INNER HELIOSPHERE FROM STEREO DUAL VIEWS**

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Heliosphere or interplanetary space is filled with various types of solar wind structures, which may significantly influence the space environment near the Earth and cause severe space weather. Traditionally, solar wind is learned and monitored through in-situ measurements of spacecraft at a limited number of locations, e.g., the Wind and ACE spacecraft at L1 point near the Earth, the STEREO twin spacecraft in the Earth orbit at 1 AU and the Ulysses spacecraft in the large elliptical orbit around 5 AU. This way can only obtain the in-situ solar wind properties rather than the overall distribution of solar wind in the heliosphere. Alternatively, large-scale solar wind structures in 3D may be reconstructed by using interplanetary scintillations (IPS) technique. However the spatial resolution and cadence of the reconstructed solar wind maps are quite low. In this work, we show a newly developed method to reconstruct 3D solar wind in the inner heliosphere by using imaging data from dual views. This method is established on the correlation analysis and model-free. By applying this method to real observations from STEREO twin spacecraft, which keep taking pictures with a cadence of 40 minutes from two angles of views, we find that the periodic pattern hidden in the small-scale solar wind transients can be retrieved and the large-scale CME structures can also be clearly reconstructed though some limitations exist. This method demonstrates its merit and potential in reconstructing and monitoring 3D solar wind structures in the inner heliosphere.

**EUHFORIA IN THE ESA VIRTUAL SPACE WEATHER MODELLING CENTRE**

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The goal of the ESA ITT project AO-1-8384-15-1-NB VSWMC-Part 2 is to further develop the Virtual Space Weather Modelling Centre (VSWMC), building on the Phase 1 prototype system and focusing on the interaction with the ESA SSA SWE system. The objective and scopes of this project include:

1. The efficient integration of new models and new model couplings, including a first demonstration of an end-to-end simulation capability.

2. The further development and wider use of the coupling toolkit and the front-end GUI which will be designed to be accessible via the SWE Portal.

3. Availability of more accessible input and output data on the system and development of integrated visualization tool modules.
The consortium that took up this challenge involves: 1) the Katholieke Universiteit Leu- 
ven (Prime Contractor, coordinator: Prof. S. Poedts); 2) the Belgian Institute for Space 
Aeronomy (BIRA-IASB); 3) the Royal Observatory of Belgium (ROB); 4) the Von Kar- 
man Institute (VKI); 5) DH Consultancy (DHC); 6) Space Applications Services (SAS); 7) 
British Antarctic Survey (BAS).
The VSWMC-Part 2 project started on 17 February 2016. At the time of the ESWW15 meet-
ing, Phase 2 will be finished, which means that all models (EUHFORIA, CTIM, CTAN2, 
BAS-RBM, COOLFluID, GUMICS, etc.) and model couplings will be installed and operational 
in the VSWMC. Hence, it will be demonstrated how easy the models can be run and 
how easy model couplings can be set up and used. For instance, EUHFORIA can be run and 
coupled to Gumics-4 and Geo-effects models (Kp-index, bow shock stand-off distance,...). 
Moreover, visualization tools are installed as models and can thus be coupled to the models 
to get directly plots and/or video’s as output of a run. The VSWMC system is being 
developed under ESA’s Space Situational Awareness (SSA) Programme and is intended to 
become an operational system as part of the ESA SSA SWE system.

RECONSTRUCTING THE LATITUDINAL POSITION AND 
THE GEOMETRY OF CORONAL HOLES WITH EUHFORIA 
MODEL

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We investigate the capability of the empirical solar wind model adopted in EUHFORIA 
(European heliospheric forecasting information asset) to recreate the geometry and size of 
coronal holes, and subsequently of the fast solar wind. The empirical solar wind model follows 
that of Wang-Sheeley-Arge model, and combines the Potential Field Source Surface (PFSS) 
and the Schatten Current Sheet (SCS) models. The outer boundary of the PFSS model is 
placed at a radius of $R_\text{ii}$, and the inner boundary of the SCS model at $R_\text{i}$. Considering that 
the $R_\text{i}$ lies below the $R_\text{ii}$ we take a series of sets of the two radii by varying $R_\text{ii}$ within the 
interval $[1.4, 3.0]R_\odot$ with a step of 0.1$R_\odot$, and the $R_\text{i}$ within the interval $[1.3, 2.8]R_\odot$ with 
the same step. The study is repeated for 12 coronal holes of different latitudinal position 
and geometry. We compare the modelled coronal holes with boundaries obtained by remote 
sensing EUV observations using the CATCH tool (Collection of Analysis Tools for Coronal 
Holes). Preliminary results of the study indicate that a previously defined pair of PFSS and 
SCS radii results in underestimated coronal hole sizes. It also indicates that different radii 
sets give better results for different types of coronal holes.
INTERACTION BETWEEN MAGNETIC CLOUDS AND
GALACTIC COSMIC-RAYS: A TEST-PARTICLE
MONTE-CARLO APPROACH

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Magnetic clouds (MCs) are large interplanetary structures presenting topologies of closed magnetic loops that could represent interplanetary signatures of coronal mass ejections. A unique and powerful analysis tool allowing to retrieve the magnetic configuration of a MC is the Grad-Shafranov reconstruction, relying on the hypothesis of axial invariance of the magnetic configuration i.e., assuming a 2.5D geometry. Once the MC configuration is known, the interaction between MC and cosmic-ray energetic particles can be investigated: a test-particle Monte-Carlo approach is proposed here. By integrating test-particle trajectories from the boundaries through the magnetic structure is possible to build a density map of particle counts on a gridded 2.5D simulation space. The full-orbit integration is needed for galactic cosmic rays presenting gyroradii comparable with the MC dimensions. A comparison between model and cosmic-ray observations is presented.

NARROW CORONAL HOLE-LIKE STRUCTURES IN
MICROWAVES

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The interest into specific narrow coronal hole-like structures as an eventual source of the slow solar wind is growing up now. Such kind of structures ("dark coronal corridor", "dark lane", "small coronal hole", "coronal parting", "S-web" and others) have an evident association with local open magnetic field areas. Usually narrow elongated coronal hole-like structures are prominently directed toward peripheries of coronal holes and/or active regions cores. A reduced plasma density and a depression of the emission permits to these structures. In microwaves coronal hole-like structures of interest have a reduced brightness temperature ("low brightness temperature regions - LTR") compared with brightness temperatures of the quiet Sun at corresponding wavelengths. Microwave spectral polarization observations of LTR give a new possibility to analyze parameters of the coronal hole-like structures atmosphere, its association with open magnetic field lines and conditions of the slow solar wind creation at different heights above the photosphere. Multichannel spectral polarization observations at 3.2-4.7 cm wavelength band and a construction of 2D maps of the microwave solar emission are realized now at the Ventspils International Radio Astronomy Centre (VIRAC), Latvia with the RT-32 radio telescope. The presentation concerns to an evaluation of possibilities of LTR microwave observations and the analysis of some LTR corresponding to narrow coronal hole-like structures in the periphery of active regions based on observations by the VIRAC RT-32 and the Nobeyama Radio Heliograph (NoRH). As an example brightness temperatures of LTR in the periphery of AR12086 are reduced by 8% for 1.76 cm (NoRH) and 4% for 4.09 cm (VIRAC) from the quiet Sun brightness temperature. Thus the electron plasma density of LTR could be evaluated as 0.52 - 0.6 of the quiet Sun plasma density according the simplified plasma emission model and taking into account the antenna diagram width. The association of LTR with the PSFF simulation of the open magnetic field is shown also.
MUL TISPACECRAFT OBSERVATION OF SUPRA-THERMAL ELECTRONS FOR THE WIDE CME ON MARCH 12, 2012

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On March 12, 2012, a very fast Coronal Mass Ejection (CME) with a speed of about 2000 km/s was released from the Sun. Its interplanetary counterpart (ICME) was detected in-situ on March 15, 2012 by spacecraft located at L1 close to the Earth, and by STEREO A. When the ICME arrived, they had an angular separation of \( \sim 100 \) degrees. The Earth crossed the East flank of the structure and showed unambiguous ICME in-situ signatures, while STEREO A crossed the West flank and showed less clear markers. At the moment of the eruption, the CME was surrounded by three different coronal holes, which were located with respect to the CME launch site East (negative polarity), South-West (positive polarity) and West (positive polarity). This matches with the polarity observed in-situ at 1 AU. Apart from this, supra-thermal electrons show both signatures of bidirectionality and its absence as the spacecraft transits the ICME, indicating that only part of ICME remained a closed structure, whereas the other parts were eroded, possibly due to interaction with the fast solar wind. We investigate the early kinematics of the CME using the Graduated Cylindrical Shell (GCS) model, the differences between the signatures of the ICME observed by Earth and STEREO A at 1 AU and the interaction process with the surrounding CHs.

RECONSTRUCTION OF SOLAR CORONAL MASS EJECTIONS BASED ON GL98 MODEL BY DIRECTLY FITTING TO CORONAGRAPH DATA

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We use GL98 (Gibson and Low 1998, ApJ) analytical CME model to reconstruct three dimensional (3D) magnetic field and the corresponding plasmas density. Parameters of the GL98 model are adjusted to directly fit the CME coronagraph images, such as outline and brightness for two different observation time to derive the 3D magnetic field and plasmas density. Velocity of the CME can also be obtained using the self-similar theory from B. C. Low 1982, ApJ. Direction of the symmetry axis of GL98 model are determined by the magnetogram of the CME source region. Then the reconstructed CME is put into Space Weather Modeling Framework (SWMF) to simulate the evolution of CME in interplanetary space. We give a prediction of the CME arrival time at the Earth with an error of five hours comparing to the actual DSCOVR in-situ measurements.
CAN WE USE CORONAL DIMMINGS AS APPLICATION FOR SPACE WEATHER FORECASTING?

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Coronal dimmings are temporary regions of reduced extreme-ultraviolet emission that form in the wake of CMEs in the low corona due to plasma evacuation. As they are observed prior to the appearance of CMEs in white-light coronagraphs, coronal dimmings provide early information on the associated CME and build an important back-up in case no coronagraphic data are available. Especially, for Earth-directed events they are of interest because they provide immediate information whether a halo CME is front or back sided. For a set of 62 Earth-directed events, we established the statistical relationship between coronal dimmings and their associated CMEs using optimized multi-point SDO and STEREO data. We found that the dimming area, its brightness and the total magnetic flux within the dimming region strongly correlate with the CME mass, while their corresponding derivatives (i.e. the area growth rate, the brightness change rate, and the total magnetic flux change rate) show the highest correlations with the CME speed (c=0.6-0.7). Based on these results we aim to provide early CME parameter estimates for real-time space weather forecasting based on observations of coronal dimmings. By applying a multiple linear regression model, we use our dataset to identify the best combinations of dimming parameters to calculate the CME mass and its maximal speed. We will also aim to derive coronal dimming cut-off relations to predict fast (>1000 km/s) and massive Earth-directed CMEs (> 5 × 10^{15} g).

TRACKING AND VALIDATING ICMES PROPAGATING TOWARDS MARS USING STEREO HELIOSPHERIC IMAGERS COMBINED WITH FORBUSH DECREASES DETECTED BY MSL/RAD

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The Radiation Assessment Detector (RAD) instrument onboard the Mars Science Laboratory (MSL) mission’s Curiosity rover has been measuring galactic cosmic rays (GCR) as well as solar energetic particles (SEP) on the surface of Mars for more than 6 years since its landing in August 2012. The observations include a large number of Forbush decreases (FD) caused by interplanetary coronal mass ejections (ICMEs) and/or their associated shocks shielding away part of the GCR particles with their turbulent and enhanced magnetic fields while passing Mars. This study combines MSL/RAD FD measurements and remote tracking of ICMEs using the STEREO Heliospheric Imager (HI) telescopes in a statistical study for
the first time. The large dataset collected by HI makes it possible to analyze 149 ICMEs propagating towards MSL both during its 8-month cruise phase and after its landing on Mars. We link 45 of the events observed at STEREO-HI to their corresponding FDs at MSL/RAD and study the accuracy of the ICME arrival time at Mars predicted from HI data using different methods. We also investigate the properties of the FD themselves and how they compare to measurements at Earth.

LONG LIVED RECURRENT STRUCTURES IN THE INTERPLANETARY MAGNETIC FIELD

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We have studied the interplanetary magnetic field, measured by space probes covering four solar cycles. We have found recurrent magnetic field enhancements lasting for several years. It is clear that the magnetic structures are associated with co-rotating interaction regions which develop from the high speed solar wind flow from coronal holes. However, a surprising finding was that the magnetic polarity has changed in one event, proving that a southern and a northern coronal hole was involved in that event, which suggests that active solar longitude may be present. The increase of the magnetic field at the slow-fast stream interface is also present in the radial component of the field, in other words the open solar magnetic flux density is modulated by solar longitude. This is not the case close to the Sun, as measured by Messenger, proving that the flux enhancements develop during solar wind propagation. Therefore, three-dimensional modelling of the interaction region was performed to reconstruct the rearrangement of the magnetic field during solar wind propagation. The recurrent magnetic increases have impact on space weather events. The association of the CIR events to geomagnetic indexes were also investigated.

THE IN SITU SOLAR WIND AND GALACTIC COSMIC RAY CORRELATION AT MARS AND ITS COMPARISON WITH EARTH OBSERVATIONS

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The Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft have been observing the in situ solar wind properties since its arrival to Mars at the end of 2014. Together with the Galactic Cosmic Ray (GCR) observation continuously monitored by the Radiation Assessment Detector (RAD) on the Martian ground, we are able to analyze the correlation of the solar wind evolution and the modulated GCR variations at Mars. The transient variations (mostly observed as short-term decreases) in these in situ observations are usually related to either the impact of Coronal Mass Ejections (CMEs) erupted from Solar active regions or the pass-by of High Speed Solar Wind Streams (HSS) arising from Coronal Holes (CHs) on the Sun. During the opposition phase in 2016 when Earth and Mars were radially aligned on the same side of the Sun, we observe the stable evolution of a few CHs on the solar
surface over several solar rotations and analyze the re-current in situ solar wind and GCR signatures at both Earth and Mars.

MODELING THE EVOLUTION AND PROPAGATION OF 10 SEPTEMBER 2017 CMES AND SEPS ARRIVING AT MARS CONSTRAINED BY REMOTE SENSING AND IN SITU MEASUREMENT

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On 10 September 2017, solar energetic particles originating from the active region 12673 produced a ground level enhancement at Earth. The ground level enhancement on the surface of Mars, 160 longitudinally east of Earth, observed by the Radiation Assessment Detector (RAD) was the largest since the landing of the Curiosity rover in August 2012. Based on multipoint coronagraph images and the Graduated Cylindrical Shell model, we identify the initial 3-D kinematics of an extremely fast coronal mass ejection (CME) and its shock front, as well as another two CMEs launched hours earlier with moderate speeds. The three CMEs interacted as they propagated outward into the heliosphere and merged into a complex interplanetary CME (ICME). The arrival of the shock and ICME at Mars caused a very significant Forbush decrease seen by RAD only a few hours later than that at Earth, which was about 0.5 AU closer to the Sun. We investigate the propagation of the three CMEs and the merged ICME together with the shock, using the drag-based model and the WSA-ENLIL plus cone model constrained by the in situ observations. The synergistic study of the ICME and solar energetic particle arrivals at Earth and Mars suggests that to better predict potentially hazardous space weather impacts at Earth and other heliospheric locations for human exploration missions, it is essential to analyze (1) the eruption of the flare and CME at the Sun, (2) the CME kinematics, especially during their interactions, and (3) the spatially and temporally varying heliospheric conditions, such as the evolution and propagation of the stream interaction regions.
COMBINING SOLAR RADIO SPECTRA WITH FRENCH AND CHINESE INSTRUMENTS

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Solar Radio Monitoring (secchirh.obspm.fr) is a website for the combined visualization of solar radio data. This website is made possible by the support of the French Space Agency CNES. The main objective of this website is to support multi-wavelength data analysis and space missions dedicated to research on solar activity and on solar-terrestrial relationships, in particular SOHO, STEREO and SDO. It produces and provides synthetic data including mapping of sources observed by the Nançay Radio Heliograph (NRH) and composite dynamic spectra. The combined survey permits to quickly identify and select solar events, to identify the complementary radio data for the space-based observations, and it gives an overview of the coronal and interplanetary situation. In the context of the Chinese-French project for operate large radio telescopes dedicated to the observation of the Sun, we firstly combine the MUSER (MingantU SpEctral Radioheliograph) spectra with other solar radio instruments in the same time zone (Gauribidanur (India), Culgoora (Australia) and Wind/Waves (Space)). The addition of the MUSER spectrum on the solar radio-monitoring website allows us to expand the spectral band from 400 MHz to 2 GHz with high spectrographic quality. Secondly, we can produce a long continuous observation, extending over more than 14 hours, by combining MUSER spectra with the ORFEES radio spectrograph at the Nançay station (France). This combination is also done with the aim of preparing the combination of MUSER data with NRH in order to provide a long continuous solar imaging in the region of 400 MHz where the spectra covered by the two instruments overlap. In addition, the combination of MUSER, NRH, ground-based instruments and space instruments will facilitate the access to solar radio data for non-experts and provide to radio-astronomers complementary diagnostics of solar activity.

SENSITIVITY OF THE ELECTRON PROTON HELIUM INSTRUMENT (EPHIN) ON ENERGETIC PHOTONS DURING SOLAR FLARES


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Timing of Solar Energetic Particles (SEPs) with respect to flare emission (e.g., hard X-ray production, type III radio bursts) and CME signatures (e.g., type II radio bursts) is generally a tool for identification of the particles acceleration source. Of special interest are near and relativistic electrons that are measured by the Electron Proton Helium INstrument (EPHIN) aboard the SOHO spacecraft. The GOES satellite provides continuous soft x-rays measurements of solar flares. However hard x-ray observation and imaging became available with the launch of RHESSI in 2002. Although EPHIN aboard SOHO, launched in 1995, was designed to measure charged particles it is sensitive to hard x-rays during solar flares allowing investigating the time profile of hard X-ray flares with minute cadence. Here, we will present on the one hand the underlying measurement principle utilizing a GEANT 4 simulation of the instrument and on the other hand the application to a selected number of flare events.
Coronal holes are areas of open magnetic field and are usually detected in EUV image data where they appear more dark compared to the ambient corona. Deriving reliably the coronal hole boundary is of high interest, as its area, underlying magnetic field, and other properties give important hints towards high speed solar wind acceleration processes and with that compression regions arriving at Earth. In this study, we statistically verify an intensity–based threshold method for identifying and extracting CHs from the physical standpoint using plasma properties (density, temperature and emission measure) derived from multi–wavelength remote sensing observations. Using the differential emission measure (DEM) analysis method by Hannah & Kontar (2012) on EUV data from the Atmospheric Imaging Assembly (AIA) on board the Solar Dynamics Observatory (SDO) as well as boundary conditions of CH plasma found in Saqri et al. (2019) we extract boundaries of over 100 CH during the whole SDO cycle (2010-2018). These boundaries are compared with boundaries we derive by varying the threshold of an intensity–based extraction method that uses 193 EUV observations. From this statistical analysis we are able to propose an optimal threshold range as well as relevant errors for the CH boundary. This study acts as an error estimation for further studies using the same or similar extraction methods for CH.

Coronal Mass Ejections are large disturbances emanating from the Sun and are mostly associated with flaring activity at our star. They transport solar plasma and magnetic field in the interplanetary medium and can interact with the space environments of planets. Known as one of the most important drivers of space weather, improving our understanding of how interplanetary CMEs (ICMEs) evolve, as well as their generic features, is critical to develop prediction tools for predicting their effects in space. ICMEs are routinely measured in situ by spacecraft dedicated to the monitoring of the solar wind (such as ACE or Wind), or as a by-product of planetary missions (e.g. Messenger, Venus Express). Then, ICMEs
can be monitored at different heliospheric distances. On the other hand, statistical analyses such as superposed epoch studies can reveal generic features in the time series of in situ parameters. Here, by combining different catalogues of ICMEs detected at three spacecraft (MESSENGER at Mercury’s orbit, Venus Express at Venus orbit, and ACE at L1), we investigate the features of the superposed epochs for the magnetic field profiles of these events and how these features evolve with heliospheric distances. By using a proxy for the speed of these ICMEs (which is not readily available for all the missions), we find that slow and fast ICMEs have very different magnetic field profiles. At all spacecraft, slow ICMEs have a less intense sheath at the front of the magnetic ejecta, and a magnetic profile inside the magnetic ejecta that is more symmetric, when compared with fast ICMEs. This asymmetry increases with heliospheric distances, when comparing ICMEs at Mercury’s orbit with those at L1. We interpret the differences in the profiles of slow and fast ICMEs at different heliospheric distances as the result of the conditions of ICME ejections as well as propagation processes in the solar wind, in particular relaxation conditions. Such a study is important in providing a picture for how ICMEs propagate in the interplanetary medium.

LONG–TERM EVOLUTION OF CORONAL HOLES AND RELATED CO–ROTATING INTERACTION REGIONS

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We investigate a sample of persistent coronal holes which occurred over the time range 2007 – 2014 and were observed from multiple perspectives. From combined SOHO/EIT, STEREO and SDO EUV data, we extract coronal hole parameters such as area, location, magnetic field characteristics, and follow them in time. The resulting parameters are related to in–situ solar wind measurements at L1 from ACE/Wind. We show that coronal holes undergo several evolutionary steps that are characterized by specific value ranges in the extracted parameters. On a statistical basis, this supports the results from the case study performed by Heinemann et al. (2018), who found that the coronal hole evolution has three phases, growing, maximum and decaying phase. These phases are also mirrored in the in–situ proton bulk speed of the associated high–speed streams. In addition, we investigate if and how these evolutionary properties are reflected in the galactic cosmic ray measurements of the recurrent Forbush decreases.
DOES THE OCCURRENCE OF A SOLAR FLARE FOLLOW A POISSON PROCESS OR WITH MEMORY?

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The statistics of waiting time (\(\Delta t\)) provides a useful tool to understand the correlation of successive bursts: whether it is independent or related to a previous event? The waiting time distribution (WTD) of solar flares show a common feature of a power-law-tail profile that may arise from a non-stationary Poisson process (Wheatland 2000; Aschwanden 2010; Li et al. 2014) or from a memorable-correlated process (Lepreti et al. 2001; Greco et al. 2009; Telloni et al. 2014). Here we present waiting time statistics of solar flares either treating the Sun as a global system (Li et al. MNRAS, 2018) or in an individual active region (Li et al. in preparation). The Kolmogorov-Smirnov test is applied to examine the reliability of Poisson hypothesis for the flare production. The flare WTDs are then fitted with the statistical models in natures of both a discrete random process (non-stationary Poisson distribution) and a continuous memorable process (Weibull and Lévy function). Our analysis leads to the following conclusions: (1) the occurrence of "super flares is much closer to a random process when treating the Sun/Star as a single self-organized criticality (SOC) system (Bak, Tang and Wiesenfeld, 1987); (2) the flare production during the solar maximum shows a certain amount of memory; (3) Flares originated from an individual active region can be well understood with the continuous memorable process.

PROVIDING GLOBAL CONTEXT FOR INTERPRETATION OF THE HELIOSPHERIC DISTURBANCES OBSERVED BY THE PARKER SOLAR PROBE AND SOLAR ORBITER

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The interpretation of multi-spacecraft heliospheric observations and three-dimensional reconstruction of the structured and evolving solar wind is challenging. Numerical simulations can provide global context and suggest what may and may not be observed. Community Coordinated Modeling Center (CCMC) provides both mission science and space weather support to all heliospheric missions. Currently, this is realized by real-time simulations of the corotating and transient disturbances by the WSA-ENLIL-Cone model and providing: (1) global structures of the solar wind speed and density at the ecliptic, (2) temporal profiles of solar wind parameters at the spacecraft, and (3) magnetic field connectivity at the spacecraft. In this presentation, we will show numerical results achieved by the updated modeling system which involves the revised WSA model, Cone model parameters fitted by the science-quality data, and re-calibrated model-free parameters from August 2018 to April
2019. In addition to the in-situ predictions, we will also present synthetic white-light observations that can be directly compared with the heliospheric imagers onboard STEREO-A (HI-1 and HI-2), Parker Solar Probe (WISPR), and Solar Orbiter (SoloHI).

**INSTALL A NEW CORONAGRAPH ON ISS**

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Korea Astronomy and Space Science Institute (KASI) plans to develop a coronagraph and to install it on the International Space Station (ISS) collaboration with NASA Goddard Space Flight Center (GSFC). This project started 2017 and the coronagraph will be launch on 2021. The main science objective for the mission is (1) Is there evidence for interchange reconnection contributing to the slow solar wind? (2) Is there evidence for closed fields opening up and filling the solar wind with plasma? To estimate these scientific objection, we developed the coronagraph which is externally occulted with a field of view from 3 to $\sim 12$ solar radii ($R_\odot$), simultaneously covering all latitudes. From the observation by using the photometric filter around the 400nm band, we could estimate the 2D electron temperature and electron velocity distribution in the $3R_\odot \sim 12R_\odot$ corona.

**EISCAT OBSERVATIONS OF THE IONOSPHERIC RESPONSE TO SOLAR FLARES**

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Geomagnetic storms have dramatic effects on the geospace in general and in the ionosphere in particular. Their effects have been extensively studied by various means and instruments. What is less reported though is the ionospheric response to the flare sometimes preceding the coronal mass ejection responsible for a geomagnetic storm. In this presentation, we report a couple cases of flares that had a clear impact on the electron density measured by the EISCAT incoherent scatter radars. The large EUV fluxes of the flares are seen to have an immediate response in the E- and F1-regions of the dayside ionosphere: the electron density increases by a factor up to 2.5 at 110 km altitude. Only X-class flares seem to affect the high-latitude ionosphere sufficiently so that their effect is visible in EISCAT data.

**INTERCHANGE RECONNECTION AND THE SLOW SOLAR WIND**

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The acceleration of the solar wind remains one of the most enduring problems in solar system science. In particular the origin of the slow solar wind (SSW) – and its rapidly varying, filamentary structure – remains a mystery. Analysis of the magnetic topology of the Sun’s atmosphere that suggest that "interchange" magnetic reconnection in the corona may play
a key role in the SSW structure. Here we will discuss new techniques for characterising the
global magnetic field topology, as well as models that reveal how interchange reconnection
leads to mixing of the plasma between the open and closed magnetic flux domains.

STATISTICAL ANALYSIS OF CORONAL HOLE PROPERTIES
DURING 2018 WITHIN THE FRAME OF FAST SOLAR WIND
MODELING WITH EUHFORIA

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One of the major challenges in current space weather research concerns the prediction of the
characteristics of the high speed streams (HSS) upon arrival at Earth (or at other planets),
based on properties of their sources, the coronal holes (CHs) observed at the Sun. This
work aims to provide a statistical overview of the CH characteristics detected in the Sun
throughout the year 2018 during which the minimum of Solar Cycle 24 was still in progress.
The ultimate goal of this analysis is the extensive survey of the properties of the CHs, such
as latitudinal and longitudinal extent, position on the solar disc and CHs shape. This is
necessary to clarify which of them and at what level, influence the modeling of the fast wind
streams in the heliospheric solar wind by means of the new heliospheric 3D MHD model
called EUHFORIA (EUropean Heliospheric FORcasting Information Asset). Simulations
and first results indicate that the input to EUHFORIA needs to be modified accordingly,
in order to reflect the different types of CHs in the simulation of the associated fast solar
wind.

INVESTIGATING THE EVOLUTION AND INTERACTIONS
OF THE SEPTEMBER 2017 CME EVENTS WITH EUHFORIA

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Coronal Mass Ejections (CMEs) and their Interplanetary counterparts (ICMEs) are the
primary source of strong space weather disturbances at Earth and other places in the helio-
sphere. Key parameters determining the geo–effectiveness of CMEs are their plasma dynamic
pressure and internal magnetic field intensity and orientation. In addition, phenomena such
as the interaction with other CME structures along the way, or the pre–conditioning of in-
terplanetary (IP) space due to the passage of previous CMEs, can significantly modify the
properties of single CME events and influence their geo–effectiveness. Therefore, investigat-
ing and modeling such phenomena via physics–based heliospheric models is crucial in order
to assess and improve our space weather prediction capability in relation to complex CME
events. In this regard, we present a comprehensive analysis of the CME events that erupted
from AR 12673 during the unusually active week of September 4–10, 2017, with the aim
of validating for the first time the prediction capabilities of the EUHFORIA model in the case of complex CME events. As AR 12673 rotated along with the solar disk, CMEs were launched over a wide range of longitudes, interacting with each other and paving the way for the propagation of the following CMEs. Following the eruptions, ICME–related signatures were observed at both Earth and Mars, while associated particle events were reported at Earth, Mars, and STEREO–A. In terms of impact on Earth, an intense geomagnetic storm, triggered by a strong southward magnetic field associated to an ICME sheath, was recorded on September 8, 2017. In order to study these CME–CME interactions and their influence on the geo–effectiveness of single CMEs, we simulate the events using the EUHFORIA model. With the intent of preserving a predictive approach, we use kinematic, geometric and magnetic input parameters for the CMEs as derived from remote–sensing and multi–spacecraft observations of the CMEs and their source regions. We model CMEs first using an over–simplified cone model, and then a more realistic flux–rope model so to quantify the improvement in the prediction of the interplanetary magnetic field and CME geo–effectiveness at Earth in the latter case. Furthermore, we investigate the modelling of CME–CME interactions considering the spatial and temporal evolution of ICMEs in terms of their shocks, sheaths and ejecta structures in the heliosphere, and we quantify the impact of such phenomena on the propagation and evolution of single CME events. Results from this study will not only benchmark our current prediction capabilities in the case of complex CME events, but will also provide better insights on the large–scale evolution and interaction of complex CME events in the inner heliosphere.

**NUMERICAL MODELLING OF STEALTH SOLAR ERUPTIONS AND COMPARISON WITH IN–SITU SIGNATURES**

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Coronal Mass Ejections (CMEs) are huge expulsions of magnetized plasma from the Sun into the interplanetary medium. A particular class of CMEs are the so–called stealth CMEs, i.e., solar eruptions that are clearly distinguished in coronagraph observations, but are not associated with clear signatures close to the Sun, such as solar flares, coronal dimmings, EUV waves, or post–flare loop arcades. Observational studies show that about 60% of stealth CMEs are preceded by another CME whose solar origin could be identified. In order to determine the triggering mechanism for stealth CMEs we are using the MPI–AMRVAC code developed at KU Leuven. We simulate consecutive CMEs ejected from the southernmost part of an initial configuration constituted by three magnetic arcades embedded in a globally bipolar magnetic field. The first eruption is driven through shearing motions at the solar surface and the second is a stealth CME, both being expelled into a bimodal solar wind. We analyze the parameters that contribute to the occurrence of the second CME. Furthermore, we compare the simulated signatures of the CMEs with the in–situ data from ACE spacecraft at 1AU. This study aims to better understand the triggering mechanism of stealth eruptions and improve the forecasting of their geomagnetic impact.
OBSERVATIONAL ASSESSMENT ON CME MASS PILE UP IN INTERPLANETARY SPACE

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Coronal mass ejections (CMEs) propagating in the heliosphere are exposed to a drag force due to the ambient solar wind. Mass pile-up in interplanetary space can have strong effects on the drag force, and with that on the CME propagation time and energy input to the magnetosphere. For a sample of well observed events, we determine the de-projected 3D mass and its evolution up to a distance range of about 15Rₛ using combined STEREO-SECCHI COR1 and COR2 data, for which no pile-up at the CME front is found (see also Bein et al., 2013). Applying the GCS forward fitting model (Thernisien et al., 2006, 2009) on COR2 data, we obtain the volume of the CMEs. Working under the assumption that the CME mass is constant beyond 15Rₛ and that the CME undergoes self-similar expansion, we estimate the CME density at the distance of 1AU. The results are compared to in-situ proton density data measured for the associated ICME’s sheath and magnetic structure for which we derive a trend towards a mass increase at the CME front.

MODELING OF CORONAL MASS EJECTIONS AND PROGNOSIS GEOMAGNETIC ACTIVITY ACCORDING GROUND-BASE PATROL OBSERVATION

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We present models of the propagation of coronal mass ejections (CME) based on the interaction of CME with the solar wind through aerodynamic drag. The parameters of the solar wind are calculated according to the observation data of the STOP magnetograph. The parameters of the CME at the initial stage of propagation are determined from the data of the patrol telescopes.

DEVELOPMENT OF THE TEST AND CALIBRATION PLATFORM FOR SPACE CHARGED PARTICLES RADIATION ENVIRONMENT RESEARCH PAYLOADS

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Introduction of the requirement and design of the medium- and high-energy electron accelerators and low energy proton and heavy ions tandem, for calibration the satellite borne charged particles detectors, with extremely weak beam current used by simulating the charged particles radiation environment of space is presented. Firstly, we focus on physical design and simulation of extremely weak uniform parallel electron beam of the 200keV
medium-energy one, by using electron trajectory program Egun. Secondly, we gain the sim-
ulation results of electron trajectory in the initial focusing system, the accelerating tube
and the twice beam broaden on different conditions which include without grid, with ideal
grid and with 1mm aperture grid in the spherical electron gun. Thirdly, we conclude that
the beam density can be weaken by factor 8 from the electron gun to the target area, and
satisfy the requirement of our detector scaling experiment (the beam density is $10^5 \sim 10^9$
/cm²s at the $\Phi$ 50 mm target area). Fourthly, by using the same idea we suggested the
constructor of the 2MV high energy electron accelerator and the 2*6MV proton and heavy
ion tandem accelerator, and gain the beam as we required to simulate the space radiation
of those charged particles. Ultimately, we successfully construct the National Space Science
Space Charged Particle Radiation Facility for payloads testing and calibration.